PSP's support of Science Education through Teacher Development: A Case Study.

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DECLARATION

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ABSTRACT

An analysis of a teacher development programme known as the Cluster Project is central to this research. Study of the form, processes and outcomes of the project model draws attention to teacher professional development (TPD) as a critical strategy for improving science education in primary schools.

High quality teaching at the foundational level supports children develop the appropriate level of knowledge that would allow them to take up and succeed at science at higher levels. With the object of strengthening primary science education the Primary Science Programme (PSP) implements a Cluster Project in Western Cape schools. The project model offers training workshops, classroom guidance and essential resources to support teachers develop both their knowledge and teaching competencies to teach science well. Training workshops are designed to build teachers' understanding of critical science concepts, improve science content knowledge, and offers guidance with curriculum implementation and assessment of learning. In-classroom support and team-teaching, supported with teaching and learning materials and other resources, assists with improving teaching practice in context.

This interpretive case study analyses the Cluster Project model and its processes within three theoretical frames: activity theory, complexity theory, and a research-developed qualitative framework to trace teacher professional development. Activity theory is applied to the purpose, organization and function of the Cluster Project, while complexity theory probes the meaning and implications of educational change for teachers and TPD. The qualitative framework with its five critical indicators of autonomy, knowledge, practice, and collaboration and continuing development analyses empirical evidence of TPD with respect to six teacher participants.

Activity theory draws attention to the use of flexible adaptive teacher professional learning models which can accommodate frequent change to curriculum and context, and further highlights the importance of promoting collaboration and reducing contradictions in order to improve learning outcomes. Complexity theory expands understanding of teacher professional learning through its focus on the critical concepts of pedagogy, holism, learning as a nonlinear process, the unpredictability of teaching and learning, networking and connectedness, change by emergence and self-organization, changing environments, and teacher development programmes as open, complex adaptive systems.

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This research observed the six teacher participants were able to improve aspects of their teaching of science, thereby achieving a measure of professional development, although this was not a general observation within the Cluster Project teacher population. Research findings show that teachers' active participation in meaningful practical science experiences promotes teacher learning, improves practical science in the classroom, and encourages the ready take-up of helpful and innovative science teaching ideas and strategies. This research recommends that practical science teaching, integrated with language and mathematics teaching, should form an essential part of education and training programmes for both pre-service and in-service primary and high school science teachers.

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OPSOMMING

Die analise van`n onderwyser-ontwikkelingsprogram, bekend as die Groepsondersteunings Projek, is die kern van diè navorsing. Studie van die vorm, prosesse en uitkomste van die projekmodel, vestig die aandag op onderwysers se professionele ontwikkeling as `n kritiese strategie vir die verbetering van wetenskaponderrig in primêre skole.

Hoë gehalte onderwys in die grondslagfase, ondersteun die kinders se ontwikkeling op `n geskikte vlak van kennis wat hulle in staat sal stel om wetenskap verder te neem en daarvan `n sukses te maak op senior vlak. Met die doel om wetenskaponderrig te versterk in die primêre skool, implimenteer die Primêre Wetenskap Program (PSP) tans `n Groepsondersteunings Projek in die Wes-Kaapse skole. Die model voorsien opleiding deur slypskole, klaskamerleiding en noodsaaklike leerhulpmiddels om onderwysers se kennis en onderrigvaardigheid, om wetenskap as vak goed te onderrig, te ontwikkel. Opleidingsslypskole fokus daarop om onderwysers se begrip van kritiese wetenskaplike konsepte en opgradering van wetenskapinhoudskennis op te bou en ook om te help om die kurrikulum te implimenteer en kinders se leerwerk te assesseer. Klaskamer ondersteuning en span-onderrig, met die hulp van onderrig-en leerhulpmiddels, help met die verbetering van die onderwyspraktyk in konteks.

Diè interpreterende gevallestudie analiseer die Groepondersteunings Projek model en die prosesse binne drie teoretiese raamwerke, die aktiwiteits-teorie, kompleksiteits-teorie en `n stel aanwysers wat ontwikkel is om bewyse van onderwysers se professionele ontwikkeling te ontleed. Die aktiwiteits-teorie is toegepas op die doel, organisering en funksie van die Projek, terwyl die kompleksiteits-teorie die betekenis en implikasies van die opvoedkundige verandering vir onderwysers en onderwysers se professionele ontwikkeling ondersoek. Die stel aanwysers met vyf kritiese fokuspunte: outonomie, kennis, praktyk, samewerking en voortdurende ontwikkeling, lei die analise van ses onderwyser-deelnemers se professionele ontwikkeling.

Die aktiwiteits-teorie beklemtoon die belangrikheid van aanpasbare professionele leermodelle wat gereelde verandering aan die konteks en kurrikulum kan akkommodeer, en beklemtoon ook die belangrikheid om samewerking bevorder, teenstrydigheid te verminder en om sodoende die leeruitkomste te versterk. Die kompleksiteits-teorie verbreed die insig van onderwyser se professionele leer deur die fokus te plaas op die kritiese konsepte van pedagogiek; holisme; leer as `n nie-lineêre proses; die onvoorspelbaarheid van onderrig en leer;

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netwerk en aaneenskakeling; verandering deur die ontstaan en self-organisasie; veranderende omgewings en onderwyser-ontwikkelingsplanne as oop, komplekse aanpasbare stelsels.

Diè navorsing het waargeneem dat die ses onderwyser-deelnemers in staat was om aspekte van hul wetenskap-onderrig te verbeter en sodoende was hulle in staat om `n mate van professionele ontwikkeling te behaal alhoewel dit nie `n algemene waarneming binne die Groepsondersteunings Projek se onderwyspopulasie was nie. Navorsingsbevindings dui aan dat onderwysers se aktiewe deelname aan betekenisvolle, praktiese wetenskapondervindings, leer kan bevorder en begrip kan bevorder van `n praktiese implimentering daarvan in die klaskamer en moedig die geredelike opname van nuttige en innoverende leer-idees en strategieë aan. Die navorsing beveel aan dat praktiese wetenskap-onderrig, integreer met tale en wiskunde, `n noodsaaklike deel moet vorm van onderwys-en opleidingsprogramme vir voor-diens en in-diens primêre en hoërskool wetenskaponderwysers.

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DEDICATION

This work is dedicated to Mohammed Amien and Zohra Dharsey with much love and gratitude.

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ACRONYMS

ABET	Adult Basic Education and Training
ACE	Advanced Certificate in Education
ANC	African National Congress
CAPS	Continuous Assessment Policy Statements
CDE	Centre for Development and Enterprise
CPD	Continuing professional development
CPUT	Cape Peninsula University of Technology
CTLI	Cape Teaching and Leadership Institute
DoE	Department of Education
DBE	Department of Basic Education
ECD	Early Childhood Development
FET	Further Education and Training
HE	Higher Education
HEIs	Higher Education Institutions
HG	Higher Grade
HODs	Heads of Departments
ICSU	International Council for Science
INSET	In-service teacher
JET	Joint Education Trust
LOLT	Language of Learning and Teaching
MST	Mathematics, Science and Technology
MTN	Mobile Telephone Network - South African cellular service provider
NCS	National Curriculum Statement
NGOs	Non-governmental organizations

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NPO	Non-profit organization
NQF	National Qualifications Framework
NRC	National Research Council
NRF	National Research Foundation
OBE	Outcomes-Based Education
PCK	Pedagogical content knowledge
PISA	Program for International Student Assessment
PSP	[Western Cape] Primary Science Programme
RNCS	Revised National Curriculum Statement
ROSE	Relevance of Science Education
SAAO	South African Astronomical Observatory
SAARMSTE	South African Association for Research in Mathematics, Science and Technology Education
SAASTA	South African Agency for Science and Technology Advancement
SACE	South African Council of Educators
SACMEQ	Southern and Eastern Africa Consortium for Monitoring Educational Quality
SAQA	South African Qualifications Authority
SCI-BONO	Sci-Bono is the largest science centre in Southern Africa
SG	Standard Grade
STEM	Science, technology, engineering and mathematics
STI	Science, technology and innovation
SYSTEM	Students and Youth in Science, Technology and Mathematics
TESA	Teacher Education in South Africa
TIMSS	Trends in International Mathematics and Science Study
TPD	Teacher professional development
UNESCO	United Nations Educational, Scientific and Cultural Organization

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UNISA	University of South Africa
USAID	United Stated Agency for International Development
WC	Western Cape
WCED	Western Cape Education Department

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CHAPTER ONE: RATIONALE AND PURPOSE

1.1 Introduction

Following South Africa's first democratic election in 1994, the ANC (African National Congress) led government reorganized all spheres of governance, in the process initiating redress of political, social and economic inequities deeply entrenched in all sectors of society during the apartheid regime. Given the critical role of education in promoting vertical mobility in the labour market and in economic and social improvement, the government deemed the transformation of the country's inequitable education system to be imperative. New legislation and policies introduced sweeping educational reforms at all levels. Provisions for more equitable and quality education included re-orientating programmes for teachers to ensure they would be sufficiently acquainted with the changes and would be able to implement these proficiently in schools and in classrooms.

However, it is precisely at school and classroom level that policy implementation encountered some serious obstacles. Most notable amongst these pertained to the majority of the teaching corps and the quality of their professional knowledge and skills. Research into the slow pace of transformation in education regularly identifies "low teacher quality and poor teaching" (Bernstein, 2011: 4; Murtin, 2013:2; Spaull, 2012, 2013; OECD, 2013a:34) and severe deficiencies in both quality and the distribution of teachers (May, 1998) as significant hurdles to real progress. Critical teacher knowledge and skills deficits, together with their negative impacts on the quality of education and learner performance observed have foregrounded the urgent need for intensive and extensive in-service teacher development and support nationally, especially in key subjects such as science and mathematics.

The education system inherited from the Nationalist Government was highly segregated, disconnected, authoritarian, unequal and inefficient, necessitating major change and restructuring at all levels. Change efforts initially focused on establishing a unified and uniform structure. Further strategies were intended to transform education to improve access, quality and redress in line with the constitutional principles of democracy, human rights and equity, and to promote socio-economic sustainable development (DoE, 2002b: x). Wide-ranging

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reforms included merging the separate education departments into a unified national education system, instituting a more democratic system of school governance, introducing a new standards and qualifications authority, the NQF (National Qualifications Framework), instituting measures to redistribute the financial and human resources more equitably, renovating higher education and introducing a new national curriculum with an outcomes-based approach (OBE) (Keevy, 2006:2-3; OECD, 2008:28). Outcomes-based education, with its emphasis on the achievement of outcomes specifiable in terms of skills, knowledge and values, constituted a dramatic shift away from apartheid education with its emphasis on rote memorization of content and test-driven assessments.

While some of the changes in education received support, a number of academics expressed serious reservations about the introduction of outcomes-based education in South Africa at the time. Jansen (1998: 2-3) for instance noted that "the language of innovation associated with OBE was too complex, confusing, and at times contradictory", and in his view OBE "had little to do with the realities of the classroom life", and was also "too complex and inaccessible for most teachers to give its policies meaning through their classroom practices". Elsewhere, Jansen and Taylor (2003:3) drew attention to the under-preparation of teachers for this complex curriculum, and to the large-scale discrepancies in resources and capacity between the few privileged schools and the large mass of disadvantaged schools, as critical challenges for implementation. According to Jansen and Taylor (2003:3), this meant that well-resourced teachers and schools were more likely to implement the OBE curriculum as intended than were teachers in poor schools, resulting in an exacerbation and deepening of existing inequalities in terms of access to high-level conceptual knowledge.

Due to the many difficulties encountered during the course of its implementation in schools, outcomes-based education has since been reviewed and remodelled as Curriculum 2005 (DoE, 1997), and the Revised National Curriculum Statement (RNCS) which became policy in 2002 (DoE, 2002a), later implemented as the National Curriculum Statement Grades R – 12 (NCS) (DoE, 2002a, 2004). In a survey of teachers' views and experiences of the NCS and its impact on their teaching practices and assessments, Mogashoa (2014: 126) noted that:

- Teachers felt they had not received adequate and appropriate training for them to be able to implement the new curriculum as required.

- There were inadequate resources to make the implementation of the curriculum a success.

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- Teachers seemed to lack appropriate knowledge and skills to develop learning activities as required by the principles of outcomes-based education.
- Teachers' inability to develop appropriate learning programmes, work schedules and lesson plans was evident in their planning documents.
- Teachers seemed confused about how to organize the assessments of learning, and recorded learner achievement in terms of the forms of assessment instead of against the learning outcomes and the assessment standards.

Important more general negative outcomes related to the implementation of the NCS highlighted in reports, according to Olivier (2013:1), were that:

- Teachers were overburdened with administrative tasks;
- There was a lack of uniformity with regard to implementation of the NCS in schools. Curriculum requirements were interpreted differently across the country and in different schools; and
- Increasing levels of learner underperformance in literacy and numeracy were observed.

In response to teachers' concerns about the NCS and the challenges experienced with its implementation in schools, the Minister of Basic Education at the time, Angie Motshekga, appointed a Ministerial Task Team in 2009 to review the NCS (Parliamentary Monitoring Group, 2010). The Ministerial Team was tasked to investigate the pressure points of the NCS, the challenges experienced by teachers that negatively impacted on the quality of teaching in schools, and to propose practical interventions that could address the challenges (DoE, 2009a). The main aim of revising the national policy documents once again was to provide more specific guidance for teachers.

Further modifications contained in the national 2010-2013 Strategic Plan for Education (DBE, 2011) introduced yet another revised set of curriculum instructions for teachers known as the Curriculum and Assessment Policy Statements (CAPS). The Department of Basic Education (DBE, 2012b) presented the CAPS to teachers as not a new curriculum, but as an amendment to the National Curriculum Statement (NCS) Grades R-12. The introduction of the CAPS in schools was not without controversy, and according to du Plessis (2013:2) much of the debate

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was about whether the CAPS are a repackaged version of the NCS or in fact a re-curriculation. Phased in over three years from 2012 to 2014, CAPS replaced the Subject and Learning Area Statements, Learning Programme Guidelines and Subject Assessment Guidelines for all the subjects listed in the National Curriculum Statement Grades R – 12, provided comprehensive details on what teachers needed to teach and assess on a grade-by-grade and subject-by-subject basis, and specified new content in some cases.

Regular major curriculum changes and the disruptive effects of these changes on the work of teachers attempting to deliver the curriculum, together with a series of educational inefficiencies, draws attention to the flaws in the reformed education system. Although on paper improvements in education can be distinguished in legislation, policy development, curriculum reform and the introduction of new ways of delivering education, persistent problems were observed in a number of areas such as poor learner achievements and labour market relevance (OECD, 2008:3). It seems the extensive reforms supported by significant spending, and various development opportunities and programmes for teachers and learners, have not noticeably translated into improved teaching and learning in schools.

In spite of considerable government expenditure and effort to upgrade the education system prominent academics, amongst others, Jansen and Taylor (2003), Ramphele (2008), Taylor (2008), Bloch (2009), Jansen (2011), and Spaull (2013) remain highly critical of education and training in the country. In his assessment of education in post-apartheid South Africa Taylor (2008:2) maintains the statistics show that educational quality has not advanced significantly in the last decade. Slow progress has meant that the "quality of basic education for a large part of the black African population is kept low" (Murtin, 2013:2), with serious consequences, including an "insufficient number of graduates" as reported by Bloch (2009:58) and the "consistent low educational attainment of the country's labour force", observed by Erasmus and Steyn (2002:1). Slow progress has also had the effect of "severely inhibiting upward mobility in the labour market and the development of skills needed to advance economic growth" (Van der Berg, 2008: 2). The general lack of progress and measurable improvement within the school system, in poor schools in particular, indicate that limited success has been achieved in terms of adequately supporting learner efforts to prevail over an inherited socio-economic disadvantage, and to equip them for a place in a modern economy. For the majority of South African learners stuck in poverty-stricken historically black schools, and constituting about "80% of the country's enrolment" (Van der Berg, 2008:2), an ineffective education

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system consistently excludes them from meaningful educational opportunity, and for the country it translates into unpromising and bleak socio-economic growth and development.

Criticisms regarding the ineffectiveness of several key changes in education are supported by ample research and statistics that show minimal improvement in teaching and learning in South Africa. Chronically poor learner performances in the Annual National Assessments (monitoring performance in languages and mathematics nationally), systemic tests (tracking languages and mathematics in the Western Cape only) and TIMSS (international benchmarking test) for assessing mathematics and science have been recorded since 1994. In 1995, for instance, Grade 8 learners' performances in mathematics and science in the TIMSS were significantly lower than that of learners' performances recorded for other countries participating in the study (HSRC, 2011). The trend analysis from 1995 to 2012 showed that the TIMMS national average scores remained static over the years 1995, 1999 and 2002, while a noticeable improvement was observed in both the mathematics and science scores during the period 2002 to 2011 (HSRC, 2011). In the 2008 ANAs of Grades 3 and 6, on average, out of 10 learners, eight were functioning at levels lower than 50 % (DoE, 2009b). Further on, the Grades 1 to 6 and Grade 9 assessments of 2013 showed some progress in literacy and numeracy in the lower grades. In Grade 3, 59% of learners achieved above 50%, compared to 36% in 2012. In Grade 6, 27% of learners achieved above 50%, compared to 11% in 2012. However, in Grade 9, 3% of learners achieved above 50%, compared to 2% in 2012 (DBE, 2013). According to Van der Berg (2008:1) the massive differentials on achievement tests and examinations recorded across South Africa show that schools diverged in their ability to convert inputs into positive outcomes, and the school system was not yet systematically able to overcome inherited socio-economic disadvantage, and poor schools least so. Bernstein (2011: 4, 8) maintains the shortage of good teachers is a key reason why is the education system is not producing improved results, particularly in scarce but vital subjects such as mathematics and science.

Inequalities that separated different communities in South Africa during the apartheid era are still reflected in the education system, and clearly visible in the "seriously limited and inequitably distributed physical, human and material resources" (Adler, Reed, Lelliott and Setati, 2002: 54) in both urban and rural schools across the provinces. The unavailability of key resources has played a significant role in the consistent weak performance of learners, (Reddy, 2006), especially in key subjects such as mathematics, science and technology as

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demonstrated in the TIMSS (Trends in International Mathematics and Science Study, 2003) and SACMEQ (Southern and Eastern Africa Consortium for Monitoring Educational Quality) tests.

In a country such as South Africa where poverty circumscribes the lives of the majority, Adler (et al., 2002:53-54) recommend that the juxtaposition of resources and equity needs to be acknowledged, and that the availability and use of the necessary resources for education cannot and should not be taken for granted. Two immediate concerns mentioned by Adler et al. (2002:54) concerning the effects of under-resourced schools on the quality of education are that "limited and limiting conditions may result in a diminished focus on learning and teaching", and "there may be very little in some schools to draw on to adequately support and advance teaching and learning". In their reconceptualising of the notion of resources in use, Adler (et al., 2002:59) emphasize the importance of teachers' own knowledge base and teaching skills beyond the mere acquisition of a formal qualification as an essential resource. Supporting the understanding that the total quantity and quality of teachers is a crucial factor for ensuring quality education service delivery, and it stands to reason that education services are weakened where deficiencies in either quantity or quality occur in terms of the critical human resource in schools.

The quantity and quality of teachers are both critical issues in education, but what is undeniable is that the role of knowledgeable and capable teachers in the life of a child is decisive. Teaching and learning, both complex human activities, are influenced to a large extent by the competency levels of teachers (Delors, 1996:141). Teachers are essential catalysts in the teaching-learning process, supporting learners to develop their thinking and learning skills, particularly their critical and creative thinking. As the main drivers of all learning activities in the classroom, teachers are well-placed to ignite learner curiosity, inspire independent thought and action, encourage creative and critical thinking, encourage intellectual rigour and create the conditions for success in formal and lifelong education (Delors, 1996:141). Commissioned to prepare the youth to engage the future confidently, teachers have the important task of equipping them with the knowledge, skills, attitudes and values to build their futures purposefully and responsibly.

Teaching is also by its very nature an improvisational activity that requires "complex cognitive processing of a host of competing factors" at any given time (Riel in Heinecke & Blasi, 2001:30), and therefore teachers need, on a daily basis, to be flexible and adaptable to many

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changes. Teachers are regularly called upon to shape and reshape the course of education as learner needs change, as learning expectations shift, as new technologies and other resources are introduced, as the knowledge landscape alters and as the curriculum is revised. During the course of designing and presenting learning experiences in the different subjects for children of different ages and with diverse interests and abilities, teachers as a group are allowed greater powers of discretion in making important decisions with and on behalf of the children they know best (Fullan & Hargreaves, 1991: 14). The important education decisions they make are influenced by the quality of knowledge they have with regard to children and how they learn, the current curriculum and how they can use available resources creatively to support the curriculum, subject content, different teaching strategies and the different forms of assessment for monitoring learning effectively. During periods of change teachers draw on this essential knowledge and their creativity as they align their daily teaching activities, classroom resources and assessments with the revised requirements.

Change in education, and especially curriculum change is not new, but "the rate and frequency with which changes are introduced" (Sikes in Fullan & Hargreaves, 1992:36) directly affect and have implications for the work of teachers, and the professionals training and supporting teachers. Reforming daily teaching practice is labour intensive, and demands a range of adjustments to curriculum support materials, instructional practices and behaviour, and beliefs and understandings. Therefore, for many teachers changing teaching practice and daily classroom routines can seem daunting. This seems more so for those who possess "poor pedagogical skills and weak content knowledge" (Du Toit & Sguazzin, 2000: 12) as a result of inadequate education and training.

For others, coping with deviations from existing practices introduced through reforms is challenging especially where their "practices and beliefs are not well matched with revised demands" (Hewson, 2007: 2), and teachers would need time and support to adjust and to learn "because they may be asked to teach in ways that are unfamiliar to them" (Remillard, 2000: 331- 332). Teacher education and training is also not a straightforward process as teachers are as diverse a group as the children they teach. Differences amongst them in terms of competencies, years of teaching experience, content areas taught and learning preferences renders the "one-size-fits-all" model of professional development inadequate for meeting their diverse professional development needs.

Apart from personal and professional differences, teacher education and training programmes to promote quality teaching also need to take into account the diversity of contexts and conditions in which teachers work. Constantly changing roles and expectations of teachers and schools means that teachers are required to teach in increasingly culturally diverse classrooms, develop differentiated learning opportunities to accommodate children who have gaps in their learning or those with special learning needs, integrate the latest technologies effectively where these are available, engage in evaluation and accountability processes, and involve parents more in schools (OECD, 2009b: 49). It is only through ongoing professional learning that teachers can keep abreast with change, and regularly update their skills, knowledge and understanding in order to provide quality education.

Education researchers agree on the urgency of ongoing and constructive in-service teacher professional development (TPD). Adler (in Adler et al., 2002: 2) stresses that it is imperative for "repairing, redressing, professionalizing and most importantly, changing educational practices" for improving the quality of education in South Africa. In their 1990's model for education change Fullan and Hargreaves (1992:1) saw the logical approach to this as connecting change with teacher development in systematic, purposeful and constructive ways. Thus, according to this model, an appropriate starting point for improvements in mathematics and science, as recommended by Reddy (2006: xviii), would be to ensure that the one-third of teachers teaching these subjects, who do not possess appropriate knowledge and skills, receive the necessary education and training. Kahn (2013:5) draws attention to the large numbers of teachers who need training citing statistics from the Edusource (1997:108) audit of science and mathematics teachers in South Africa that found that although 85% of mathematics educators were professionally qualified as educators, only 50% had specialised in mathematics in their training, and while 84% of science educators were professionally qualified, only 42% were qualified in science, which at the time meant that an estimated 8 000 mathematics and 8 200 science educators needed to be targeted for in-service training to address the lack of subject knowledge.

Both Du Toit and Sguazzin (2000), and Fullan and Hargreaves (1992), caution that producing genuine sustainable change and improvement through any intervention is contingent upon the quality of professional opportunities, as well as the guidance and support teachers are likely to receive. Monitoring and evaluating the results of teacher training programmes and their impacts on teaching and learning in the classroom is essential for determining whether or not

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professional development programmes are achieving their purposes. Guskey (2000) recommends that well-designed, purposeful monitoring and evaluation form an integral part of TPD, and maintains these processes do not have to divert attention away from planning, implementation and follow-up, and also do not have to be time-consuming, costly and complicated, but are important because of their potential to provide meaningful information for making thoughtful, responsible decisions about professional development processes and effects. Through monitoring and evaluation programme developers can establish whether any changes have taken place as a result of professional development, whether progress and success can be claimed, and how to improve future programmes.

Poor progress in some schools and the repeated poor performances of South African learners in proficiency tests such as the nationwide systemic assessments in literacy and numeracy and TIMSS for mathematics and science, coupled with research strengthens the case for in-service teacher development. The pressure exerted by stakeholders on the government since the initiation of the change processes to realize some positive outcomes from its reforms has been described. Among the many challenges encountered in the transformation process has been in-service teacher education, training and support. It is in response to this situation and research, and in order to achieve the national reform objectives, that the DoE/DBE identified in-service teacher education and development as a key focus area, and has committed itself to making on-going education and training programmes available to in-service teachers. A critical challenge for the education authorities has been how to provide coherence, direction and focus to the teacher education and training sector which is responsible for developing, nurturing and supporting professional teachers as one key component in the qualitative transformation of the education system. A key focus of this process is improving pedagogy – the way teachers teach.

The DoE/DBE acknowledges that the kind of teacher education and professional development that can substantively improve teachers' knowledge and practical competencies relevant to the education challenges and changes unique to South Africa is essential to the transformative agenda. This agenda emphasizes the critical role of teachers who are capable of flexibility and creativity in the face of change, and who are committed to improved quality of education. As a relatively newly reconstituted bureaucracy, the South African education system appears to be profoundly challenged in its efforts to locate, develop and make available appropriate strategies and programmes for supporting the education and training of a large cohort of in-service

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teachers in a way that allows them to raise their proficiency levels to those required for simultaneously implementing change, and delivering quality education.

Improving teachers' knowledge and teaching competencies is one of the most important investments of time and money the national government can make in education. Therefore, it is important to know what is going well and where corrections are needed in order to improve the outcomes of processes. Educational research plays an important role in providing critical information to policy makers, professional development providers and others about the quality and impact of TPD.

It follows that ongoing research of education and training programmes, such as the Western Cape Primary Science Programme's (PSP) 2007–2009 Cluster Project, and critical reflection of its impact on science teaching and learning in primary schools is important and can contribute to improving our understanding of TPD that is effective for achieving the national reform objectives and quality education.

1.2 Rationale

This research focusses on a programme of in-service science teacher development known as the Cluster Project, and examines its context and constituents, its outcomes, and some of the challenges experienced by the programme developers, teacher participants, and schools involved with the project. The analysis includes, and is underpinned by, reference to the national goals and processes instituted to raise and sustain the capacity of the teacher work force for science education, as well as other critical issues around teacher development.

By all accounts, the implications of recent curricular and other modifications in education for the work of teachers appear not to have been thought through sufficiently by the DoE/DBE, thus impacting negatively on the successful implementation of these at classroom level. To its credit, the Department of Education (DoE) convened nationwide information programmes to orientate in-service teachers to curriculum and other policy changes as these were introduced over the years. However, persistent uncertainty amongst teachers about how to implement these successfully in their particular contexts, together with other obstacles, such as shortages of essential material and infrastructural resources, presented themselves at the time and appear to be continuing issues frustrating meaningful transformation. A number of teacher development programmes were implemented by various organizations, including NGOs, in response to

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teachers' perceived need for more guidance and support. Some poorly organized and insubstantial DoE programmes and those presented by other organizations that showed little to no impact on teaching and learning raised concerns about the inefficient investment of time, effort and money, whereas systematic, structured research-based approaches to teacher development are understood by education researchers to be more effective for improving professional competency.

One of the biggest challenges for the DoE/DBE has been to reverse the negative and enduring legacy of "Bantu Education" which was designed to perpetuate the educational deprivation of black learners with the aim of producing a largely uneducated and unskilled labour force and for maintaining black servitude. Part of this strategy meant that the exploration of science and mathematics was "intentionally diminished in black schools" (Medupe, 1999:63-64), a strategy that seriously deprived many learners of the opportunity to develop their potential in these disciplines. A related consequence is the current shortage of suitably qualified and capable Black mathematics and science teachers.

The dearth of knowledgeable and appropriately skilled teachers sorely inhibits efforts to improve learner achievements in mathematics and science, especially in the poorer rural and urban schools. Science, mathematics and technology education is advocated worldwide as an "essential prerequisite for modernization and economic development" (Naidoo & Savage, 1998: xiii), and economic progress in turn is critical for promoting growth in all other respects**.** Recognizing the importance of science and technology for stimulating socio-economic upliftment the DoE employed numerous strategies including reforming the curriculum and providing material resources to improve learner achievements in the key subjects of science and mathematics from primary to tertiary levels.

Despite these measures limited success has been achieved thus far in substantively transforming the legacy of apartheid education. Explanations offered are well-known, including unequal financing and resourcing of schooling, the nature of school leadership and administration, negative impacts of curriculum change and the pace of this change, concerns regarding the professional competency of teachers, and the quality of teaching and learning. As has been noted, the shortage of suitably qualified and capable teachers is generally cited as a major stumbling block for significant progress in mathematics and science education.

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Complying with national policies and goals, the DoE made professional development for Mathematics, Science and Technology (MST) teachers a high priority. The DoE endeavoured to reduce the number of unqualified and under-qualified teachers by means of various capacity-building programmes. Some of the programmes prioritized by the DoE to develop the capacity of teachers in the key subjects include:

- The Mathematics Science and Technology ACE (Advanced Certificate in Education), a funded programme was introduced in 2000 (Khuzwayo, Bansilal, James, Webb & Goba, 2015:1). Education and training for teachers via the MST-ACE, intended to facilitate the introduction and implementation of the National Curriculum Statement (NCS).

- The National Strategy for Mathematics, Science and Technology Education in General and Further Education and Training was adopted by government in 2001. The strategy aimed at raising participation and performance by historically disadvantaged learners in Senior Certificate mathematics and physical science, providing high-quality mathematics, science and technology education for all learners taking the first General Education and Training Certificate and Further Education and Training Certificate, and increasing and enhancing the human resource capacity to deliver quality mathematics, science and technology education. The strategy has been periodically reviewed and was last updated in 2007 into an expanded MST strategy.

  The MST strategy also involved the identification of dedicated Mathematics and Physical Science (Dinaledi) schools. In conjunction with the Adopt-a-School Project, private partners were sourced to support the development of these schools. By May 2008, 276 Dinaledi schools were adopted by 14 partners, (Burger, 2009). Critical to the success of the Dinaledi project was the availability of teachers capable of teaching secondary school mathematics and science well.

- The National Professional Diploma in Education programme, introduced in 2002, aimed at advancing the qualifications of those teachers who did not meet the minimum professional qualification requirements.

In addition to the above, Funza Lushaka bursaries were made available by the DoE as an incentive for mathematics, science and technology teachers to improve their qualifications, and to attract greater numbers of trainee teachers. In 2008, the sum of R180 million was distributed

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through about 5 000 bursary awards to new and returning students in the critical learning areas. With an expenditure of about R122.8 billion for education during the 2008/09 period (Burger, 2009) South Africa had one of the highest levels of government investment in education globally. Apart from its huge financial investment in education and teacher development, the South African government conceded that it could not build a high-quality education sector unaided. It considered – and continues to consider – creative and dynamic partnerships with the public sector, civil society and international partnerships valuable for the achievement of its education goals. The success of key national initiatives such as the South African Literacy Initiative (SANLI), for example, has largely been attributed to partnerships with the private sector and NGOs. The DoE favoured collaboration with NGOs and the private sector, and sought to extend its associations, particularly in the areas of in-service teacher development, school improvement, Adult Basic Education and Training (ABET), Early Childhood Development (ECD) and Further Education and Training (FET), as well as evaluation, research and monitoring. Burger (2009) further reports that NGOs have emerged as key partners in education transformation, and serve as a source of creativity and innovation.

Responding to the need to support and promote science education in previously disadvantaged schools, the Western Cape Primary Science Programme (PSP) emerged as a NGO and a non-profit organization (NPO) involved with teacher development, expressly to augment teaching and learning in poor communities. The current study investigates one of its models for teacher development, the Cluster Project, which aims to promote Natural Sciences education in Western Cape primary schools. The central concern is whether in fact the project model provides the kind of training and support it purports to do with respect to preparing teachers to implement the curriculum knowledgeably and creatively, to make the transition from traditional teacher-centred teaching methods to more learner-centred approaches, and to teach primary science confidently and competently.

In view of its importance, research into TPD has attracted much attention, producing copious literature. Important views acknowledged by the current study include those expressed by Onwu (2000:49-50) that “science teacher education in the real world cannot be pressed into preconceived and simplified models of teacher education”, and Ball (1986:41) that “there is no model for teacher education which is guaranteed to be successful in all circumstances”. Also, referenced is Elmore (2002:11) that the greater challenge “…is not so much about knowing what good professional development looks like; but it’s about knowing how to get it rooted in

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the institutional structure of schools". Based on such ideas of the need for science teaching to be creative and flexible in terms of a variety of teaching contexts, the intention of this research is not to present the Cluster Project as a template for in-service teacher development, but rather to examine its processes and outcomes for promoting science in primary schools and in a range of diverse contexts.

In-service teacher education and training is recognized as an important lever for change and improvement in the education system. Education researchers agree that substantial material support and professional development of teachers, school administrators and education officials is needed to adequately serve the educational needs of all South African school children. However, distinguishing effective professional development programmes from those that prove ineffectual requires further research.

Reflecting on, and critically evaluating existing professional development programmes such as the PSP's 2007–2009 Cluster Project is necessary, and may bring to light some elements of innovation and resourcefulness, as well as limitations and complexities, thus serving to guide the design and delivery of more effective professional teacher development programmes which are relevant to the South African context and its particular educational needs.

1.3 Purpose and Problem Statement

The aim of this research is to develop a deeper understanding of in-service teacher education and training for improving science teaching in primary schools. In applying case study research to this purpose, I selected the Cluster Project developed and implemented by the Western Cape Primary Science Programme (PSP) for study. The Cluster Project, with its focus on improving teachers' professional capacity for fostering science teaching and learning in Western Cape primary schools, was examined.

Selection of this particular project for the case study proceeded from two key aspects of this research: in-service teacher development and primary science teaching. Currently various short and long-term professional development programmes for in-service teachers are offered via a range of institutions, including Higher Education Institutions (HEIs), the Western Cape Education Department (WCED) and its professional development arm known as the Cape Teaching and Leadership Institute (CTLI), and a number of NGOs. Electing to focus on the work of NGOs instead of government agencies or HEIs narrowed the field of choice

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considerably. Selection was further simplified by the fact that very few NGOs involved with in-service teacher development at this time are dedicated specifically to promoting science education in primary schools.

Information about the organization essential to this research is the fact that the PSP is a recognized institution in the field of education and it is stable and mature, with a long history of involvement in in-service teacher training, and it works collaboratively with both teachers and significant stakeholders, such as the government (DoE/DBE) and its provincial and district offices, tertiary institutions, the private sector, international development agencies and other partners, to train and support teachers. Important aspects of the Cluster Project are that the model comprises training workshops and in-classroom support for teachers, it is a long-term model extending over a two-three year period, it is usually conducted in collaboration with disadvantaged schools where undeniable challenges for teaching and learning exist, rural and urban schools are included, and voluntary school and teacher participation is required.

The PSP makes notable claims for the significance of its Cluster Project as a model for improving science teaching, with the main strategy including training, so that teachers may strengthen their science concept and content knowledge, and classroom support for improving their teaching practice. The organization maintains that the design and delivery of its model speaks directly to the professional training needs of primary science teachers, especially those working in disadvantaged schools, seeing the contextual challenges as distinctive of the South African educational landscape. Such claims give rise to certain questions:

- What specific evidence supports such claims?
- To what extent, is the Cluster Project relevant to the professional training needs of primary science teachers, particularly in disadvantaged schools in South Africa?
- What are some of the contextual factors that impact on science teaching and learning in disadvantaged schools?
- And, how does the Cluster Project support teachers to cope with some of the challenges they face in promoting primary science?

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1.4 Research Questions

In reflecting on the importance of quality professional development at present, and in particular for science education, it is important that teacher development efforts of this nature be examined and evaluated more thoroughly with a view to establishing their effectiveness, and thus their authority and merit. For this reason, the critical question framing this research asks:

Does the "Cluster Project" model contribute substantially to teacher professional development and primary science education?

Sub-questions derived from the central question include:

1. How is the Cluster Project organized for in-service TPD to promote primary science?

2. Does the Cluster Project model meet the professional training needs of in-service primary science teachers?

3. What is the significance and value of the Cluster Project for primary science education in a challenging educational environment?

It is PSP policy to regularly engage researchers and evaluators to assess their courses and projects. This practice serves a dual purpose: it allows the organization both to reflect on its processes and to inform partners, and existing and potential funders about the outcomes of programmes offered to teachers. Several studies evaluating PSP's work in TPD have been produced over the years: an evaluation of the 2002 – 2004 Cluster Projects conducted by the University of Durban Westville under the leadership of Professor Clifford Malcolm (2004), a report by Professor Peter Hewson (2007), and a summative impact report on the 2007-2009 Cluster Project prepared by an independent evaluator, Angela Schaffer (2009).

In keeping with its policy to support research of its work with teachers, the PSP also endorsed this research of the 2007–2009 Cluster Project. PSP's sanction facilitated the collection of data for this research, and allowed free and easy access to the organization's records of the project, crucial documents such as those mentioned above, as well as contact with PSP facilitators, and with the Cluster Project schools and teachers. With permission from the organization and the WCED, the teacher interviews and lesson observations were conducted at selected Cluster Project schools.

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Forty primary schools across five districts of the Western Cape, later reduced to 37 schools, with an average of 4 science teachers per school, were at that time associated with the Cluster Project. This research examines indications of professional development with respect to 6 teachers who participated in the PSP's 2007–2009 Cluster Project. An attempt was made to include an even number of male and female teachers in this research, and the selection of teacher participants was subject to criteria such as voluntary participation and candidate suitability. This research of the 2007–2009 Cluster Project, described and discussed in detail in Chapters 5 and 6, examines the influence of the project on teachers and their professional development for improved primary science, particularly in terms of meeting the challenges presented by a reformed curriculum, and those particular challenges located in the classroom.

In focusing the two complementary lenses, Activity Theory and Complexity Theory, described and discussed in detail in Chapters 3, 5 and 6, on the Cluster Project model the intention is to contribute to the existing body of knowledge associated with South African in-service teacher development, and specifically primary science teaching and learning. The purpose is to shed some light on the two key elements of TPD and primary science education, and to review the impacts of government and other developments on the two critical issues. It is hoped that the benefits of this research will extend to the PSP itself, since insights regarding its role in in-service teacher development could serve to inform the design and delivery of future projects both in South Africa and elsewhere.

1.5 Research Limitations

Various challenges were encountered during the course of this research. These include the researcher's employment with the organization whose development model is the object of study, the researcher's professional development as a science facilitator, and the issue of language differences.

During the research period the PSP was managing several teacher development projects concurrently. Employed by the PSP as a science facilitator, the researcher served most of the projects, with her main effort concentrated in the Cluster Project. This position entailed presenting workshops to groups of teachers each school term, assisting teachers with curriculum interpretation and implementation, as well as supporting teachers with lesson planning and presentation. Given that this research paper focuses specifically on the Cluster

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Project, the fieldwork and data collection activities were conducted during the course of performing the above-mentioned work tasks. The strategy was advantageous for this research since it facilitated access to, and interaction with, teachers and learners. Another derived benefit was that an association of professional confidence and trust between researcher and teachers was established during the course of project delivery. The fact that the researcher was employed by the PSP as a science facilitator raises valid concerns about impartiality, credibility and reliability of this research. Multiple methods and empirical materials are employed in the data collection processes. Data for the research was acquired via multiple data collection techniques and from multiple sources of evidence. The major sources of evidence include documents, archival records, interviews, direct observation, photographs and physical artefacts.

Also pertinent to this research is my own professional development as a science facilitator. My appointment with the PSP commenced in January 2008. I was considered suitably qualified academically having acquired a Master's Degree in Curriculum Studies with Stellenbosch University in 2006. In addition, extensive primary school experience spanning 23 years of teaching most of the subjects offered at the primary school level, and science and mathematics in particular, was considered an advantage. However, at that stage I had not received any formal training as a facilitator, nor had I any experience teaching at the FET (Further Education and Training) level. My professional development as a science facilitator paralleled my involvement with the Cluster Project. My decision to make the Cluster Project the focus of study added a further dimension to my development as a facilitator. While orientating to my role within the organisation and developing an understanding of my function as a facilitator more clearly, these processes encouraged deeper reflection on the Cluster Project, its purpose, role and outcomes. Such processes of enquiry and reflection can be considered an advantage to this research, encouraging investigation and observation of greater breadth and depth. For this reason, I conscientiously journalized both my involvement with the Cluster Project and my development professionally as a science facilitator for the duration of the programme in order to record my experiences as a researcher and my observations of the project.

Addressing language differences between researcher and participants proved challenging. The dominant languages of the Western Cape are English, Afrikaans and isiXhosa, according to an empirical study done by the Western Cape Language Committee of the provincial government (2002). I am proficient in two of these, namely English and Afrikaans. The inability to communicate in isiXhosa placed obvious limitations on the assistance I was able to provide to

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isiXhosa first language teachers. To facilitate the training and support that formed part of the Cluster Project, PSP management decided that all interactions with teachers by way of workshops and classroom interactions be conducted mainly in English. This decision was carried through to this research as well.

Having to deal with many languages amongst research participants is a challenge. In addition, not being able to communicate with participants in their mother tongue is also acknowledged as a limitation. Gathering and recording information obtained from participants as faithfully and accurately as possible is essential in research. Waldrip and Taylor, (1999) recommend that participants' responses should be reported verbatim, and it can happen that essential information can be lost through translation. Mindful of this, the research elected not to use translations, and instead conducted interviews with teachers, learners and school management teams in English.

Data triangulation involving a number of teachers from different schools, and methodological triangulation, drawing on more than one method for gathering data, was used in this interpretive case study, as a means of overcoming the weakness or intrinsic biases and problems associated with single method studies.

1.6 Chapter Outline

Chapter 1 presents the rationale for the research, and situates it in the broader context of curriculum reform and national concern for science education. The critical concern amongst education researchers and practitioners regarding teacher development and its significance for improving science education is identified and described. An explanation is provided for the selection of the teacher development model, the Cluster Project, for this interpretive case study. Clarification of purpose is related to the role of the project in teacher development and primary science education, supported by a brief overview of its design and operation, and some background information about the service provider, the PSP. In addition, three challenges for this research are described.

Chapter 2 analyses key aspects identified by and for this research in the light of significant observations: science, science education and teacher professional development (TPD). Discussion is linked to, and underpinned by, educational endeavour in South Africa, with references to teachers' context of work, teachers' professional capacity, and institutions

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involved with teacher education and training. In the course of this discussion attention is drawn to specific contextual realities and their implications for TPD.

Chapter 3 explains the two methodologies framing this research, activity theory and complexity theory. In-depth discussion traces the development of both theories, highlights critical emphases and implications of the theories for educational research, and further describes their service to the research.

This chapter also reviews several teacher development models and frameworks prior to developing a separate framework for interpreting TPD in the current study. Models and frameworks reviewed for the third framework in this research are Janse Van Rensburg and Le Roux's (1998) critical indicators of professional development, Bell and Gilbert's (1994) professional development framework, Reid's quadrants of teacher learning (Fraser, Kennedy, Reid & McKinney, 2007), Kennedy's analytical framework (2005), North Central Regional Educational Laboratory's Five Phases of Professional Development (1997 -1999), Hackling and Prain's Primary Connections professional learning model (2005), Clarke and Hollingsworth's Interconnected Model of professional growth (2002), and Loucks-Horsley, Hewson, Love and Stiles's Professional Development Design Framework (1998). Thereafter, five focus areas are identified in a framework for investigating TPD in this research.

Chapter 4 provides an overview of the qualitative case study research design and the research tools used for data collection, and presents some information about the processes for data analysis before giving attention to issues of ethics, validity and reliability, as well as the additional limitations of this research.

Chapter 5 presents the Cluster Project model, its purpose, design, implementation and outcomes within an activity framework. The chapter provides information about the teacher participants, project schools and contexts, PSP facilitators, donor funding for project work, additional collaborations and describes specific ways in which these collaborations benefitted the project, teachers and learners. Analysis of TPD is further expanded through Engeström's (1987, 1993, 2001) Activity Theory, Learning Cycles, Contradictions and Boundary Crossing, and the complexity framework described in Chapter 3.

Chapter 6 analyses TPD based on empirical interview data from Cluster Project teachers. The data is analysed using a qualitative framework developed in Chapter 3, and consisting of five

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key focus areas of: professional autonomy: professional knowledge, professional practice, professional collaboration, and continuing professional development.

Chapter 7 summarizes the key findings of this research, offers some recommendations for the way forward for TPD in terms of fostering science education in the primary school, and proposes important and relevant issues for further investigation.

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CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Those values and aspirations of a country reflected in its national curriculum underpin the school curriculum content and pedagogy, and the work of the teachers at the school. Thus, while the national curriculum guides the work of teachers in classrooms and schools, it also informs their initial and ongoing education and training so that they are in theory aware of its specifications and the content they have to teach. An important aspect of science teacher education and training is an awareness and understanding of the most important goals and purposes of science education contained in the curriculum. These include understanding that the broad aim of science education is to inspire, nurture and sustain the curiosity and questioning of young people (Harlen, 2010; National Curriculum in England, 2013:4). Two important benefits derive from implementing the aim successfully: a more scientifically literate population, and greater numbers of young people motivated and able to take up science and technology at higher education levels and in the work place to meet a country's growth needs.

A national curriculum is not simply a neutral collection of knowledge with instructions which appears in schools, classrooms and textbooks. It develops from the "political, cultural, and economic conflicts, tensions, compromises", experiences and practices of a people (Apple, 1993:1). Its development adheres to a "selective tradition" (Apple, 1993:1), which has suitably qualified and esteemed citizens and/or groups deciding upon its structure and content; their decisions are based upon their knowledge, interpretations, thoughts, ideas, experiences and shared visions and ambitions for education in their country. The national curriculum so devised goes on to become an important constituent of the school curriculum, which comprises all learning and other experiences that each school plans for its learners for each subject. As a framework for educational development in the country, through its schooling system, the national curriculum is intended ideally to create coherence in terms of what is taught in schools in order to ensure that all children are taught essential knowledge in key subject disciplines. Ideally it communicates the skills and knowledge that young people ought to gain in all schools, and the successful implementation of this involves teachers, learners, parents, employers and the wider community. Thus, the ideal national curriculum should specify the context, purpose

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and content for various subjects particularly science, mathematics and technology for schools and teachers. The curriculum for science details, amongst other things, the development and progression of key concepts and content for learners from primary to tertiary level, as well as detailing the specific ways in which learning can and should be assessed and reported on by teachers.

The translation of clearly defined goals into a coordinated set of courses from primary to tertiary level in a national curriculum represents only one phase of science education. An equally critical phase is the implementation of the curriculum in the classroom by well-trained and knowledgeable teachers working in supportive environments. By its very nature the discipline of science demands that teachers possess basic knowledge and pedagogical content knowledge and are competent to interpret the prescripts of the curriculum in the classroom. In terms of achieving the goals of science education, volumes of research show that the role of a competent teacher is pivotal, and educational effort for promoting science largely depends on the quality of the teacher's knowledge and professional capacity to develop children's knowledge of science and inspire an interest in science. This also involves motivation and enthusiasm on the part of the teacher.

At a time when the world is increasingly being shaped by science and technology, the steady decline nationally of enrolments of young people in science is cause for concern. Improved science teaching strategies are urgently needed to develop science more solidly through the schooling system. Curriculum reform alone cannot accomplish the change that is needed. This chapter reflects on the importance of science and science teaching, its global status, the work of science teachers, and the processes involved in their professional development. This reflection is closely associated with developments in South Africa with regard to the status of science education, curriculum change events and some of their impacts on science education, and corresponding teacher development processes. A summary of key observations concludes the chapter, serving to locate this research specifically within the broad sphere of primary science education in South Africa.

2.2 The Importance of Science

At this juncture it is necessary to address important questions about science relevant to the purposes of science education and this research: What is science? What does it mean to be

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"scientific literate'? What is the nature of science? Who are the people involved in the study of and research in, science, what do they do and how do they do this? And, how does the work of a scientist relate to science education and the work of science teachers?

The word "science" derives from the Latin words "scire" (to know) and "scientia" (knowledge) (Webster, 1979; Harper, 2014). Those deeply involved with science reject the view of science as a collection of disciplines, and instead have made numerous attempts to develop a more suitable general and universally accepted definition of science. However, the existence of a range of views on the nature of science makes this a challenging endeavour.

From its origins in natural philosophy (the study of nature and ideas about nature), science has undergone a great deal of change over the years. Tracing its evolution, Solomon and Aikenhead (1994:17) show that the science of the 20th century differed dramatically from the science of the 17th, 18th and 19th centuries, as its very nature was shaped and reshaped by historical and social forces over time, both from outside and inside the realm of science. The advances made by science in the 21st century allow scientists to use sophisticated equipment for making observations, running experiments, to employ powerful data analysis techniques, and to draw on a much greater breadth and depth of scientific knowledge than in previous centuries. Science today also benefits from the expanding diversity of perspectives of members of the scientific community.

While some interpret science as a way of thinking or working, and emphasize the scientific method of enquiry, others explain science as a body of knowledge and a series of processes of discovery. Whichever way it is conceptualized or utilised, science will always search for explanations for what goes on in the natural world, investigate evidence, and attempt rational explanations for natural phenomena. As has been mentioned, this investigative process has evolved over centuries, demonstrating that the scientific enterprise is not a static one. In the course of its evolution, scientific practices have been transformed by the increasing knowledge, changes in societal concerns, and advances in communication and technology. Since science is deeply interwoven with history and with society, and at the same time as it has evolved and changed over many centuries, certain practices of science, together with our general understanding of science, have changed and developed.

Historically science was referred to as a body of knowledge that is reliable and can explain natural phenomena rationally and objectively, while more recent definitions of science also

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include the methods involved in the pursuit of this knowledge. In the late nineties Wilson (1998:59) explained “science” as a “systematic activity for building and organizing knowledge in the form of testable explanations and predictions about the universe”, while a decade later the British Science Council (2010) interpreted “science” as “the pursuit of knowledge and understanding of the natural and social world following a systematic methodology based on evidence”, clarifying and expanding the concept of the “natural world” to include any aspect of the physical universe. The International Council for Science (ICSU) (2011:7) similarly defines “science” as “the intellectual and practical activity encompassing the systematic study of the structure and behaviour of the universe through observation and experiment.” Earlier Millar (2004: 1) offered a three pronged definition of science as a product (a body of knowledge), a process (a way of conducting enquiry) and an enterprise (the institutionalized pursuit of knowledge of the material world). Whereas Chamberlain and Crane (2009:1) see science as simply learning about the world, and rather than emphasizing science content, they see science as including all dimensions of science, by means of which knowledge is obtained through observations and investigations that can be substantiated by others, all of which supports the process of the learning and understanding of science. This conceptualization of science corresponds with that put forward by the USA National Research Council (NRC) (2007) who state that knowledge and understanding of both elements – science as both a body of knowledge that represents current understanding of natural systems, and the processes whereby that body of knowledge has been established and is being continually extended, refined, and revised – are essential for the process of learning science. These various conceptualisations of science show that there are many varied and multifaceted definitions of science, and to date no agreement on a universally accepted description of science.

The practitioners of science, the scientists, are curious about the natural world and, in their investigations, engage scientific methods, such as observing, measuring, classifying and performing experiments to gain knowledge and understanding of the natural world. Through their investigation scientists strive to discover and understand the what, how and why of phenomena. Chamberlain and Crane (2009:1) identify three key aspects of science knowledge for which scientists are responsible, and these are to “understand, explain, and apply knowledge” and, drawing on a range of processes, such as careful observations, designed experimentation, and logical reasoning, scientists work towards accomplishing these aspects. In the process scientists generate and build knowledge, develop technologies, and investigate

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and solve problems. They use scientific methods to test hypotheses, and analyse the empirical evidence to either corroborate or refute these hypotheses.

The scientific method is critical to rigorous scientific inquiry. It involves a step by step process and set of techniques and principles designed to promote scientific inquiry and to broaden knowledge and understanding. The steps include: the formulation of a hypothesis, experimentation, the gathering of evidence, and interpreting and aligning the results of an investigation against the research question. The scientific method has come a long way since the philosophers of ancient Greece, with some variations and disagreement as to how it should be utilized. For example, challenging the notion that science always begins with a question or hypothesis, Vanderwolf, Cook, Coutts, and Cropp (2005: 12) maintain that this is not invariably the starting point, as a great deal of science can arise from contemplative observations, referring to studies conducted by Louis Pasteur in the late 1800s and Alexander Fleming in the 1900s. Extending this observation Shuell (1997) writes that scientific investigations are not the static, rigid, and hermetic processes they are often thought to be. Instead, they are processes in which data, observations, interpretations, and theories are open to engagement, peer review, criticism and debate. More recently, McLelland (2006:2) extended the explanation and writes that scientific investigation may take different forms, there is no single method that all scientists use, creative flexibility is essential to scientific thinking, but each must ultimately have a conclusion that is testable and falsifiable, otherwise it is not science. She explains further (2006:6) that the basic steps of scientific enquiry are easy to understand and to follow, and the processes of science are useful, they are not only applicable to scientific research but can also be used for solving everyday problems.

Where thorough and rigorous processes are used for investigations, scientific conclusions are generally accepted as reliable, but remain contestable and subject to revision or modification as new evidence comes to light. For the reason that "good science demands the ethical practice of science" (Stern & Elliott, 1997:3), scientists are required to adhere to a strict ethical and professional code. In addition, for science knowledge "to be usable" scientific advances have to be "known and owned" (UNESCO, 2010:10). This agreed-upon principle obliges scientists to communicate their research and findings to their peers and society as accurately and clearly as possible, and, as far as possible, devoid of any form of bias. As findings and understandings are made known, these are subjected to peer reviews, debated and reinterpreted in academic

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circles, and either confirmed or disconfirmed. In this way, the general public is informed of new knowledge as it comes to light as a result of rigorous research.

Scientific literacy is the general term for a person's or the general public's "awareness and understanding of basic scientific information, concepts and theories" (Laugksch, 2000:71).The importance of a scientifically literate world population is emphasized by ICSU (2011) who state that basic science literacy, coupled with scientific "ways of knowing'; in other words, drawing conclusions based on observation, experiment and analysis, are essential tools for every citizen to be able to engage in rational debate and sound decision-making based on scientific knowledge. Being scientifically literate enables an individual to differentiate vague and unsupported claims or conclusions from probable and relevant ones. The USA National Research Council (NRC) (1996:13) writes that being scientifically enables an individual to:

- experience the satisfaction of understanding the natural world;
- use scientific thinking in making personal decisions;
- participate intelligently in societal discussions on science and technology; and
- attain the skills and knowledge required for finding a place in and being productive in current and future economies.

Science today occupies a "central position in the Western worldview" (Carter & Smith, 2003: 45), and is generally regarded as an essential tool for the growth and development of both a country and its citizens. In this context, it has been found that, where science and technology supports the commercial interests of a country and its people, the economy is more successful (United Nations Conference on Trade and Development, 2003; Arnold, Schwaag Serger, Bussillet and Brown, 2009; OECD, 2013b). Access to, and application of, science and technology have been found to be a key criterion distinguishing developed from less developed or under-developed countries. Countries, such as Norway, Switzerland, China, and Japan, which boast a strong foundation in science and technology, appear to be developing at a faster rate than other countries with relatively poor education in these disciplines (OECD, 2013b). A poor grounding in basic science has serious disadvantages for learners and ultimately for a country, inhibiting research and innovation, in addition to restricting economic, social and educational development. In such countries this is exacerbated by insufficient science and technology research, development and facilities. Unable to compete with science and

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technology driven countries such as Switzerland or Japan, less developed countries such as South Africa, and many of the countries on the African continent, lag behind and are unable to generate the same kind of growth and prosperity.

Science and increased scientific activity distinguishes the modern era from any other time. The impacts of science, either developing from the technology associated with it or from scientific and technological innovations, are manifest in almost every aspect of our 21st century lives. It has improved our understanding of the natural world, and generated a range of information as well as numerous inventions and products that have significantly improved our lifestyle. A prime example is the field of medicine and healthcare, in the form of a longer and healthier life and previously unimagined cures for, and prevention of, diseases. Inventions from the basic electric light bulb to complex computers, satellite technology and cellular communication have forever altered the way people are able to interact with the world, access information and communicate with each other. However, the negatives side can be seen in the continued environmental degradation, increased pollution and its effects, increased loss of animal and plant species, and the development of destructive weapons of war. In addition highly controversial issues surrounding such innovations as stem cell research, cloning, genetic modification, toxic chemical weapons, and certain agricultural practices, such as monocultures, are generating an increasing number of environmental and social problems.

However, in spite of the growing number of negative outcomes, given its importance for economic growth and its benefits to humankind, particularly in the field of medicine, most education systems assign a high status to the study of science, its sub-disciplines and technology. Beyond political, economic and social motivations, those concerned about the future of the planet and the survival of the human race consider the role of science and science education as crucial to rising to some of the current challenges, whether at the global level in the form of climate change and the gradual destruction of the planet's ecological systems, or at the local level in the form of issues of food security, environmental degradation, sustainable living, and including finding solutions to sustaining economic growth with minimal disruption to the natural environment. Critical links between those important world issues affecting humankind, and science and technology, have inspired global and local initiatives to ensure all citizens acquire a basic knowledge of science.

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Despite these efforts on the part of governments to promote science and technology, studies show that, on a global scale, particularly in poor and developing countries, relatively few people appear to have even an elementary understanding of science and its benefits, and how science works (McComas, 2002:3; Miller, 2001; USA National Science Board, 2006; ICSU, 2011), with a 2010 UNESCO (2010:10) report showing that “a large majority of poor people and countries remain excluded from the creation and benefits of scientific knowledge”. Mc Comas, Clough and Almazroa (in Mc Comas, 2002: 3) argue that a poor understanding of how the scientific enterprise operates is potentially harmful, particularly in societies where citizens with little or no science knowledge occupy positions to influence policy matters related to science and technology, when citizens have to weigh scientific evidence presented in legal proceedings, or when they participate in deciding on allocating important funding for development projects and research. Some of the problems associated with a poor understanding of science also become apparent in the broader society where ordinary citizens, with little or no specialized scientific knowledge, have to access scientific information via the media and other sources; their lack of basic science knowledge renders them vulnerable to being misled.

Researchers have found that poor science understanding and learning can be attributed to the way the subject is taught in schools (Gilbert, 2006:29; Tytler, 2007; Hoban, 2010; ICSU, 2011). Gilbert (2006:29) further contends that this lack of understanding stems from unsatisfactory science teaching, and textbooks which emphasize the recall of factual science content, to the detriment of learning in a holistic way about the nature and functions of science. In support of Gilbert’s (2006) observation of science teachers in New Zealand, Wellington and Lakin (1994), reporting on a study done with UK science teachers also found that, where teachers have never reflected on issues relating to the nature of science, in addition to simply presenting the content, they have tended to undervalue such ideas in their teaching, a tendency the authors consider unhelpful for promoting sustained and valuable science learning. Investigating and reflecting on how teachers are educated, trained and supported for science teaching in schools, and the support materials made available to them, can help to highlight the root causes of poor science learning so that impediments and shortcomings can be addressed within education systems.

2.3 Science Education

In the 21st century people live and work in demanding and often turbulent environments requiring a basic knowledge of science to do more than just survive. Thus the challenge for

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every education system is to produce suitably qualified and competent science teachers to ensure that when learners are adults they are able to live and work satisfactorily and productively in the current environment.

Scientific and technological innovations have benefitted humankind in terms of freeing many people from arduous labour and from disease, and increasing both agricultural and industrial output. However, science and technology have brought chemical weapons and destructive military hardware. Together with these, other activities such as animal experimentation and the media portrayal of scientists as eccentric, sinister, socially irresponsible and anti-social “nerds” (Pettus, 1992: 349-350), has done little to improve the negative image of, and indifferent attitude towards, science and the work of scientists.

However, despite such possible negativities, I argue that science education is important to an individual’s more informed understanding of the world in terms of helping him or her to critically assess her or his impact on the world, and understand some of the consequences of human behaviour. There are increasingly clear indications that certain human activities, such as the irresponsible management of natural resources and unsound production and consumption practices are the leading cause of environmental changes with serious consequences for the planet’s future ecological equilibrium. Repercussions from ill-advised processes further exacerbate the environmental and economic recovery and the development initiatives of many countries as they are having to deal with increasing population pressures, simultaneously with decreasing resources and environmental degradation. All of these threats speak to the urgency for a more scientifically literate and environmentally responsible world population.

For one to be scientifically literate one needs to have a thorough understanding of the “nature of science”. A lack of agreement on what is understood by the “nature of science” exists among philosophers and historians of science, scientists, and science educators. However, in order to establish how the “nature of science” has been and is understood by this constituency and its importance in science education I examine several explanations of this concept. Lederman (1992) found, in a study he conducted in the early nineties on students’ and teachers’ conceptions of the nature of science, that they understood the phrase to refer to the epistemology of science: science as a way of knowing, or the values and beliefs inherent in the development of scientific knowledge. Twenty years later Abd-El-Khalick (2012) came up with a simpler explanation, seeing the “nature of science” as involving understanding science as a

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knowledge generation and validation enterprise. Adding another dimension to the concept, the OECD (2009a: 128) distinguished between knowing science and knowing about science: “knowledge of science” involves understanding fundamental scientific concepts and theories, whereas “knowledge about science” includes “understanding the nature of science as a human activity and the power and limitations of scientific knowledge.” Earlier McComas, Clough and Almazroa (in McComas, 2002: 4) made an explicit link between science and science education, seeing the “nature of science” (NOS) as going beyond the mere knowledge of scientific concepts to encompass the scientific enterprise for science education. In unpacking this idea these authors examine the concept through multiple lenses, arguing that, the “nature of science” should include the purposes of science and how science functions in particular social contexts. The authors (McComas, et al., 2002) argue that, the concept is broader than science itself: it is not directly concerned with the natural world in the way that science itself is, but is instead a fertile hybrid arena within which aspects of various social studies of science, including the history, sociology, and philosophy of science, are blended with research from the cognitive sciences, such as psychology, into a rich description of what science is or encompasses, how it works, how scientists operate as a social group, and how society both directs, and reacts to, scientific endeavours. Science educators, by understanding the “nature of science” in this way, are guided in presenting science both accurately and more meaningfully to their learners. According to Matthews (in McComas, 2002: xiv) a crucial benefit for learners and practitioners of science coming out with a comprehensive grasp of the “nature of science”, including its social context, is that it affords them the opportunity to distinguish meaningful and useful science from superficial parodies of science and pseudoscience. Thus, a comprehensive and sound understanding of the “nature of science” has the potential to develop in an individual the ability to make more informed decisions when presented with scientific claims and evidence.

For science educators, an important consideration in developing this kind of understanding in children is the age learners should be when the “nature of science” is integrated into their science learning, and whether young children would be able to cope with the “nature of science” concepts to which they are introduced at that point. Lederman (1992) argues that certain aspects of the “nature of science” can be accessible to, and important for, primary and secondary school science learners. Both Lederman (1992, 1999) and McComas et al. (2002) argue that, critical to their learning, and to the development of an understanding of the “nature of science” children need to learn that science knowledge:

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- derives from the attempt to understand and explain natural phenomena,
- is tentative and subject to change,
- is empirically based: science knowledge derives from / is based on observations of the natural world, although science relies heavily on observation and experimental evidence, rational arguments and scepticism are equally important,
- is subjective (theory laden),
- necessarily involves human inference, imagination and creativity. This is closely related to an understanding of observation and inference, and the functions of, and relationships between, scientific theories and laws,
- is socially and culturally embedded,
- is not limited to one particular or prescriptive scientific method, and therefore cannot be said to depend on a universal step-by-step scientific method,
- demands accurate record keeping, peer review and replicability,
- demands that new knowledge be reported clearly, openly, and in as objectively as possible,
- assumes that science and technology impact each other, and that
- is built upon the understanding that scientific ideas are affected by their social and historical context.

It is generally understood by science educators that the primary objective of science education is to help children develop an understanding of scientific inquiry and of the "nature of science". While the common sense notion amongst many science educators is that inquiry based learning is the vehicle for achieving both these objectives, Abd El Khalick (2012) is quick to point out that, while inquiry may appear to be an ideal method for helping learners and teachers develop informed views of the "nature of science", it does not necessarily follow that engagement with inquiry results in an improved understanding of science. Abd El Khalick (2012) rather advocates carefully planned and structured opportunities for reflection on inquiry experiences as prerequisites for achieving the in-depth and useful understandings of the "nature of science". Thus the challenge for, and responsibility of, science teachers, according to McComas (2002:5), is for them to translate their own comprehensive understanding of the knowledge generation process into meaningful and useful classroom experiences, together with appropriate classroom conversation and discourse. The practice and development of science therefore depends on science teachers and their teaching of the subject.

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For this to happen, I would argue that one needs to consider what kind of education, training and support science teachers need for them to be able to engage children in meaningful learning experiences and to inspire an appreciation for, and a holistic understanding of, both science and the nature of science, and their interrelatedness, and for them not to see science simply as a set of isolated and meaningless facts to memorize and reproduce. Current educational programmes may be contributing to the problem of unsustainable human environmental practices. Robinson and Shallcross (2007:8) see this as so, arguing that, as long as education helps to foster a "culture of denial" which rejects the link between modern life styles and threats to the future of ecosystems and humanity, and a disregard for the limits of science and technology to generate solutions for negative ecological trends, the threat to sustainability will increase. They suggest that finding solutions to, and changing environmentally harmful human practices, involves transforming existing approaches to science and environmental education. Insights derived from science have the potential to foster a better understanding of the nature and impact of technological improvements, in particular industrial development, on the environment, and the implications of these for human life on this planet. In this context Murcia (2005:1) argues that a rapidly increasing industrialised world means that societies and individuals are increasingly called upon "to engage with, understand, and take up science research and applications of science" as they confront new technologies and explore more sustainable development practices.

Greater effort is now being focused globally on STI (science, technology and innovation) capacity building. Extending people's and countries' technical, vocational, engineering, entrepreneurial, managerial and scientific capacity has become a potentially valuable means of promoting sustainable development and inclusive globalization. According to Mashelkar (in Watkins & Ehst, 2008: x) STI capacity building could also stand for "solve, transform and impact", since science, technology and innovation has the potential to empower citizens to *solve* social and economic problems, *transform* their societies, and make a positive *impact* on the standard of living and quality of life of society's poorest members. Thus knowledge derived from science, technology and innovation can contribute to greater improvements by, for example, building the capacity to ensure clean drinking water, develop innovative waste management systems, promote environmentally responsible farming practices, add value to natural resources, and help industries develop their competitive capacities but in an environmentally responsible and sustainable way. In addition, science and scientific research has the potential to promote further investigation into, and discussion of, critical global issues,

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such as the over-reliance on fossil fuels and nuclear energy, greenhouse gas emissions, climate change, food security, and sustainable development. Developing scientific research is fast becoming a vital means of helping society adapt to the adverse impacts of past practices, and for repairing some of the damage done in the past, or at least retarding further environmental degradation, as a way of securing both the future of the planet and the quality of life of its inhabitants.

Active and productive participation in global discourse and decision-making related to critical global issues requires a sound scientific and technological knowledge base on the part of those involved. In the early nineties, Haigh (in Qualter, Strang, Swatton & Tayor, 1990: 11) saw one of the greatest social problems of our time as being the large numbers of people who were accepting without questioning, “any old codswallop” to do with environmental sustainability. The authors were arguing that good science teaching rather than having to do with the content, facts and practicalities, should be concerned with the imperative to reduce the ignorance and gullibility of the population regarding environmental issues. This idea had already gained currency by the mid-eighties. The Royal Society (1985:10) declared that the “uninformed public is more vulnerable to misleading ideas related to controversial issues” such as acid rain, nuclear power, animal experimentation or alternate medicine. In this context they emphasized that “an enhanced ability to sift the plausible from the implausible can be considered one of the major benefits of a better public understanding of science”. Now in the 21st century, prominent science education scholars and science-based organizations, such as the International Council for Science (ICSU), continue to campaign for worldwide accessibility to science and science education for all. ICSU (2011:3) advocates basic science literacy and scientific “ways of knowing” for all, including the drawing of conclusions based on observation, experiment and analysis to equip people for rational debate and sound decision-making. Teachers and the quality of their efforts play a crucial role in these processes.

The task of educating and inspiring future scientists of the country, and ensuring that a greater number of people emerge from the education system with a sound knowledge of basic science concepts, is a mammoth task. In this context educational effort in schools is critically linked to the quality of pre-service teacher education and ongoing in-service development, together with ongoing support for science teachers. Deficiencies in this area are likely to mean that teachers are ill-prepared to teach scientific subjects, and a further concern for the International Council of Scientific Unions (ICSU), an international non-governmental organization dedicated to

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promoting science is that "poorly trained teachers may well be driving learners away from scientific disciplines rather than attracting them" (ICSU, 2011:9). Informed, confident, inspired and expert teachers are needed to challenge children, engage them in appropriate opportunities that inspire learning, and motivate them to choose careers in the various scientific disciplines.

With no "Planet B" as a likely option, humans have to seriously and urgently reconsider their actions in planning the way forward. Unless there is collective effort to encourage sustainable use of Earth's resources, and turn the tide of, or at least minimize the destruction of the environment, research suggests a very real threat to our existence. All nations of the world are coming together to find solutions to the global crises, and are beginning, in varying degrees, to work collaboratively to explore, engage and expand more sustainable development practices supported by scientific and technological research, not just for the sake of the planet but for the survival of the human species. While Planet Earth has recovered from many previous natural disasters, Clayton and Radcliffe (in Robinson & Shallcross, 2007:8) argue that there is reason to believe that it cannot survive a future human-induced catastrophe without concerted efforts to comprehensively educate a generation in science and the environment. The mission for humankind and its survival is clear, and the task of science education and well-trained capable science teachers critical.

While a concern and drive for more accessible and improved science education appears to be universal, a review of developments in this area highlights a stark contrast between advances made in science education in developed countries in comparison to the lack of significant progress in less developed countries such as South Africa. Elaborating on the global status of science education, reference is made to a report produced by the International Council for Science (ICSU) in 2011. Their April 2011 report uses data acquired from large-scale learner surveys conducted in both developed and less developed countries to review the status of science education internationally. Studies involved in the survey include the Program for International Student Assessment (PISA) study, the Trends in International Mathematics and Science Study (TIMSS) studies and the Norway-based international Relevance of Science Education (ROSE) project.

The 2011 report produced by ICSU describes the quality of science education in terms of secondary school student performances and the level of interest in science, using data from questionnaires. ICSU's (2011:11) findings show that countries and regions differ greatly with

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respect to the level of development achieved by learners in science education as well as the appeal of scientific and technological careers for young people. Some of the top ranking countries consistently producing superior science results for the 2003 and 2007 TIMSS and PISA include Singapore, Chinese Taipei (Taiwan), the Republic of Korea, Japan, and Finland, with a poor showing from African countries which consistently achieved results below the international average. Further ICSU (2011:3) inferences are in alignment with some common conclusions derived from the PISA, TIMSS, and ROSE studies, namely that learner achievement in mathematics and science is highest in countries such as Japan and Finland, where educational effort appears to be highly valued, and where teaching is a well-regarded profession. In addition, high learner achievement in science did not necessarily translate into greater interest in scientific or technical careers in these countries. In fact the converse appears true: countries with the lowest achievement appear to have the largest percentage of youth interested in careers in STEM (science, technology, engineering and mathematics). The most likely explanation for this may be that science, mathematics, and technology are perceived to be the “gateway” subjects guaranteeing greater opportunity and the promise of a better future. The level of global concern for science and mathematics education and development indicates that this perception on the part of young people in these countries may be a widespread phenomenon.

The desired outcome of education common to those nations competing with each other in the world market is to develop and secure economic prosperity and sustainability. This goal is seen to be closely associated with, and dependent on, science and mathematics education, and appropriately high learner achievement in these subjects. Using a pipeline metaphor, Turner (2008:3) shows how school science can be seen as one end of a vital process intended to channel science-oriented learners, upward from the schools, through to post-secondary institutions. This has been seen by many science educators, economists and industrialists as assuring the economy of a country a consistent supply of highly trained scientists, technologists, engineers and mathematicians. Research has shown that, in view of the fact that the educational efforts of many less developed countries appear constrained by a lack of teaching materials, including books, libraries, computing and communications technologies, community-based science centres, laboratory facilities and equipment, as well as a shortage of skilled teachers (ICSU, 2011:3), their science education programmes are considerably reduced and poor in quality.

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The economic considerations referred to above seem often to be the main driving force for science education. The general view that the key function of science education is to provide the human resources of sufficient quality and quantity to satisfy national economic requirements persists in many countries. The economic argument for science education and school science also appears to hold more sway with government and business, which are often the main sources of finance for scientific and technological research and endeavour. Poor learner achievement in science and mathematics frequently fuels agitated discussion about the global competitiveness of a country, South Africa being no exception. According to Turner (2008: 4) the economic argument is often used to serve vested interests and is often not well supported by economic data; he quotes studies from the United States that show only about a third of those who are in possession of post-secondary degrees in science or engineering are in fact employed in positions related to their training. However, other studies, such as that of Phumaphi (in Watkins & Ehst, 2008: x) show that "science and technology has been central in the advances made against poverty and to stimulate economic growth and development." STI (science, technology and innovation) capacity building in less developed countries has become vital for progress in poverty alleviation, balanced socio-economic growth, and a country's integration into the global knowledge-based economy.

Since science, according to Hassan (in Cetto, 2000:313) is regarded as the universal language of the 21st century, "the importance of science education for economic development should not be underrated". He cautions that if a country fails to speak the language of science its science illiteracy can reduce its competitive potential in the international economic arena. As it is, reports indicate that some less developed countries, lacking the capacity in terms of technology and human resources to access and utilize advances in science and technology, are restricted from becoming serious contenders in the world market. An added challenge for both developed and less developed economies currently maintained by the exploitation of natural resources such as coal, oil, natural gas, gold, iron-ore, and other metals, is the knowledge that these resources are finite, emphasizing the need to develop citizens' resourcefulness and innovation in preparation for this inevitability. A shift in focus from developing new technology to developing human capital, the key resource in a knowledge-based world economy, can be achieved by strengthening science, technology, engineering and mathematics education.

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In this context, quality science education can go a long way towards ensuring a higher level of scientific literacy amongst the general population thus making them better prepared and more able to adapt to changing living and working conditions. Summarizing some of the benefits of scientific literacy for all citizens, Hackling, Goodrum and Rennie (2001:7), as was discussed in 2.2., include the following: it helps people to be interested in and understand the world around them, to engage in the discourses of and about science, to be sceptical and questioning of claims made by others about scientific matters, to be able to identify questions, investigate and draw evidence-based conclusions, and to make informed decisions about the environment and their own health and well-being. Incorporating these elements into science education at all levels of schooling, from primary to tertiary level, has the potential to promote attitudes, and the knowledge and skills relevant to current and future economic, social and political developments.

Research shows that solid grounding in science knowledge and skills starts in the primary school years (Harlen, 1993:3), and even before the child enters the formal schooling phase. In the process of making sense of the world around them, young children are naturally inquisitive and seek explanations for the phenomena they encounter. It is during this period of orientation to the world, referred to as the golden years by the Montessori approach that teachers have the golden opportunity to build on the child's natural curiosity. Harlen (1993:3) maintains that children in the primary years build a structure of ideas of the world around them, whether they are taught science or not. The author argues that, without intervention in terms of introducing a scientific approach into their exploration of the world, the ideas children develop may be "non-scientific", and may obstruct learning at the secondary level. Trying to change children's firmly held notions at a later stage by teaching the "right" ones often proves difficult.

Learning science and scientific ways of knowing and thinking, at the primary level is crucial for developing a learner's long term interest in science. For this reason the primary science teacher is key to developing the knowledge foundation for continued study in science, and to engendering in learners a passion for science and an understanding of its significance in a modern society. Problems arise when primary teachers who are usually generalists do not have a firm knowledge base in science. In this context Parker and Heywood (in Gilbert, 2006: 315) argue that "primary teachers may often lack a personal scientific background on which to draw and that many may themselves hold misconceptions of current scientific ideas". This lack of a science knowledge base may also affect their ability to encourage and support expanded

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learning in science. The impact of this is serious, and research suggests that poor science education at the primary level may contribute to the negative attitudes to science that learners have developed by the time they reach secondary level and beyond. The result for them is a "disenchantment" with, and "disengagement" from, Science according to Turner (2008: 7) and Aikenhead (in Tytler, 2007:18), as a large number of learners between the ages of eight and sixteen move from a state of enthusiasm and engagement with the study of science to a state of indifference or disdain for the subject, as was observed by these researchers was the case for both girls and boys at this level.

Regardless of the principal motivating factors, whether social, economic, democratic, environmental or cultural; there is consensus that effective and stimulating science education at all levels is fundamental to the progressive development of a global society, and is important for the majority of people who may or may not opt for careers in science (ICSU, 2011). Governments are encouraged to accord the highest priority to improving science education at all levels; and developing nations such as South Africa are advised to invest in science education, not only at university level but at the primary and secondary levels as well.

2.4 Science Teacher Development

Since the professional development of primary Science teachers is at the heart of this research, the term as it applies to teachers requires examining and defining. "Professional development" is often used interchangeably in the literature with other terms such as in-service education, teacher training, teacher education, and staff development. A general survey of the literature reveals that staff development is seen as mandated participation by some, in-service education to others connotes after-school workshops, "training" is seen by some as one of many strategies for learning and teaching, and teacher education is generally understood to include initial or "pre-service teacher education and training (Loucks-Horsley, Hewson, Love & Stiles, 1998). However, this research focuses mainly on the work of in-service teachers and favours the term "professional development" to describe this, using the terms to refer to teaching and learning activities and processes for practicing teachers, in order to differentiate in-service work from initial teacher education and training.

I looked at various discussions of this concept in the literature in order to develop a clearer understanding of what teacher professional development (TPD) essentially involves, and what

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would constitute the general characteristics of effective and meaningful professional development processes. While much has been written on the subject in recent years, Evans (2002:124) notes that "there is still much in the field that is imprecise and unclear", along with "inevitable gaps in the professional development-focused knowledge base" (Evans, 2008a).Thus a clear and precise understanding of the concept, processes and outcomes of TPD starts with examining the parameters within which it could or should be defined. As Evans (2002:130) points out, "defining – or, at the very least, interpreting – teacher development is essential to those who are concerned to categorise work in the field within clear parameters". In support of this view, she states that "establishing the parameters of what may be considered to constitute teacher development work is impossible to do without a clear understanding of the concept". This section therefore commences with an exploration of the concept "TPD", followed by a description, analysis and critical evaluation of various teacher development models and strategies.

In simple terms, professional development refers to the development of a person in his or her professional role. Although an analysis of the precise meaning of TPD, based on the complete range of definitions and discussions to be found in the literature is beyond the current scope of this research, in seeking basis of understanding a number of definitions are reviewed, of which a selection is mentioned and discussed, particularly in terms of how each applies to the kind of research of this study. These various interpretations of TPD by researchers and theorists serve to highlight the different dimensions of the concept.

Seeing professional development in terms of processes and products, Kiehl (2008) argues for the development process as involving a collection of activities that systematically increase teachers' knowledge of academic subjects and advance teachers' understanding of instructional strategies. Loucks-Horsley et al. (1998) define professional development in particular social contexts as "the opportunities offered to educators to develop new knowledge, skills, approaches, and dispositions to improve their effectiveness in their classrooms and organizations". Drawing attention to aspects of, and likely motives for, personal and social development, neither interpretation includes reference to the teacher's personal agency in the learning process.

Focusing on individual teachers and their effort, Fullan (1991: 326), writing in the early nineties, maintained that professional development refers to "the sum total of formal and

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informal learning experiences throughout one's career, from pre-service teacher education to retirement, with impact determined by a combination of motivation and opportunity". Expanding on Fullan's description, Villegas-Reimers (2011) sees formal experiences as including the completion of a program of initial teacher preparation, attending workshops and professional meetings, mentoring, and completing research; informal experiences may include reading professional publications, viewing television specials related to an academic discipline, and joining study groups with other teachers. Both Fullan (1991) and Villegas-Reimers (2011) acknowledge initial teacher education and categories of learning experiences, but neglect to clarify clearly how this learning becomes evident, or how the learning is interpreted, internalized by teachers themselves, and further carried through into their professional function.

Other scholars see the individual teacher's professional development as extending beyond training and the acquisition of knowledge and skills. Day (in Evans, 2008b) broadens the definition to include ongoing collegiality and teachers as change agents:

> *Professional development is the process by which, alone and with others, teachers review, renew and extend their commitment as change agents to the moral purposes of teaching, and by which they acquire and develop critically the knowledge, skills, planning and practice with children, young people and colleagues through each phase of their teaching lives.* (Day in Evans, 2008b:30)

Acknowledged by Evans (2008b:30) as one of the very few available stipulative definitions of professional development, Day's definition addresses critical aspects of an individual teacher's professional development.

In her formulation Evans (2008a) emphasizes the evaluative and mental internalization aspects of professional development. Using the term "professionality", she explained the multidimensionality of development as "an ideologically-, attitudinally-, intellectually- and epistemologically-based stance on the part of an individual, in relation to the practice of the profession to which s/he belongs, and which influences her/his professional practice" (Evans, 2002: 130). She expanded on this definition, describing TPD as an "on-going process", a "form of personal enlightenment, which may vary in scale from being massive to miniscule", and as "relevant to the individual's professional life and practice", "a mental, not a practical, process – though it may (and often does) motivate practice" and "an independent, not an interpersonal,

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process – though its stimulus may be (and often is) found in interaction with others" (Evans, 2002, 130 – 131, 2008a). In comparison to Day's version, Evans's account, although not quoted in its entirety, is more broadly formulated with "a range of applicability that extends from an individual- to a profession-wide level" (Evans, 2008b:30). The interpretations of TPD presented by Day (in and Evans, 2008b) and Evans (2002, 2008b) show less emphasis on improved teaching practice in the classroom and the impact of these improvements on children's learning.

A condensed interpretation of teacher development presented earlier by Guskey (2000: 16) identifies three defining characteristics of professional development: "intentional, ongoing and systemic". Elmore (in MacNeil, 2004:20) prefers to emphasize the context of teacher learning as significant, maintaining that a "potentially successful programme for improving instructional practice is highly focused on specific content and the pedagogy that goes with it, and is delivered as close as possible to the classrooms and schools in which it will be used". A range of other perspectives emphasize the consequential aspects of professional development, such as the specific impact of professional development on the teacher's work in the classroom and the outcomes of this for children's learning.

Various perspectives of professional development regard improvements in instructional practices and learner achievements as significant indicators of successful and effective TPD. In the early eighties Calderhead (1984) was already establishing this connection, arguing that:

> *... instruction and children's learning will most likely be effective if teachers know their learners, their subject matter and the business of classroom organization well, and if they are able to design and implement activities for learning which are: well-matched to learners' existing knowledge and skills, which provide opportunities for further development, and which are well-managed and involve feedback to ensure productive learning and performance.* (Calderhead, 1984)

Later, Guskey (2000:16) surfaced this link more clearly, arguing that:

> *... professional development in some cases may involve learning to redesign educational structures and cultures, it generally involves those processes and activities for enhancing the professional knowledge, skills, and attitudes of*

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educators so that they might, in turn, improve the learning of their students (Gusky, 2000:16).

The general consensus amongst education researchers and theorists in this area is that TPD is a purposeful activity for developing and effecting improvements in the professional capacity of teachers, ultimately for the benefit of the teachers themselves and the children for whom they are responsible.

The current study takes cognizance of some of the essential intricacies of TPD discussed above: that it is a purposeful activity, a process of learning which is personal and particular to the teacher, that it involves motivated action to achieve an objective, is a continuous process as teachers adjust to change and try to stay up to date with new policies and trends or to learn fresh strategies, techniques and methods for classroom challenges, that it involves reflection on practice and outcomes of practice, is socially connected as teachers learn from and with others, is contextually bound as teachers utilize the opportunities for growth presented in their context, that it can proceed independently or in collaboration with others, and that this may in due course enhance the person's professional facility with respect to her/his knowledge, understanding, skills, attitudes and/or competencies. These elements would all become evident in the person's function as a teacher and in the way children learn.

Irrespective of the dimension researchers choose to draw attention to, there is general agreement that meaningful TPD is fundamental to achieving improvements in teaching and learning. Within the science education realm the important consideration is what kinds of knowledge, understanding, skills, attitudes and competencies are required of science teachers for them to knowledgeably and competently support and promote useful science learning.

As has been mentioned, the domain of science does not comprise a fixed body of knowledge. Rather its dynamic nature can be attributed to improvements in technologies that support a rapidly expanding knowledge base, and an increasing relevance of science for environmental, economic, political and societal issues. Teachers' knowledge should therefore not remain static, but should evolve with these kinds of developments. For this to happen teachers would need ongoing opportunities to build and update their understanding and ability in science. Traditional approaches involving the transference of science content as a body of facts and rules to be memorized must give way to approaches that favour inquiry, investigation, reasoning, problem-solving and application. At the same time, the needs and adversities

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presented by an ever-changing society impact events within a school and classroom. This requires that teachers develop their understanding of how learners with diverse cultures, language competencies/needs, interests, abilities and experiences make sense of, and are able to apply, scientific ideas, and what a teacher should do to support and guide them in this process. Such realities call for a range of different approaches to supporting teachers to develop their knowledge and understanding of science, and to foster pedagogies for more productive science teaching and learning. Driver, Newton and Osborne (2000:298) advise that this is a process and that teachers need an "enculturation into the practice of science teaching just as their learners need enculturation into the practice of science", substantiating the widely held observation that teachers need specialized knowledge and insights for teaching science.

An enculturation into the practice of science requires that teachers bear a sound knowledge of science, as well as knowledge of pedagogies best suited to teaching science. Webb and Glover (2004: 103-104) argued that, if the main aim of science education is to help learners develop their understanding of science, then quite clearly teachers cannot achieve this if they lack the necessary content and pedagogical knowledge. Shulman, (in Webb and Glover 2004: 104), in describing the seven different kinds of teacher knowledge types, emphasize content knowledge (knowledge of science and about science) and pedagogical content knowledge (how to teach the subject matter) as essential knowledge types for science teachers, over and above the different types of knowledge all teachers are required to possess such as knowledge of the curriculum, of learners and their characteristics, of the education contexts, of education goals, values, history, and philosophy, as well as general pedagogic knowledge. Webb and Glover (2004: 104) state further that, while content knowledge is important as underpinning pedagogical content knowledge, both knowledge types are equally important in science teaching. They argue that a teacher can hardly know how to teach a subject if the teacher is ignorant of the subject, and, while knowing the subject matter is necessary, this is not sufficient to guarantee effective teaching of the subject.

PCK (pedagogical content knowledge) represents what teachers know or ought to know about teaching a specific content field such as science. As pedagogical knowledge is distinctive in terms of the subject, the responsibility rests with teachers to develop their knowledge and experience of a range of approaches suited to teaching specific science content. Amongst its many benefits, science-specific PCK enables teachers to present subject matter in an immediate, comprehensible and interesting manner, and this specific PCK can serve as a vital

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resource for teachers to resist common misconceptions in science by drawing on alternate teaching strategies. Teachers need to understand subject matter in depth and flexibility to help their learners create useful cognitive maps, relate one idea to another, and recognize and address misconceptions as they arise. Teachers also need to be aware of how ideas connect across fields and with everyday life, and help children make these positive and interesting connections. Apart from permitting teachers greater competency and confidence, Webb and Glover (2004: 105-106) describe that the ways in which PCK enables science teachers to:

- Plan, knowing the "big picture", and understanding what they are aiming at;
- Recognize the seed of a scientific idea in what learners say or write and support and encourage the process;
- Recognize "blind alleys" and redirect learners accordingly;
- Put forward scientific ideas for learners to consider in a manner that encourages thinking, investigation and reasoning; and
- Assess learner progress and involve learners in assessing their own progress.

Since PCK involves critical strands of knowledge for the most effective ways of teaching specific science content and concepts to particular diverse groups of learners, one needs to consider what are the kinds of processes that can most effectively improve science teachers' knowledge and competencies, and what kinds of the challenges are associated with designing and implementing teacher development programmes to improve science teaching and learning.

Critiquing current approaches to professional development, Díaz-Maggioli (2004) cites the following as critical stumbling blocks:

- Top-down decision making: traditionally, professional development arrangements are designed by administrators, district officials and consultants rather than by teachers. By restricting teachers' participation in decision-making, and prioritising administrative needs, these programmes often become a burden to professionals instead of a welcome solution to classroom problems.
- The idea that teachers need to be "fixed': too often, professional development is motivated by the erroneous idea that, if students don't learn, it is because their teachers

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do not know how to teach. This view persists tenaciously in many sectors, and has given rise to myriad approaches to teaching and professional development, all claiming to be the ultimate solution for teaching problems.

- Lack of ownership of the professional development process and its results: given that they are often not consulted during professional development, some teachers will question their investment in programmes aimed at changing the way they usually "do" things in the classroom that they consider to be working.

- The technocratic nature of professional development content: more often than not, teachers in professional development programmes are taught techniques they are expected to replicate in the classroom. Most of these methods, however effective, are standardized for communication purposes and do not necessarily serve the specific needs of teachers and learners in specific contexts. Teachers usually need to invest considerable time and effort in transferring these practices to their classrooms. Attempting to do so often requires much more time, effort, planning and co-ordination than the professional development planners originally anticipated.

- Universal application of classroom practices regardless of subject, student age, or level of cognitive development: it is not uncommon to hear of school districts running the same professional development programmes for all grade levels. While certain teaching practices and learning principles might be suitable across the board, a one-size-fits-all approach, though economical, has been proven ultimately to be ineffective.

- Lack of variety in the delivery modes of professional development. Once a decision is made to invest in professional development, the cheapest format is often chosen for the purpose – usually a lecture, workshop, or seminar. While so much has been written about the importance of differentiated instruction in the classroom, Díaz-Maggioli (2004) sees it as ironic that when it involves instruction for teachers, undifferentiated approaches usually prevail.

- Inaccessibility of professional development opportunities. Professional development opportunities seldom reach teachers at a time when these are really needed. Also, when teachers are not included in the planning and delivery of professional development programmes, their education and training needs can remain unmet.

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- Little or no support in transferring professional development ideas to the classroom. Transferring new ideas and pedagogies to the classroom is perhaps one of the most difficult tasks a teacher faces. A lot of effort is put into helping pre-service teachers bridge the gap between theory and practice, yet the same support systems are not available to in-service teachers.

- Standardized approaches to professional development that disregard the varied needs and experiences of teachers. Researchers have pointed out that teachers go through certain developmental stages as they progress in their careers, each of which triggers specific needs and crises that they need to address when these occur. The standardized nature of traditional professional development programmes assumes that all teachers should perform at the same level, regardless of their particular experience, education, and training needs.

- Lack of ongoing, regular systematic evaluation of professional development programmes. Given the complex nature of teacher competence, assessing development programmes often seems impossible. These are inevitably omitted.

- Little or no acknowledgment of the individual and diverse learning characteristics and styles of teachers among professional development planners. Most professional development models for teachers ignore the fact that teachers possess unique learning characteristics and styles that need to be taken into consideration if the programmes are to be successful. Although the characteristics of adult learners have been the focus of research for many years, they are too often overlooked.

Often opportunities for professional development for teachers consist of the occasional short, one-off in-service programme, typically presented as a half- or full-day training workshop. During this brief period teachers are introduced to the "latest teaching strategies", "new resources", the "latest curriculum revisions" or "new theories of teaching and learning." Time and again the content of the programme bears little or no relation to the teachers' daily work, with little or no follow-up support provided to help teachers implement the new knowledge, skills and/or resources in their classrooms. While for some teachers this may well be sufficient, a serious shortcoming of such programmes noted by Wade (1996) is that often teachers are spoon-fed pre-packaged activities and treated as curricular consumers rather than professional educators. On the other hand, in the early nineties, Fullan (1991:315) saw the most serious

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concern as being that "nothing has promised so much and has been so frustratingly wasteful as the thousands of workshops and conferences that led to no significant change in practice when teachers return to their classrooms". This concern is shared by many, and emphasizes the need to distinguish effective science teacher development programmes from those that have little or no impact on teachers' content and/or pedagogical knowledge and practice.

Since TPD is critical for improvements in learner achievements and education in general, it needs to be the subject of increased research. Understanding how it can be achieved in any meaningful way is ultimately beneficial for the education system as a whole. What follows is an analysis of some conventional as well as innovative models of TPD.

For some insights into diverse TPD configurations, various forms were surveyed, their basic features described and briefly analysed. Since scores of models for TPD have been devised and newer models are regularly being introduced, only a selection was reviewed. The criteria for selection focused on the prevalence of the model relative to the South African context, as well as its relevance to this current study. These include the traditional, cascade, site-based, self-directed, cluster, resource-based, teacher-leader and mentoring models.

2.5 Models of Teacher Development

2.5.1 Traditional Model

This is the standard and most prevalent type of professional development, usually "consisting of short-term or one-session workshops, training seminars, lectures, and conference sessions" (Smith & Gillespie, 2007:2013-2014). It represents a centralized approach, is standardized TPD, and in many cases the cascade model of scaled delivery (Hooker, 2008:3) is implemented.

School districts, professional agencies, and teacher-training institutions may design a series of sessions on topics, such as assessment or classroom management, or for specific subject areas, such as mathematics, science, or language. The selection of topics depends on the senior officials' perceptions of what teachers need. Teachers then select the sessions they wish to attend from the range offered. The decision to attend a particular session may follow from a recommendation from the school, the teachers' level of interest and motivation to learn more about a topic, or the general perceived need for continuing education.

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Critics are sceptical of the value of this approach as regards its impact on teachers and improvements in teaching and learning. They argue that much is left to chance since little or no classroom support accompanies this kind of professional development. Unless it is presented as a series of workshops over a longer period of time, the one-shot approach of workshops does not address the long-term developmental nature of learning. This is especially true if the programme favours the transmission or passive mode of learning, with little or no involvement expected from the participants.

2.5.2 Cascade Model

This model is based on the training-the-trainers concept, and its special allure for many education officials is its potential to reach a greater number of teachers in a cost-effective manner. It appears to be the preferred approach, especially in less developed countries such as South Africa, although minimal gains from this model have been demonstrated thus far (Ono & Ferreira, 2010). The one-to-many format is favoured because it is perceived to facilitate large-scale project delivery and the rapid diffusion of information across education systems.

In this model one or two representatives of a school are provided with information, mostly via a training-based model. The school's delegates in effect become the "agents", "leaders", "frontline team" or "champions", and they are expected to faithfully disseminate the information upon their return to the school. They may serve as the co-ordinators, managing further processes at the school. A benefit of this approach is that it can encourage new alliances and relationships, possibly collaborative, among participating teachers from different schools.

Some known impediments of this approach pertain to the quality of training received and the competency of the school delegates. Ono and Ferreira (2010), in a South African case study of this approach and its outcomes, report that "teachers frequently complained about district trainers who themselves did not always understand the curriculum", while others may lack depth of understanding of the subject matter or of how to implement teaching strategies effectively in particular contexts. In many respects the school delegates may lack the leadership and facilitation skills needed to execute their task adequately, or they may not have mastered the knowledge and skills sufficiently to ably lead, guide and support their colleagues.

Often this lack of mastery on the part of these delegates can be attributed to the format of the programme they have attended, with its emphasis on the transmission or passive model of

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learning. Citing two important disadvantages associated with this approach, Hooker (2008:4) argues that cascade training flows through levels of less experienced trainers until it reaches the target group, and in the process complex information tends to be diluted, distorted or lost. Without incentives to participate, collaborate and experiment with new strategies, teachers may be reluctant to take direction from their "more knowledgeable" colleagues. The cascade model with its "one size fits all" approach also does not take account of contextual issues and this omission may well hinder implementation since conditions at the training facilities often do not match those at the schools.

2.5.3 Site-Based Model

As indicated, this model is positioned at the site of intervention, the classroom, school or district. Smith and Gillespie (2007) favour the term "Job-Embedded Professional Development Model", which emphasises its particular location and relevance to the teachers in that location, and their work.

The model focuses on the professional education and training needs of individual teachers, who are supported on location in gradual processes of learning to master content and pedagogy. This is a time-consuming and labour-intensive approach that requires locally-based knowledgeable and skilled facilitators. The challenge may be to secure the services of sufficient numbers of such facilitators for the programme to be successful. As it takes place over an extended period, there is the risk of matters such as personal and professional issues relating to either the teacher or facilitator, and school issues, such as a change in school leadership, disrupting the process.

The advantage of this model for teachers is that they have a greater say in deciding on the type of support they need and the content of instruction. The programme can include study circles or discussion groups to promote peer learning, and the formation of communities of practice. Teachers benefit from "flexible, sustained and intensive" professional development (Gaible & Burns, 2005:21), and from the opportunity to share and interrogate difficulties and challenges more closely related to their own work contexts. Regardless of the time or cost factor, Feiman-Nemser (2001), Smith and Gillespie (2007), Gaible and Burns (2005), and Hooker (2008) favour site-based teacher development and support with its focus on the context and the

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individual teacher's professional training needs for producing sustained systematic improvements in education at the site.

2.5.4 Self-Directed Model

This model permits teachers to be the drivers of their own professional development. Teachers determine their own professional development goals and select activities that will help them achieve these goals (Gaible & Burns, 2005). In the self-directed model teachers actively engage in a range of activities, such as reading books on education or a field of study, taking university courses, keeping a journal, conducting case studies, taking online courses, conducting web-based research, participating in a community of practice, or observing colleagues teaching. Many of the activities described are mentioned in the South African Council of Educators (SACE) Professional Development Points Schedule (2008).

A number of teachers already participate incidentally in informal self-directed development processes, for example, when they request advice from an experienced colleague, establish collaborative partnerships with other teachers, or conduct their own research. The responsibility for development rests entirely with the teacher and requires little direction or support from the school or district. This approach may appeal to teachers who are motivated self-starters, are creative and innovative in their teaching, and who have already developed teaching skills and a mastery of their subject. These teachers may be working at well-resourced schools with relatively small class numbers, and with strong support from their HOD and/or principal.

The self-directed model is best suited to advanced teachers working towards improving their knowledge and skills and/or qualifications, helping "teachers become models of lifelong learners" (Hooker, 2008: 6). While all teachers should be encouraged to engage in processes of continuous professional development, Gaible and Burns (2005:23) advocate teachers and schools not make this approach the main means of providing TPD. Rather, it should complement and extend other models being used in or outside of the school. An obvious limitation is a lack of resources such as computers and Internet access, and textbooks and other printed material, a lack which may constrain teachers' efforts to improve themselves professionally.

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2.5.5 Cluster Model

The classic model for clustering involves bringing a number of schools together to form a cluster or network, with a central school usually serving as the lead school. The lead school often becomes the meeting place for the teachers to come together formally for professional development opportunities or to exchange ideas informally.

The main advantage of clustering of neighbouring schools is that it facilitates the organization and administration of programmes, especially if the schools are spread out over a large area. As can be discerned in its organization, this model favours the participatory approach, and promotes co-operative learning within and between schools sharing similar contexts and demographic conditions. School-based and cluster-based approaches may be district, school, grade or subject focused. The particular format may differ, and may be based on a single school model, or may involve the clustering of schools for joint activities and support. As with the site-based model, it is located close to the site of intervention.

Well-positioned and well-structured clustering programmes permit the integration of professional development activities with school improvement plans, and, according to MacNeil (2004:3), these have been "used to good effect in many developing as well as developed countries". Through this approach, teachers accustomed to working in isolation are brought together, thereby fostering communities of practice. The approach encourages better use of local resources, promotes the sharing of resources, is responsive to teachers' immediate needs, and provides opportunities for on-site reflection and improvement of teaching practice (Jita & Mokhele, 2014). Teachers have a greater opportunity to share experiences and resources with each other within and amongst schools, extending collegiality beyond a single school.

The curricula and content may vary in design, from unstructured and loosely organized, to highly structured. In this model various modes of programme delivery are employed, and include analysing and developing teaching and learning materials, workshops, conferences, training seminars, and on-site support. The benefit of this model is that it simultaneously addresses the professional needs of the teachers, as well as the specific needs of the learners and schools in an area, so that they complement each other. Jita and Mokhele (2014:1) further identify "product benefits" relating to improved content knowledge and improved pedagogical content knowledge and "process benefits" of collaboration, instructional guidance and teacher leadership, related to the approach. If organized well, and financed/subsidised by the DBE,

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especially in rural areas where schools are widely dispersed, it can, in some instances, be a cost-effective professional development model to use with groups of teachers.

2.5.6 Resource-Based Model

This model is based on the use of resources, which may either be printed materials such as textbooks, lesson plans, teaching notes and worksheets, or technologies such as computers, video-presentations, or television broadcasts. While this approach may appeal to teachers who have well developed teaching skills and subject mastery, Towers and Rapke's (2010) study shows that it works equally well with pre-service teachers, especially when using advanced technologies and electronic devices that appeal to younger teachers. However, providing the necessary technologies and training teachers to use them effectively can be very costly.

The process is aligned with teachers' needs and provides scaffolded learning opportunities. Guidance and support is inherent in the materials which present content and important concepts to teach, provide a collection of well-organized and well-structured learner activities, and tasks to try with learners, offer suggestions for lessons, and recommend alternate pedagogical approaches that can be used in the classroom. Teachers develop their professional proficiency through using the materials, and this process may require minimal human support with implementation.

The advantage of this approach is its extended range: teachers located in very remote areas can be reached in this way, making learning opportunities easily accessible for many more teachers. Printing and disseminating materials, if sponsored by the DBE, can reduce training costs, but the model offers no guarantee that innovations would be implemented as suggested, unless the DBE or school districts support, monitor and evaluate teaching and learning activities in the classroom.

2.5.7 Teacher-Leader Model

This model builds capacity within a school or district. Teachers demonstrating advanced teaching ability and subject mastery are provided with additional opportunities to deepen their content and pedagogical knowledge, thereby allowing them to strengthen their proficiency. They are further provided with opportunities to share their insights and experiences with other teachers.

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For this model to be effective lead teachers are strongly recommended to broaden their knowledge and understanding of adult-learning and their facilitation skills so that they are able to plan, lead and implement development programmes in support of other teachers. Grant (2008:88-89) argues that for teacher leadership to emerge in a school, certain structural and cultural conditions are necessary, these include, a culture of distributed leadership, support from school management and other teachers, and collaboration and shared decision-making within a culture of mutual trust, support and enquiry.

Through this model the contribution and achievements of a greater number of teachers other than those serving in official leadership positions are recognized and acknowledged. At the same time, human resource capacity is developed (Law, Lee, Wan, Ko, & Hiruma, 2014), and the support can be expanded to reach many more teachers. In practice, this approach may incorporate aspects of mentoring and coaching, and is framed similarly to the cascade model.

2.5.8 Mentoring Model

A mentoring model allows younger or novice teachers to benefit from the insights, guidance and assistance of older and/or more experienced teachers in all aspects related to teaching. The model focuses on the professional training needs of young teachers, allows them to access information, and to develop their instructional practice in a supportive environment.

Mentoring can occur as a one-to-one approach, or as a many-to-many approach that has several mentors working in a team with less experienced teachers (Hooker, 2008: 15). According to this model, young teachers, in the process of collaborating with colleagues within and across schools, gain from the understanding and experiences of others through the collegial relationships formed. In this way mentoring helps to reduce a teacher's sense of isolation and anxiety, strengthening their confidence (Hooker, 2008:16). Mentoring is labour intensive, and a sufficient number of knowledgeable teachers with sound teaching ability and interpersonal skills is required for quality mentorship processes.

Although structural and organizational overlap between the various models of professional development may occur, differences with regard to their particular objectives, content, and formats are clearly distinguishable. Different forms of teacher development, whether effective or not, have at their core the commendable purpose of improving the quality of teaching and of children's learning. While no single model can be considered appropriate for all

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circumstances, during the late 1980s Ball, Higgo, Oldknow, Phillips, Straker and Wood argued that "more successful programmes involve substantial school-based work and the sharing of ideas amongst teachers" (1986:41). More recently, some important aspects emphasized in research are that TPD processes that are systematic, structured and supported (Garet, Porter, Desimone, Birman and Yoon, 2001), sustained, intensive and collaborative (Stoll, Harris and Handscomb, 2012:8), and that are research-based (Toom, Kynäslahti, Krokfors, Jyrhämä, Byman, Stenberg, Maaranen and Kansanen, 2010) prove to be more effective for improving the professional competency of in-service teachers. Research has also shown that quality professional development can change teachers' practices (Darling-Hammond, 2000), and, where professional development programmes are deployed successfully, student learning is affected positively and improved results are achieved (Díaz-Maggioli, 2004).

Although there is general agreement amongst education researchers and practitioners that processes of professional development can help teachers gain new knowledge and adopt new practices, opinions differ as to how this can be achieved. Accounting for these differences of opinion, Smith and Gillespie (2007: 214) maintain that "professional development, like all other educational effort, is influenced by changing trends, paradigms, philosophies and approaches". Such influences may develop from advances in knowledge following from research, or from policy changes that emerge from the wider political, social and economic context.

2.6 Measures of Teacher Development

On the subject of the effectiveness of teacher development programmes in science, mathematics and technology, Loucks-Horsley et al. (1998:36-37) offer seven key indicators that are both enlightening, and have the potential to serve as a useful guide for professional developers. In the author's view, effective professional development experiences:

- Are driven by a well-defined image (based on a thorough knowledge and understanding) of effective classroom learning and teaching. Expanding on this, the authors see it as including a commitment to all children learning mathematics and science since it emphasises strategies such as inquiry-based learning, investigations, problem solving, and application of knowledge, it uses approaches that emphasize in-depth understanding of the core concepts as well as approaches that challenge learners

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to build new understandings, and it develops teachers' understanding and application of assessment.

- Provide opportunities for teachers to build their knowledge and skills, helping teachers to develop their content knowledge and pedagogical content knowledge, and to select content and integrate this with the curriculum and learning experiences.

- Use or model with teachers the strategies teachers will use with their learners, such as collaborative work, investigation and reflection.

- Build a learning community using co-operative learning, and providing opportunities for teachers to learn from and share with each other, and in so doing, contributing to greater collaboration amongst the teachers within the school and between schools, fostering collegiality and establishing a community of practice.

- Support teachers to serve in leadership roles by developing teachers as agents of change and promoters of reform.

- Provide links to other parts of the education system by integrating the programme with other initiatives at the school, at district level and/or with national policies.

- Are provided by developers who are continuously assessing their work and making improvements to ensure positive impact on teacher effectiveness, student learning, leadership, and the school community.

To this list, others such as Smith and Gillespie (2007); Giordano (2008), Marx, Freeman, Krajcik and Blumenfeld (in Fraser & Tobin, 1998), and Corcoran, McVay and Riordan (2003) have added that effective TPD programmes should:

- Acknowledge prior knowledge and experiences, and be responsive to teachers' particular needs. Teachers who have content knowledge but lack an understanding of how to teach the subject matter require different kinds of support to those who lack both content and pedagogical content knowledge.

- Extend over a longer period than has been the norm. Short-term efforts are inclined to bring about change in discrete and mechanical aspects of teaching, while extended programmes acknowledge the developmental nature of learning. Teachers are given

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more opportunities and time to learn about and apply their practice, especially if follow-up and reflection is included into the programme.

- Connect the learning with the teachers' own work context and support teachers to plan for implementation, helping them to identify possible barriers and to strategize to facilitate application.

While the above criteria are instructive in terms of what effective teacher development programmes should achieve, there are researchers and practitioners who have other concerns, particularly about the sustainability of such programmes and their integration with the school programme and ethos as well as with the community. Elmore (in MacNeil, 2004: 4) cautions that it "…is not so much about knowing what good professional development looks like; it's about knowing how to get it rooted in the institutional structure of schools", directly connecting the processes with its core purpose, which is to ameliorate teaching and learning processes in the classroom. Guskey (2000:51) emphasizes evaluation as the key element, suggesting that systematic information gathering and analysis be incorporated as a central component of all professional development activities as a means of enhancing the success of processes. Yet others consider conditions within the teacher, school, district and community significant, for example, voluntary engagement by the teacher with, and genuine interest and support from, school leadership, the quality of school leadership, availability of resources, quality support from district officials and curriculum advisors, a culture of learning and collegiality within the school, the educational expectations of different stakeholders, and the quality of support from parents.

TPD and support may be shaped in a variety of ways depending on the underlying assumptions of the programme designers (about teachers, learning and professional development), key elements (pertaining to structure and organization) and implementation requirements (as regards policies, funding, access, shared goals and expectations, resources and support, time, mechanisms for assessment and evaluation) and whether all these may differ according to context. In spite of these various factors, learner achievement is consistently held as a critical indicator of the effectiveness of any professional development model or programme. Regardless of the model there is a shared goal, based on sound reasoning, that improving teaching improves learner performance. Teacher quality is consistently ranked high as a

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significant factor influencing learner achievement, and thus the positive impacts of professional development on teacher knowledge and practice are equally meaningful outcomes.

Whatever the model, what the various authors cited in this section agree that professional development programmes designed for teachers should ideally not be solitary, isolated, uni-modal, overly theoretical, disjointed "once-off" events, disconnected from the classroom; they should be thorough, purposeful and meaningful processes since they should be seen as being embedded within the larger context of educational improvement. For science teachers, I argue, such processes need to pay special attention to developing science-specific content knowledge and pedagogical content knowledge, as well as practical application of these in the classroom.

2.7 Teacher Development in South Africa

After the deliberate underdevelopment of the human potential of the majority of the black population during apartheid, which measurably affected the teaching and learning of mathematics, science and technology, one of South Africa's greatest challenges in the post-1994 period has been to address past inequities, and to provide quality education to all, thereby growing the human resources of the country. As was described in Chapter 1, government resolutely undertook to bring about greater improvements in science and mathematics education.

As was described in the previous chapter, in its commitment to developing the science potential of the country, the government developed new policies and strategies for science education, established science and technology research centres, expanded educational facilities, for instance it provided computer laboratories and computer training for teachers through programmes such as the 2002 – 2012 Khanya Project (an initiative only applied in the Western Cape), and "reallocated resources from ex C-model schools to previously disadvantaged schools" (Spaull, 2013). Other strategies include:

- The creation of a Ministry dedicated to Science, Technology and Culture in 1998 to oversee policy restructuring and alignment, liaise with and co-ordinate efforts with related ministries, such as the education ministries, and to introduce supporting agencies for education, monitoring and research.

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- Prioritising research in science with the establishment of the National Research Foundation (NRF) in 1999.

- At the same time increasing the science focus at a number of universities including Fort Hare, the Universities of the North, Venda and Cape Town.

- In 2001 the Ministry of Education introduced a National Strategy for Mathematics, Science and Technology (MST) Education. This strategy was intended to increase and improve the human resource capacity to deliver high quality MST education with the purpose of providing high quality MST education to all learners.

- As part of the science and mathematics education strategy, in 2001 the Department of Education (DoE) established the Dinaledi School Project to increase the number of matriculants with university-entrance mathematics and science passes (DoE, 2009c). This was the government's flagship programme which entailed providing additional support to schools with the potential to perform well. This initiative was considered the most cost-effective way of deploying scarce resources for mathematics and science teaching at the time. Funding for these schools was secured through private partnerships in the "Adopt-a-School" Project. Additional support to sustain and enhance the efforts of these schools included providing the necessary learning and teaching materials, facilities and equipment, and extra assistance from mathematics and science subject advisors, as well as further training opportunities for these subject teachers (DoE Annual Report, 2008-2009). Other support initiatives included providing the weekly *Study Mate* newspaper supplements containing lesson and examples of examination type questions for students and teachers.

While the idea behind the Dinaledi scheme of investing in schools with the potential to succeed may have been a sound one, Reddy (2005:127) reports that by 2004 there were problems with the selection process according to predetermined criteria, and that the implementation of interventions in schools was uneven. She further noted that the project had not demonstrated the kind of gains in performance originally anticipated. She also expressed concern that the intervention had not been evaluated independently in terms of highlighting the lessons learnt from this process.

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- Prior to the Dinaledi project, the 1995 – 1999 SYSTEM (Students and Youth into Science, Technology and Mathematics) programme was introduced as a means of increasing the number of mathematics and science graduates emerging from the schooling system (Buhlungu, Daniel, Southall & Lutchman, 2006). The programme consisting of a one-year programme in physical science, biology, mathematics, ICT and communication skills focused on redress, and was designed to give students who had underperformed in science and mathematics in their Senior Certificate examinations a second-chance to obtain the matriculation exemption that would allow them to go on to studies in higher education (Kahn, 2013: 4).

- In 2000 government collaborated with HEIs (Higher Education Institutions) to develop Advanced Certificate in Education (ACE) courses for science teachers working towards improving their qualifications.

- Bursaries through the Funza Lushaka scheme, launched in 2007, were offered as an incentive for mathematics, science and technology teachers to improve their qualifications. In her Budget Vote Speech on the 23 March 2010, the Minister of Education announced that the Funza Lushaka bursaries allocation was increased from R424 million in 2010/11 to R471.9 million in 2012/13 with the purpose of improving the quality of beginner teachers in scarce and critical subjects such as mathematics and science (DBE, 2010a).

- Media interventions such as the South African Broadcasting Corporation (SABC) Education and Liberty Life programmes – the Liberty Life Learning Channel – launched in September 1990, were used to promote science.

- The establishment of NGOs dedicated to mathematics and science education, such as the Centre for the Advancement of Science and Mathematics Education (CASME) established in 1985, were supported and encouraged by government.

- Support for outreach programmes was provided, such as those offered by ABSA (Financial institution) and the Zenex Foundation.

- Support for outreach programmes organized by several universities were established in an effort to popularize science and science learning amongst the youth, together with the efforts of other institutions such as the SAAO (South African Astronomical

Observatory) working to create greater awareness of the importance of science and its disciplines.

- The Department of Science and Technology identified a network of science centres as an important infrastructure required to achieve the science and technology goals identified by the White Paper on Science and Technology (1996) and the Research and Development Strategy (2002). In terms of the National Norms and Standards for a Network of Science Centres in South Africa (2005) support was provided for the establishment of science centres such as the Interactive Science Centre in Cape Town sponsored by MTN, and Sci-Bono in Johannesburg which is the largest science centre in South Africa dedicated to promoting science and technology amongst the previously disadvantaged.

- Science teaching equipment, such as the Somerset Educational kits, was made available to schools, and the "Out of the Box" kits were provided through sponsorship from Old Mutual in 2007 (although limited to certain provinces such as the Western Cape).

- Since 2007 support was provided for science education research conferences, for example those held by national bodies SAASTA (South African Agency for Science and Technology Advancement) and SAARMSTE (South African Association for Research in Mathematics, Science and Technology Education).

Regardless of what appear to have been considerable investments of time, effort and capital, these initiatives have hitherto not produced the much-needed outcomes and systemic change in mathematics and science education. Extensive research into the status of science education, and other indicators such as the 2003 TIMSS, paints a dismal picture of persistent poor learner performances in science and mathematics for South Africa. TIMSS 2003, based on 2002 assessments, is a significant indicator of learner performance in mathematics and science, and it was the third TIMSS in which South Africa participated; the others were conducted in 1995 and 1999. Of the 50 participating countries in the 2003 study, South Africa showed the lowest performance in mathematics and science. Compared to the international average scale score of 474 for science, the South African average score was 244. Along with Ghana, South Africa had the highest percentage of learners achieving a score of less than 400 points, that is to say, well below the Low International Benchmark (Reddy, 2006). Statistically the scores for

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mathematics and science indicated no significant difference between the 1999 TIMSS and the 2003 TIMSS.

The number of learners registered for the mathematics higher grade (HG) and Physical Sciences HG examinations, as well as an analysis of matriculation results, further highlights poor learner performances in these key subjects. Education observers are particularly concerned with the reduced number of African learners who are opting for/ encouraged to opt for, or able to pass mathematics and science at HG level. According to research conducted by the Centre for Development and Enterprise (CDE) (an independent policy research and advocacy organization), only 7,129 African learners graduated in HG Physical Science in 2002, representing only 14 percent of all matriculants, and 30 percent of all HG science graduates nationally (CDE, 2004:9, Bernstein, 2005). In the 1991-2003 period, the same CDE studies show that, while the total enrolment for Senior Certificate Physical Science increased by 81 %, SG (Standard Grade) enrolment increased by 174 % and HG enrolment grew by a mere 2%.

The lack of substantive progress in mathematics and science education in South Africa is well-documented. Several studies, including those done by Ewing and Setsubi (1998), CDE (2004, 2009, 2010, 2011), Laugksch, Rakumako, Manyelo and Mabye (2005), Phurutse (2005), Makgato and Mji (2006:254), Reddy (2006), DoE (2006), Ramphele (2008), du Plessis (2009), Bloch (2009), Taylor, Mabogoane, Shindler and Akoobhai (2010), and Jansen (2011). These authors have, from their findings and in their discussions, identified a range of impediments to mathematics and science education. Together with many other impediments, they see those pertaining to schools generally involve poor school, curriculum and classroom management, together with limited resources, under-resourced schools lacking basic mathematics and science equipment, overcrowded classes, high levels of learner absenteeism, and a wide range of socio-economic issues that negatively impact teaching and learning. Those factors related to teachers and the quality of teaching include outdated teaching practices, teachers' lack of basic content knowledge, under-qualified and unqualified teachers, inadequate training of teachers, limited access to professional development programmes, teacher shortages, and high levels of teacher absenteeism. Reddy (2006:117) takes the view that no single cause can be cited for the poor learner performance, but suggests that a combination of several factors acting collectively within particular social, economic, historical and cultural contexts produce the kinds and levels of learner performance observed. Elsewhere Reddy (2005:127) further notes that vast backlogs

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in African schools with regard to basic infrastructure, learning materials, and qualified teachers continue to constrain participation and achievement in science and mathematics.

Frequent curriculum modifications and revisions amplify the difficulties located within the classroom, school and education system as a whole. Acknowledging the strain that curriculum restructuring has had on both the education system and teachers during the 2002 period of assessment, the 2003 TIMMS study recommended that South Africa not participate in the 2007 TIMMS, but defer participation to 2011 (Reddy, 2006). This would allow national interventions more time to become rooted within the system before another assessment is conducted. Therefore, the fact that the education system once again embarked on a process of curriculum restructuring with the introduction of CAPS (Continuous Assessment Policy Statement) (DBE, 2010a, 2011), this has once more evoked uncertainty, insecurity and distress amongst teachers and learners.

To all intents and purposes, government educational reforms have proved ineffectual in terms of substantially increasing the supply of black mathematics and science school-leavers and graduates. An analysis report of matriculation results for the period 1998 to 2008 shows that "some 90% of schools still did not meet the minimum performance standards in mathematics and science education" at the time the report was compiled (Simkins, 2010). Further CDE studies confirm that the mathematics and science education system is "consistently not producing sufficient numbers of school leavers equipped with mathematics and science skills to meet the country's needs" (Bernstein, 2005:1). This CDE study further states that failure to improve mathematics and science education substantially is probably the most significant obstacle to African advancement, undermining all ambitions for the country for expanded economic growth, for black economic empowerment, and for community development. The implications of this for the nation become alarmingly clear; O'Connell (Parliamentary Committee Higher, 2010) points out that over 50% of the scientific research done in South Africa in 2010 was still being done by white South Africans over the age of 50; he encouraged politicians especially to think about how the next generation of scientists will be constituted.

Irrespective of a range of efforts on the part of the government, much remains to be done to improve science and mathematics education across South Africa. The regular poor showing of South Africa in international comparative studies, along with annual reviews of the matriculation results in mathematics and physics, sparks a flurry of responses from all quarters.

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The problem of poor learner achievement in these subjects regularly has leading South African researchers academics and policy makers, as well as education officials and educators, and other concerned citizens, in agitated debate about the perceived threats to South Africa's future and its global economic competitive muscle, each sector communicating their concerns about the lack of progress and making recommendations for improvement. However, in spite of this outcry, twenty years into democracy the status and effectiveness of science education appears largely unchanged.

Researchers position teachers together with learners at the heart of the educational process. A clear understanding of the central role of competent teachers in the classroom guides international effort to improve learning by developing and supporting teachers. South Africa has followed suit investing in this substantially as indicated earlier, producing its fair share of research, especially that on the lack of substantive progress in many areas of education and attempting to come up with workable solutions. Drawing on the literature thus generated, this section elaborates on science teacher development, locating it within the broader context of educational reform in South Africa.

Consistent with global trends, the South African government has engaged various strategies to promote mathematics, science and technology. Besides introducing a ministry dedicated to advancing achievements in these areas, mathematics and science were classified as critical subjects along with language in 2001, thereby legitimizing the allocation of considerable funding to development programmes for teachers of these subjects. By themselves some of these measures can be considered progressive, but as the entire system tackles the major challenges and threats linked to the context and to the teachers themselves, as well as challenges related to institutional change and reorganization, the positive impacts from these strategies appear to have been considerably weakened.

Deficits and underperformance run deep throughout the education system. Ample literature, including several studies produced by the Centre for Development and Enterprise (CDE, 2007-2010) and others mentioned in Chapters 1 and 2, have shown this to be so. Frequent reports reflect unacceptably high levels of underperformance in the education system, culminating in recurrent poor performances in both systemic tests and formal examinations for large numbers of Black African learners. Studies also draw attention to serious impediments to learning, particularly with regard to the quality of teaching and learning, repeatedly advocating the

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urgent need for intensive support for teachers for real change and improvement to take place. For the purpose of situating and describing in-service primary science teacher development the discussion that follows focuses on the teachers' context of work, teachers' professional capacity, together with the institutions involved with TPD.

2.7.1 Teachers' Context of Work

Any decision regarding the most appropriate and effective model for teacher development necessitates consideration of its location within the broader context, together with the emerging influences that may either encourage or frustrate programmes of development. South Africa's historical past has left legacies of socioeconomic and educational disparities and inequities, several areas of underdevelopment, deeply entrenched racial divides, and many other difficult and frustrating challenges to any kind of development which could bring about meaningful change in our education system.

The disproportionate allocation of physical and other resources is one of many factors differentiating those schools performing well from those showing little or no progress. Researchers such as Taylor, Fleish and Shindler (2008:41) see this as a cause for grave concern that a very "high degree of inequality between schools remains a conspicuous feature of the South African system". CDE (2007:45) reports that the image commonplace during the apartheid years of white or Model C (former House of Assembly) schools with airy classrooms, classes numbering less than 40 learners, a full range of audio-visual aids, libraries, lush playing fields, and swimming pools coexisting with squalid, under-resourced and overcrowded schools in African townships without electricity, books, or other amenities, continues to be a ubiquitous reality in South Africa. Noting further that the continued existence of such disparities, together with inexplicably slow progress in dealing with physical backlogs, has done little to improve conditions for teaching and learning in areas where it is most needed. Infrastructural inadequacies, together with scores of other contextual realities, function collectively to retard significant advancements in certain public schools, serving only to reinforce poor learner performances, thus creating a vicious cycle of poor performance in many cases.

A public school with its staff cannot escape the adverse impacts from the area in which it is situated. As an extension of the community it serves, it remains subject and vulnerable to influences, conditions and experiences existing within that community. In numerous poverty-

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stricken areas characterized by high levels of unemployment, crime and violence, which in turn spawn a vast array of social problems such as gangsterism, alcoholism and drug abuse, child abuse and child neglect, disruption of family life and unstable home circumstances, lack of adequate responsible parental support and guidance, high numbers of teenage pregnancies and absconding fathers, the prevalence of HIV and increased Aids-related deaths resulting in a growing number of vulnerable children and child-headed households. All of these problems impose a strain on the ability of any school and its teachers to fulfil their fundamental obligation of providing quality education to all children. Collectively these factors produce negative impacts for teaching and learning that include, amongst others, high levels of absenteeism which affect the continuity of learning, a lack of support for learning from parents or guardians, poor discipline, and disrupted learning activities, all of which exert impossible levels of pressure on teachers' efforts. Bloch (2009:75, 81) observed that the level of violence and ill-discipline observed in a number of schools makes the task of teaching and learning that much more difficult, even for the most dedicated teacher or learner. Evidence provided by Simkins (in CDE, 2010:7 & 12) confirms that "socio-economic factors associated with schools are strongly correlated with their performance." Thus, given the intensity of the impact of these contextual factors on their learning spaces, prospects for learners' progress do not appear favourable. It is within these austere and often intimidating environments, and under very difficult and frustrating circumstances, that large numbers of teachers are required to deliver quality education.

At the same time as teachers in many of the disadvantaged schools have to contend with exacting contextual realities, they are often required to negotiate imposed institutional change in the form of organizational and curriculum reform. This departmental requirement presents its own set of demands, adding yet another dimension to teachers' daily pressures. Confronted with these kinds of changes can be unsettling for teachers, especially since it may call into question the extent of their knowledge, what they do every day, and the "coping strategies" they have developed. They may be asked to "change themselves and familiar teaching practices by policy makers who neither know them nor understand the contexts in which they work" (Sikes in Fullan, 1992:36). Some teachers may find themselves at variance with the change required, based upon their considerable professional knowledge, understanding and experience. In the late nineties Savage (in Naidoo & Savage, 1998:42) expressed the concern that reform is generally understood to mean change, not evolution, which means that "change may occur regardless of the quality that could possibly already exist". The cumulative effect

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of major curriculum reform repeated at regular intervals, as it has been in South Africa since 1994, can undermine teachers' confidence in their professional knowledge and teaching ability. The uncertainty and instability it engenders increases feelings of insecurity and distrust of the DoE/DBE amongst teachers, with large numbers becoming disillusioned, demotivated and dispirited. The knock-on effect of this is that increasing numbers are choosing to leave the profession, and with fewer young people opting to become teachers, shortages of specialized teachers for mathematics and science are increasing at an alarming rate (SACE, 2011:6). In a recent study Van Broekhuizen (2015:30) highlights a startling statistic that South Africa currently needs between 20 000 and 30 000 new teachers each year to meet educational demands. This alarming situation does not bode well for our country's educational progress.

Government, in choosing to overlook, or reduce the importance of, critical elements within the education context represents a serious oversight that may well affect the successful implementation of various reforms, however progressive they appear in theory. Katzenmeyer and Moller (2001:1) cautioned that "educational policy is easier to change than schools are" , which means the greater challenge for education systems is to bridge the theory-practice gap, effectively transferring policies from paper to practice. The specific historical legacies and environmentally generated influences in South Africa carry special implications for the work of teachers and teacher development processes. Thus, support systems for schools and teachers, including development programmes, should in their design acknowledge the very real obstacles teachers encounter in classrooms and schools, and assist with modifying applications to specific locations to ensure their relevance to teachers in these contexts, especially those working in deprived and often hostile environments.

2.7.2 Teachers' Professional Capacity

In this study I argue that large-scale learner underperformance in our schools can be attributed to a lack of appropriate and sufficient planning at all levels, especially as it relates to comprehensive curriculum reform and the often superficial manner in which in-service teachers are orientated to modifications (Pausigere, 2014:83). Thus taking into account the magnitude, scope and instances of major changes introduced into the South African education system for the period 1994 to 2015, a reasonable inference would be that inadequate planning and co-ordination at macro-level (national department and its auxiliaries) is at the heart of many of the disruptive influences affecting schools and teachers. These changes include the Outcomes-

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Based Education (OBE) curriculum of the late 1990s and several subsequent modifications, the most recent being the Curriculum Assessment Policy Statement (CAPS) as part of a 2010-2013 New Strategic Plan.

Ineffective and/or unsustainable planning occurs when planners do not have enough knowledge and understanding of the important aspects and realities of a range of teaching and learning contexts, or they choose to discount the importance of these in their planning process. Education planners and policy makers need to take into consideration as many aspects of the teaching force and their context of work as possible, including the diverse conditions and particular difficulties in schools and classrooms that would be likely to challenge implementation. Unrealistic expectations regarding teachers' capacity to deliver on the department's plans may have contributed to the many difficulties in implementing changes observed in schools. Ramphele (2008:157) sees the selection of strategies adopted by the DoE/DBE for education reform as failing to take into account the capacity of practitioners on the ground to support change. She argues that failing to match new ideas with working models, or to build the capacity of both teachers and parents to assume new roles under the reformed system, is at the core of persistent teaching and learning quality problems. I argue that major change can be stressful for the people involved, and the potential for the process of change to encounter opposition and complications along the way is high. Yet, if capacity and contextual factors are sufficiently aligned in the planning and support phases, it could significantly smooth the implementation process. Capacitating professionals and supporting stakeholders more fully to assume new roles is an indispensable component of any reform which is designed to ensure an efficient and relatively untraumatic transition.

Based on experience and perceptions, I see the frustration that accompanies curriculum reform as being more acutely felt by those teachers who are not sufficiently equipped and resourced to undertake and manage the process of change efficiently and confidently. A major difficulty for many black teachers teaching mathematics and science from the start of the reform process was that they had not studied these subjects at school level, nor did these subjects form part of their initial teacher training courses. Their background knowledge and competency deficits placed understandable limitations on their engagement with the new curriculum. Critiquing earlier attempts to build the capacity of teachers for curriculum reform, Jansen and Taylor (2003:45) share the opinion that the reform efforts were also too far removed from the day-to-day routines and behaviours of teachers and managers in the school context. They noted

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critically that change tended to be more visible in the external behaviours of teachers rather than in the subject- knowledge gains of their learners. Commenting on this observation, the OECD (2008: 296) identify significant policy assumptions about the kind of outcomes that would be produced and observed; these included assumptions about the capacity of teacher educators and teachers that were not based on reality, and the common-sense notion that policy could be implemented on a universal "one-size-fits-all" basis. By ignoring the on-the-ground conditions of schools that varied enormously, from well-resourced schools to mud cabins operating without basic services such as water and electricity or lacking proper blackboards, policy statements did not sufficiently relate to existing realities in many schools. In terms of the training and capacities of staff members, the conditions of work, a serious lack of equipment and shortages of essential teaching and learning resources, many schools were seriously challenged in their efforts to accommodate the DoE's demands for change. A combination of conditions in schools and teacher competency levels impacts the capacity of teachers to take on transformation and on the quality of education schools are able to offer.

Quality education and improvement in learning is supported by the quality of teachers and the quality of teaching in context. As a first step towards capacitating teachers to improve the quality of their teaching, Janse van Rensburg (1998:70) suggested in the late nineties that education researchers and professional developers need first to interrogate their assumptions about the appropriateness of technicist approaches to teacher development, an approach which assumes that teachers' lives are a void, and that any professional development involves the simple transferral of context-less information into that void. Janse van Rensburg (1998) followed this with some sound advice for teacher development work: it should preferably not take place in a void, and should not be based on the assumption that all teachers are the same and that their work contexts are the same. What she advocates is simple: South African teachers need to be supported as responsively as possible within the environment in which they do their daily teaching.

Given that, for teaching to be successful, teachers need to create optimal conditions for learning to take place, teacher education should follow the same principle. This focus on the importance of context calls to mind Elmore's (in Chung Wei, Darling- Hammond, Andree, Richardson & Orphanos, 2009:1) assertion that development and improvement above all entails "learning to do the right things in the setting where you work". Processes intended to promote capacity building of teachers should start and end with what teachers know and can realistically do in

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their particular work contexts. In the same vein, Easton (in Chung Wei, et al., 2009:1) maintains that the most powerful learning opportunities are active learning opportunities embedded in teachers' work, which begins with teachers' assessments of what their learners need and what teachers identify as areas for their own learning. From these and other studies it is clear that contextually-relevant development opportunities for teachers that acknowledge the individual needs of the teacher have the potential to ensure more realistic and successful improvements in teachers' professional capacities.

Thus, in designing a professional development programme, it is clear that a review of primary science teachers' professional competency is necessary. This may be complicated by the fact that to date data on teachers and the extent of their knowledge and pedagogical competency is inadequate since the Annual Schools Survey only reflects information on the number of teachers and their academic qualifications; there is no system-wide information about the competency levels of mathematics and science teachers at secondary schools (CDE Report No. 15, 2007: 10-11), and little or no mention being made of the competency levels of primary school teachers to teach science. Science specialization is not a requirement for teaching science at the primary school level as teachers are by and large generalists. The CDE research report (2007) further indicates that there is a shortage of teachers, particularly in specialised subjects such as mathematics and science, some teachers teaching specialised subjects are not adequately qualified, teachers are unevenly distributed throughout the education system and rural areas are in desperate need of specialised teachers, and that some specialised teachers are often under-utilised. In many cases teachers' content knowledge and teaching techniques are inadequate (Spaull, 2013), and attempts to introduce accountability into the schooling system, especially with regard to teacher professional performance have been unsuccessful thus far.

Gregorio's (in Holtman, Mukwada & Du Plooy, 2009: 61) statement that "no education system can rise too far beyond the level of the teachers in it" serves as a reminder of both the urgency for addressing science education in South Africa and the relevance of the above discussion. With few means at our disposal to determine with any accuracy the actual competency levels of science teachers in secondary and primary schools other than academic certification, we lack information about what teachers may actually need to improve their professional science teaching capacity, and thus our unease about the quality of science education in South Africa persists. Ramphele (2008: 181) warns that unless serious and more meaningful measures are taken to narrow the policy-practice divide and improve teachers' professional capacity for

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teaching critical subjects such as science and mathematics, that the gap in educational outcomes between rich and poor will increase, with the majority of Black people forever languishing at the bottom of the skills and economic ladder. Expanding on Gregorio's (2009) statement, capacitating teachers to deliver quality education to all learners is critical for both education and socio-economic transformation.

Before any intervention is planned the starting point for any programme of development for in-service science teachers is their extant knowledge of science (content knowledge) and the methodologies they use to teach the subject (pedagogical content knowledge). This may require that teachers submit to testing procedures and observations of their teaching practices to ensure that the design of the programme addresses their particular professional needs and contexts. Although this preliminary process may not appear to be popular with some teachers in light of recent discussions with teacher unions, its relevance to the process as a whole is based upon sound pedagogical reasoning. Rather than formulating programmes based solely upon assumptions of needs, or on what "expert" developers think teachers may know or may not know or need, a true picture derived from testing procedures would enable professional development providers to tailor support to the specific knowledge and/or practice needs of teachers.

Building the capacity of teachers takes time as we need to acknowledge that all learning is a long- term cumulative process, requires a great deal of coordinated and well-planned effort, and an adequate supply of resources whether human, material and/or financial. Given that current processes for primary science teacher development are often encumbered by a range of constraints, developers of programmes need to explore alternative methods for achieving these. In theory any kind of advancement in the field of science education and TPD hinges upon the contribution of those institutions responsible for teacher education and training. The immense weight of the responsibility to make a difference and ensure that all South African children receive the kind of science education they need and deserve should in theory galvanize those involved in this enterprise into action, to collaborate more closely with relevant partners and stakeholders in the pursuit of improvements in science education.

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2.7.3 Institutions involved with Teacher Development

Currently universities play a major role in the education and training of pre-service and in-service South African teachers; provincial education departments, non-governmental organizations (NGOs) and the private sector are mainly involved with in-service teacher development, functioning independently or collaboratively. Ensuring quality science education is accessible to all children rests upon the collective efforts of these institutions and organisations.

The present institutional arrangements for teacher education have developed from several processes aimed at restructuring and reorganizing the entire Higher Education sector post 1994. Prior to 1994 a diverse group of agents were involved with teacher education, with colleges of education, universities, technikons and distance education institutions responsible for the education and training of PRESET (pre-service) teachers, configured along racial category lines. Together with these institutions, the apartheid education departments (DET, HOR, HOD) non-governmental organizations (NGOs), and the private sector provided additional opportunities for INSET (in-service) teacher development. In the period following the 1994 elections, the South African government engaged a series of commissions of enquiry, white papers and legislation to transform the tertiary education sector. The process to investigate and evaluate teacher education was initiated with the National Teacher Education Audit of 1995, which established that 281 institutions at the time, including universities, technikons, and colleges of education, private colleges and non-governmental organizations were organised along racial lines and were offering accredited in-service and pre-service teacher education to some 481, 000 students. The 1995 Audit concluded that the teacher education being provided by many of these institutions was generally of a poor quality, ineffective, inefficient and cost-inefficient (TESA, 2005:3) and recommended major changes, amongst which was shifting teacher education into the Higher Education (HE) sector, a move which involved a series of major organizational adjustments.

In line with international trends, government decided that colleges of education were to be integrated into existing universities and technikons as faculties or schools. From 120 colleges in 1994 the number was reduced to 50 institutions by either merging the colleges with higher education institutions (HEIs) or closing them, and, by 2005 only 20 institutions offered teacher education programmes nationally (Gordon, 2009; SACE, 2011; DBE, 2011). Assimilating

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teacher education into HEIs was intended to encourage a more cost-effective use of resources, enhance the quality of teaching programmes and research, introduce processes of quality assurance into the system, and address the disparity in participation rates between the different racial groups. By so doing, the expectation was that a largely inefficient system would be made more relevant and responsive to the needs of a developing country. However, this process encountered a number of impediments, including, amongst others, the mergers of the HE sector, revision of the Norms and Standards for Educators of 1997/8, and problems arising from quality assurance processes. Mergers in the HE sector served to reduce the number of institutions offering teacher education even further from 26 to 20 by 2005 (TESA, 2005). During this period teacher education curricula were revised, and programme designs were adjusted to focus more on developing competence rather than on content knowledge only. The new policy dictated that teacher education curricula integrate theory and practice more closely and comprehensively, and that teachers demonstrate foundational competence (knowledge of the subject and ways to teach it), practical competence (teaching experience) as well as reflexive competence (DoE, 1997). The objective was to align the teacher education curricula with outcomes-based education. However, a concern at the time was that a large part of the teacher education curricula remained unspecified.

Government's intention was that these measures combined would meet the challenge of the sharing of scarce resources as well as the development of quality assurance processes. Quality assurance functions were assigned to various bodies, such as the Department of Education (DoE), with its Norms and Standards for Educators, the South African Council for Educators (SACE) – tasked with registering qualified educators -, the South African Qualifications Authority (SAQA) – responsible for educators' schooling qualifications- , and the Council on Higher Education with its own quality assurance facility for all higher education institutions. Described by Teacher Education in South Africa (TESA, 2005:5) as a dispersed and fragmented system, it created frustrating unwieldy and time-consuming processes, and a great deal of energy has been spent trying to work out the relationships between, and areas of authority for, each part of the system. Essentially these measures meant that teacher education would henceforth be located within the higher education sector, with curricular decisions decentralized to universities, but still strongly impacted by centralized state regulation. In the Western Cape, the main institutions engaged in teacher education include the University of Cape Town (UCT), University of Stellenbosch (US), the Cape Peninsula University of Technology (CPUT), the University of the Western Cape (UWC), the University of South

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Africa (UNISA) a distance learning institution, and the Cape Teaching and Leadership Institute (CTLI) of the WCED which offers in-service training only, but no sustained support for classroom practice.

The CTLI is an in-service Teacher Training Unit of the Internal Human Capital Directorate of the Western Cape Education Department (WCED). The WCED established the CTLI in 2002, initially as the Cape Teaching Institute. The institute later, from 2008, included training opportunities for principals. The CTIL's 2008 media release, announced training for about 160 principals and 2, 000 teachers from 2008 (Attwell, 2009). Its main purpose presently is to offer once-off in-depth training to in-service teachers and principals on how to implement and manage the curriculum and manage schools. Amongst its many functions (Attwell, 2009), CTLI is required to:

- In consultation with relevant role-players, specify education and training interventions
- Manage quality assurance and impact assessment of the training developed and delivered by service providers
- Develop and evaluate training and development programmes.

The programme of courses available to in-service teachers includes Literacy, Numeracy and Life Skills courses for the Foundation Phase teachers, Mathematics, languages, Natural Sciences, Technology, Economic Management Sciences and environmental education courses for Intermediate Phase teachers, reading and Technology courses for Senior Phase teachers and Mathematics for Grade 8 teachers, as well as courses for aspirant principals and school leaders, women already in, and being promoted into, management and leadership positions as well as courses dealing with the roles and responsibilities of heads of departments (HODs) and deputy principals. Courses may extend over four weeks, but these have been split into two blocks of two weeks each to allow teachers the opportunity to implement and evaluate their training. Teachers from all eight education districts of the province attend the courses offered at CTLI, and some courses are repeated at intervals to allow different groups of teachers to attend at different times of the year. Until recently, several of the courses offered at CTLI were designed and delivered by recognized Non-Governmental Organizations (NGOs) and independent service providers.

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NGOs involved with teacher education and training represent a diverse group. As independent bodies, they do not function as universities, technikons or state departments, although collaborative partnerships may be and are established between these institutions and NGOs. Most NGOs receive funding for their work from the private sector or from foreign donors. Historically associated with the broader social movements, NGOs played an important role in engaging the apartheid government around issues of transformation. Many are widely acknowledged for their role in teacher education during the apartheid period. Working mainly at the community level, they continue to offer in-service teachers extended opportunities to develop their professional capacity. Short courses, school-based courses, classroom support for teachers; and supplying teaching and learning materials form part of the range of services they provide.

Distinguishing the different types of NGOs involved with INSET teacher training and development as part of the National Teacher Education Audit of 1995, Vinjevold (1995:25) referred to Hartshorne's (1992) description of four types of organizations. The first type are organisations associated with certain universities that offer programmes outside of the normal state subsidised courses. They are either located in university departments of education, or form part of extra- mural studies divisions, centres of continuing education, language or science institutes, or institutes of education. The second type consists of NGOs are independent organisations set up specifically for the purpose of providing INSET to teachers in the formal school sector, of which the Primary Science Programme (PSP) is an example. The third type includes organisations with wider interests, and INSET is represented but one of the services provided. The fourth type of NGO refers to those agencies developing from local community action, with teachers serving as active members of the organisation.

The NGO sector experienced considerable reorganization after 1994. With the loss of many of its leaders to the public sector, and with funds gradually channelled away from NGOs to support government efforts more directly, many organizations were forced to close down. The current NGO sector has emerged as a valuable partner in educational transformation, and NGOs are acknowledged by government for their innovative and resourceful contributions (Burger, 2009). Government collaborates closely with various NGOs and with the private sector, and seeks to expand relationships, particularly in the areas of educator training, school improvement, ABET (Adult Basic Education and Training), ECD (Early Childhood Development) and FET (Further Education and Training), as well as facilitating evaluation,

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research, and monitoring. Several successful public-private partnerships have produced working models to promote educational transformation. An example of such an association is the Business Trust, which is a business-government partnership, implemented through the Read Educational Trust in 1, 200 primary schools, and the Joint Education Trust (JET) in 600 secondary schools (Burger, 2009). Increased financial backing from private sector entities has capacitated those NGO projects prioritized by the public sector, and Burger (2009) maintains that the success of key national initiatives, such as the South African National Literacy Initiative has depended on government collaborating closely with the private and NGO sectors.

Describing NGO involvement in education and with school development, Taylor (in Roberts & Muller, 2002:8) estimated in 2002 that around 20% of the nation's nearly 30, 000 schools were involved in donor- and NGO-initiated development projects, with a total off-budget expenditure of about R500 million annually, a total inclusive of five year commitments by organisations such as USAID, the Business Trust, the British Department for International Development, as well as numerous local and offshore donors. Assessing NGO involvement in INSET and school development programmes, Taylor (in Roberts & Muller, 2002:23-26) observed that short workshop-based courses can be effective in providing information and orientating teachers and principals to new policies, inspiring and planning individual and institutional change, and developing management systems. His concern at the time was that the type of INSET intervention offered by NGOs might be too weak for building the deep knowledge structures and professional ethos needed for more long-term qualitative improvement of teaching and learning. He advocated that donor- and NGO-initiated school reform programmes should rather play a more subordinate role, assisting national and provincial departments of education to achieve their policy priorities. He also advocated that government officials take charge and direct the resources offered by the NGO sector within the framework of public policy. For this to be realized, he suggested that the management of these collaborations be developed to systematically plan, implement, monitor and support this kind of activity in the public sector.

The above indicates the range of diverse institutions involved with INSET teacher training and development, including universities, technikons, state department such as CTLI, as well as various teacher unions and NGOs. However, allocating authority to distinctly dissimilar institutions, coupled with a lack of agreement on a broad consensus approach to in-service science teacher education and training amongst the various organizations, complicates matters

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in this sector. This makes for complex organizational and managerial arrangements, and thus processes would have to be carefully regulated, planned and coordinated for any productive or lasting impact on science teaching and learning.

2.8 Conclusion

South Africa is by no means alone in its quest to advance science education programmes. Countries across the globe engage various programmes to inspire greater interest in the study science amongst young people, with most of these countries experiencing similar challenges to those in South Africa. Nevertheless, there is general accord amongst education policy makers, researchers and practitioners that knowledgeable and competent science teachers play a critical role in any programme for boosting interest in, and aptitude for, science. There is also the understanding that effective processes of professional development are vital for ensuring that teachers are well-informed and adequately capacitated for their task. Although perspectives may differ in terms of upon which processes of development are the most effective, the agreed-upon objective for science education is to grow a scientifically literate population capable of participating actively in critical discussion and decision-making as well as in the economic growth of a country.

A plethora of research on science education and effective teacher development exists internationally and locally. Most conspicuous in the literature is the recommendation that well-planned professional development programmes for teachers are needed during periods of curriculum change, particularly when new content is introduced. Studies have found that such programmes are best implemented over a long period rather than being short term one-off courses, should include ongoing classroom support, and should involve processes of mentoring and coaching by experts, with ample opportunities for teachers to reflect on changes in classroom practice in collegial environments. The kind of multi-pronged approach advocated in the current and other studies can include, amongst others, regular training and on-site support for teachers, the supply of science kits to schools, the supply of quality printed material such as guidebooks, and hands-on workshops for teachers and children. Above all, serious efforts need to be made to provide science to the less advantaged to ensure that a sound basis in science is not a just privilege for the few.

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This study argues that excellent professional development for enhanced science teaching improves teachers' knowledge of science, science processes and research, and builds their practical competence in the classroom. This study's recommendation, which is expanded in the final chapter, is for teachers to have sound knowledge of both science (content knowledge) and teaching (pedagogic knowledge). In developing countries such as South Africa, providers of science development programmes would need to understand the special contextual circumstances for teaching and learning in schools in poor communities, offer varied learning experiences, and align support with teachers' particular education and training needs.

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CHAPTER THREE: THEORETICAL FRAMEWORKS

3.1 Introduction

Chapter 3 situates this research within its two framing paradigms, activity theory and complexity theory. The chapter describes the basic concepts, principles, and methods associated with the two theories, and explains their relevance to the purpose of the research. In addition, rather than apply a set of idealized decontextualized competencies to the task of analysing teacher professional development in the context of the Cluster Project, a separate qualitative analytical framework is developed. Its configuration follows analysis of a range of teacher development frameworks.

Activity theory is widely used as a theoretical framework for studies on human practices as development processes within their historical, cultural and environmental contexts, offering 'perspectives on human activity' and presenting the 'concepts for describing the activity' (Engeström, 1993, Hardman, 2008, Yamagata-Lynch & Haudenschild, 2009). This facility is used together with other applications to develop an understanding of a Cluster Project for professional development to promote primary science.

This research also applies a complexity lens to the Cluster Project to guide thinking and understanding of teacher learning, systems for their professional development, and the effects of curriculum change and its implications for teacher professional development. Here, Mason (2008:2) points to useful insights complexity offers of the 'nature of continuity and change', proposing that it can contribute to the 'philosophical and practical understanding of educational and institutional change' and the 'emergence' of new properties and behaviours.

A review of activity theory and complexity theory follows, as well as a review of teacher development frameworks used to develop a qualitative analytical framework to assess TPD. In Chapter 5, the activity framework is used to analyse the Cluster Project, and in Chapter 6 essential aspects of the three theoretical frameworks are used to analyse research data in terms of the research questions and objectives.

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3.2 Activity Theory

Activity theory and its activity systems analysis is one analytical framework for this research. Activity systems analysis, derived largely from Engeström's (1993) work, is a qualitative data analysis tool that is useful for identifying human activity in its social context as the unit of analysis (Yamagata-Lynch & Haudenschild, 2009). The problem-solving technique endorsed is useful for disassembling a system into its component pieces to study how the components work, and how they interact to accomplish their purpose. The case in point is a teacher development programme, the Cluster Project, and its agency for promoting primary science education.

Activity theory is located in the modern research methodology category. Although some basic principles of the theory have been identified within the field, it is best understood as a developing body of knowledge. Hardman (2005:259), referring mainly to the work of the researchers Cole (1996) and Russell (2002), and Hooker (2008:331) summarizes some basic principles of activity theory:

- Human activity is collective and human behaviour originates within the social sphere. Adams, Edmond and ter Hofstede (2003:6) describe activities as being communal, and an activity as almost always involving a community of participants working towards a common objective.

- The mind is social, developing from joint activity.

- Tools mediating our psychology bear socio-historical meanings.

- Activity theory assumes that people are active cognising agents, but that they act in sites that are not necessarily of their own choosing with tools that may either constrain or promote their actions.

- Methodologically, activity theory rejects cause and effect explanatory science in favour of 'a science that emphasises the emergent nature of the mind in activity with interpretation centrally located in its explanatory framework'. Thus, activity theorists employ contextualist methodologies, meaning that activities have a context, and contextual conditions and circumstances deeply affect the way the objective is achieved in any activity (Adams et al., 2003:6).

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- Activity theory studies development and change, which is understood to include historical change, individual change and moment-to-moment change. Looking at organizational work practices and the application of activity theory, Adams (et al., 2003:6) add that activities are never static, but are dynamic, evolving asynchronously, and that this process requires a historical analysis for understanding the current context of the activity.

- Activity systems are constantly subject to change, and activity theory sees these changes as driven by contradictions which become apparent within and between systems.

Activity theory is a 'clarifying meta-theory and not a predictive theory' (Wilson, 2006), facilitating rigorous investigation into human activities and processes through producing 'thick descriptions'. It is useful for developing a broad and in-depth understanding of human activities, and the functions, role(s) and contribution(s) of individual units, organizations, processes and systems. Pointing to its particular strengths of situating general developmental principles in time and place, and Engeström's (1993) systems thinking, which enables one to conceive of pedagogical practices as playing out in a rule bound context in which issues of power and control influence practice, Hardman (2008:65–67) considers activity theory particularly useful for in-depth study of the interactions between teachers and learners, or between professional developers and teachers.

Elaborating on practical aspects of this approach, Yamagata-Lynch and Haudenschild (2009) describe in detail those characteristics of activity theory which make it a valuable and comprehensive research framework for complex, holistic and in-depth research. It allows the researcher to map out relationships between the various elements within activities, acknowledges and examines the social influences involved in complex systems of human activity, provides a method for examining how human actions and activities are interconnected, and shows how the various interactions between the components of a system generate tensions, conflict or contradictions. Tensions, conflict or contradictions are necessary, they provide the vitality that drives human systems. These events may appear as problems, ruptures, breakdowns or clashes impacting system components. Activity systems are constantly in the process of working through these, giving rise to change within a system, change to the different parts and/or individual components of a system. Activity systems analysis provides a method

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for studying the changes that occur as systems, organizations and groups engage in learning activities.

Critical aspects of activity theory and activity theory analysis, some of which are mentioned above, together shape an analytical lens through which the Cluster Project can be holistically and systematically analysed and critically interpreted.

The next section traces the evolution of activity theory to its second and third generation form, which applies to this research, and elaborates on the identification of system components, before exploring the important concepts of contradictions, expansive learning and boundary crossing.

Engeström's (1987, 2001) notion of activity systems as units of analysis provides a useful structure for presenting and analysing data on the Cluster Project and teacher professional development in Chapter 5, and Chapter 6 further expands the analysis, referring to the crucial concepts of contradictions, expansive learning and boundary crossing.

3.2.1 History and Background

Activity theory has its origin in Russian psychology and in the work of Lev Vygotsky (1896-1934), Sergei Leonidovich Rubinshtein (1889-1960), Alexander Luria (1902-1977) and Alexei Leont'ev (1904-1979). Initially, activity theory provided a new approach to studying human behaviour and psychology, presenting robust explanations for how human development is mediated through cultural as well as biological influences (Findlay, 2003). Emerging in the 1920s and 1930s as a Soviet alternative to the behaviourist and psychoanalysis movements favoured by the West (Wilson, 2006), Activity theory has over time gained greater acceptance and applicability within the wider research community. Activity theory first made its appearance in the West in the 1970s in educational research. As indicated by Wilson (2006), its introduction into Western research can largely be attributed to a greater interest in Vygotsky's work in developmental psychology and to his theory of learning.

Developing from Vygotsky's work on 'mediated action' (Vygotsky, 1978:40; Wertsch and Tulviste, 1992:551; Yamagata-Lynch, 2010:16), activity theory was later expanded in the 1960s by Leont'ev who is credited with developing the conceptual framework for the theory since most of the key features of activity theory developed from his work (Wilson, 2006).

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Leontev is acknowledged for clarifying the distinction between individual action and collective activity, and for inserting the important component of division of labour in his definition of activity (Hardman, 2008: 69). His tiered model of functioning (Figure 3.1) illustrates activity as driven by the object, while individual actions are directed at goals.

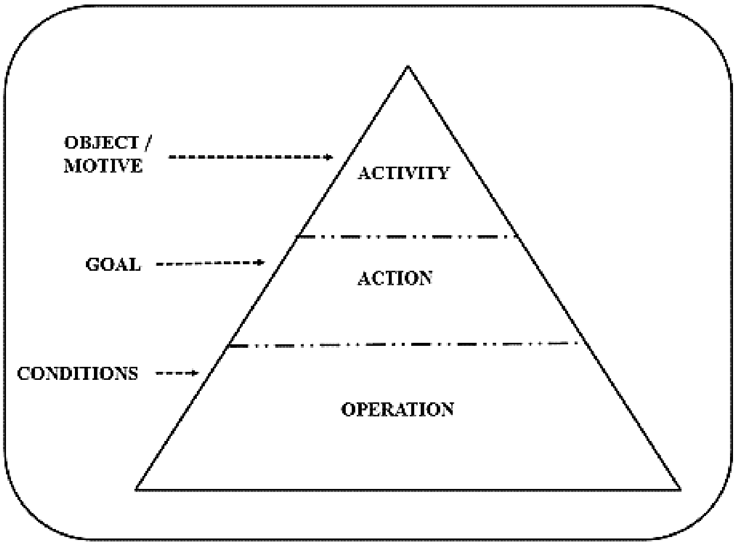

Figure 3.1: Leontev's Activity Theory (Engeström, 1987, Hardman, 2008)

Activity theory became better known after wide distribution in the 1980s of Yrjö Engeström's (1987) work and the later publication of his work with Cole (Cole & Engeström (1993) and his own research in the early 1990s (Engeström,1993). Widely acknowledged for his contribution to activity theory, Engeström's (1987, 1993, 1999) work, like that of Vygotsky and Leont'ev, initially developed in the field of education, he later shifted research focus to 'learning in work situations' and to 'applications of technology'.

Since its entry into the West activity theory has become increasingly cross-disciplinary and is widely used in a range of disciplines including education (Engeström, 1999), cultural psychology (Ratner, 2006), human-computer interaction (Kaptelinin & Nardi, 2006; Kuutti, 1996), information sciences and information seeking (Wilson, 2006), and digital library evaluation (Spasser, 2002). Reviewing the application of activity theory in the field of education, Yamagata-Lynch and Haudenschild (2009) note that, amongst other applications, activity theory can be used to summarize organizational change, identify guidelines for designing Constructivist Learning Environments (CLE), identify contradictions and tensions

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that shape developments in educational settings, and show historical development in organizational learning.

As the tradition of activity theory was taken up and re-contextualized in the West in the 1990s, three distinct generations of thought emerged. First generation activity theory (Figure 3.2) formed from Vygotsky's ideas around mediated action. Its narrow focus on individual activity or practice was considered to be a limitation of this model, and theorists were concerned that it neglected the element of mediation with other human beings through social interaction.

Second generation activity theory (Figure 3.3), inspired by Leont'ev's thinking around an activity system, accommodates mediation with other components and extends the model from the individual to collective activity. The more contemporary third generation activity theory (Figure 3.4), formed through the work of Engeström (1999, 2001:136), has multiple interacting activity systems focused on a partially shared object.

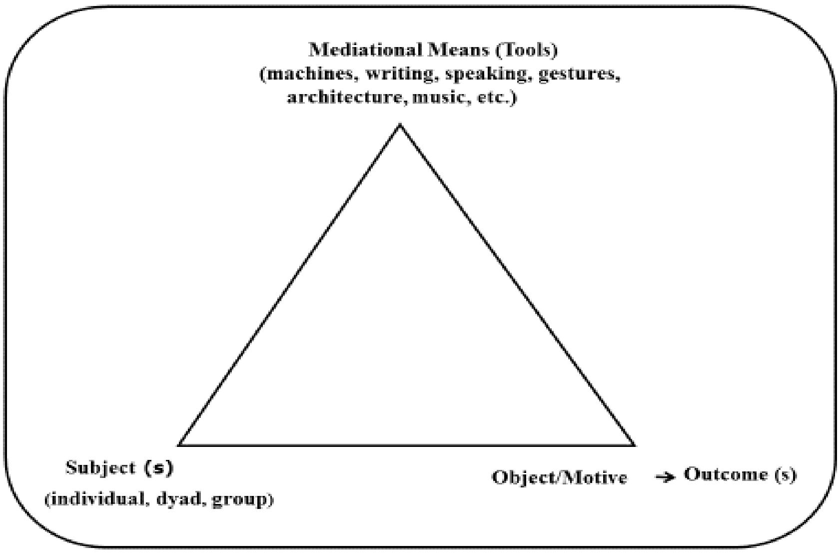

Figure 3.2: First generation activity theory model (Hardman, 2005:259).

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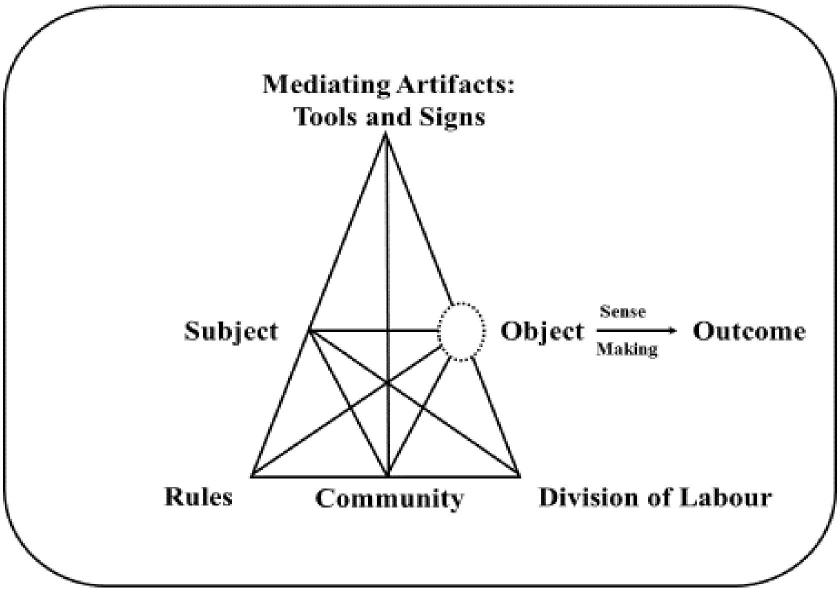

Figure 3.3: Second generation activity theory model. The structure of a human activity system (Engeström, 1987)

Different interpretations and applications of activity theory have emerged over the years. While the model developed through Engeström's work (Figure 3.3) appears to be the more dominant model currently in use, Wilson (2006) notes that an alternative model, known as systemic-structural activity theory, developed by Bedny (2003) (Figure 3.4), is also gaining support. Although both representations have retained the triadic design for illustrating the relationship between components (subject, object and tools) first developed by Vygotsky, the differences between them are apparent in the location of essential components of the system, namely the 'subject', 'division of labour', 'community', and 'tools'. A comparison between first generation and second/third generation models shows how some elements appear to be more explicitly represented in Engeström's model of activity theory, and for this reason Figures 3.3 and 3.4 are the preferred representations for this research.

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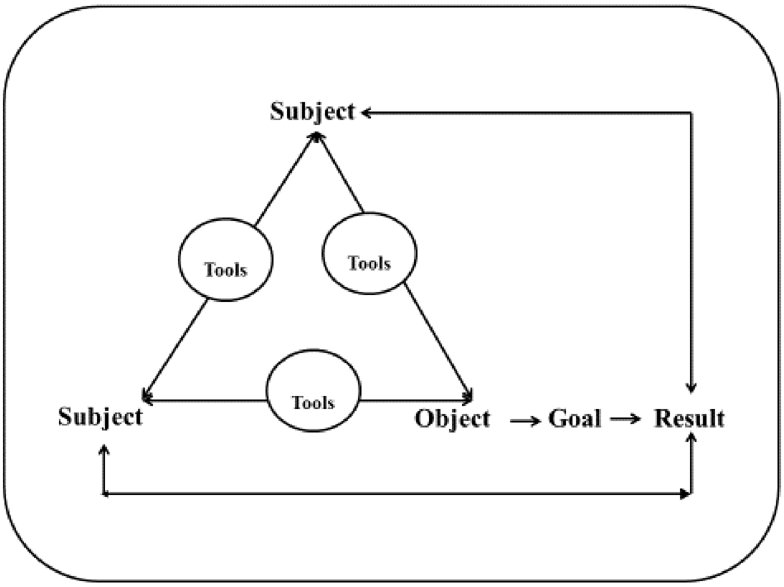

Figure 3.4: Bedny's representation of activity theory (Wilson, 2006).

3.2.2 System Components

Critical elements of a collective work activity, as shown in Figure 3.3, are positioned accordingly to illustrate the transactional relationships between the subject, tool, object, rules, community, division of labour, and outcomes. The terms used in the triadic representation are explained:

***Subject*:** Refers to the individual or a group from which the perspective of study is taken, motivated by a purpose (object) or seeking to find a solution to a problem.

***Object*:** As described by Engeström (2008b), objects are concerns, generators, and foci of attention, motivation, effort, and meaning. He maintains that people constantly change and create new objects, and new objects are often not intentional products of a single activity, but are unintended consequences of multiple activities.

Objects may refer to the subject's motives for participating in the activity and/or the products derived from the activity. Hardman (2008) views objects as the 'problem space' at which the activity is directed, the space may be transformed into the outcomes with the help of mediating instruments (tools or artefacts).

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Tools: Indicate those socially shared cognitive tools, or 'tools for thinking' (such as culture and language), and/or resources (such as a computer, printed materials) used to achieve the objective. The concept encompasses anything and everything used in the transformation process, such as sign systems, instruments, procedures, machines, methods, laws and/or processes.

In this sense, human activities are nearly always mediated through the use of tools; very rarely is there a direct relationship between the subject and object without the use of a tool of some kind. Also, tools are created and transformed as human activity develops and changes. Influenced and shaped by their cultural and historical use, Joyes (2006) maintains tools simultaneously accrue and transmit social knowledge about the cultural context in which they are developed and used.

Community**:** Is the group of distinct individuals or the organization to which the subject belongs. A subject may be part of several communities, and a community itself may intersect with other communities.

Informal or formal rules**:** These govern the subject's participation in the activity, determining how subjects fit into the community. Rules refer to both explicit and implicit norms, the conventions, and social relations within a community that may constrain or enhance actions and interactions within the system.

Division of labour**:** Indicates the assigned roles and responsibilities. This component mediates between the object of the activity and the community. It takes into account the explicit and implicit organization of the community in relation to the transformation of the object into the outcome. It accounts for the role of each individual in the activity, and embraces such factors as the power relationships, control and responsibility.

Outcomes: This represents the end product(s) of the motivated actions, and may include experiences, knowledge, and/or physical products. Outcomes can be intended- and/or -unintended, and may serve to either promote or inhibit the subject's participation in future activities.

Acknowledged for his part in expanding the original triangular representation of activity, Engeström (1999) is also known to have introduced the notion of 'rules' that regulate the

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interaction between a subject and members of the community, and to have first defined 'community' as the group with a shared goal or those performing a collective activity. Engeström (1999) expanded this definition:

- Extending the model permitted the examination of activity systems at the macro level of the collective rather than just at the micro level;
- The oval over the location of *Object* in Figure 3.3 signifies that object-oriented actions are always, explicitly or implicitly, characterized by ambiguity, surprise, interpretation, sense making, and potential for change; and
- Contradictions within activity systems serve as important drivers for change and development.

Consisting of a set or series of actions, activities are situated in meaningful contexts. The context gains meaning through influences emerging from it that may impact the activity itself, and likewise the activity impacts the context in which it is situated. Thus the various constituents of activities do not remain static, but are dynamic, continuously changing and developing. Activities always contain various mediating artifacts or tools/instruments, and the resultant state of flux within activity systems is attributed to asymmetry between various components, such as that between people and the tools. Subjects use instruments, obey rules and conform to divisions of labour; this means the elements are continuously being adapted and transformed by the subjects using them, whether consciously or unconsciously (Mwanza, 2002). Thus all the elements of the system do not remain unaffected by change; they are likewise continuously transforming as change occurs within a system.

The basic unit of analysis in activity theory is motivated activity directed towards the achievement of a particular objective. Its goal-directedness signifies that the activities are performed consciously, thus emphasizing the unity of the activity and the human consciousness, 'avoiding the dichotomies between thought and action and between individuals and society' (Hasan, 1999:44). This model supports the possibility of analysing a multitude of activities and relations within its triangular structure. However, for Engeström (1987, 2008b), the essential task is always to grasp the systemic whole and not just separate parts and their individual connections.

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3.2.3 Third generation activity theory

Engeström's involvement in its development spans second and third generation activity theory. Motivated by the concern that the original cultural-historical approach lacked consideration for cultural diversity, third generation activity theorists proceeded to develop conceptual tools to understand and integrate dialogue between cultures, multiple perspectives and voices, and networks of interacting activity systems (NGRF, 2007). This movement broadened the focus of the theory to joint activity or practice as the unit of analysis. Whereas the concept of community and division of labour had already been conceptualized, third generation activity theorists endeavoured to define the terms more expressly and formally.

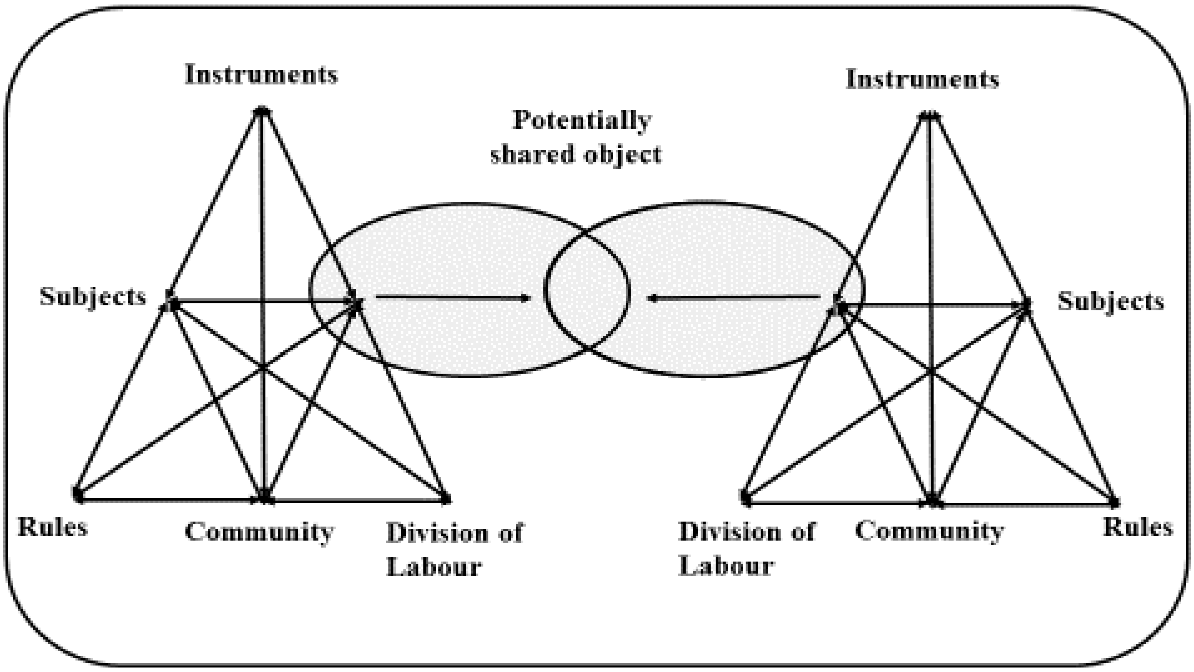

Figure 3.5: Two interacting activity systems as the minimal unit of analysis for third generation activity theorists (Engeström, 1987, 2001).

Two interacting activity systems, as shown in Figure 3.5, represent the minimal unit of analysis for third generation activity theorists. Here, the *Objects* move from their unreflected situational 'raw' state to being collectively meaningful objects, and on to becoming potentially shared or jointly constructed objects within a shared space. Engeström (2001:136) recommends that objects in this representation should be seen as moving targets and not fixed short term goals.

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Summing up the key aspects of activity theory in this form Engeström (2001:136-137) developed five principles:

- A historically evolving collective, artifact-mediated and object-orientated activity system viewed in its networked relation to other activity systems is the prime unit of analysis. While individuals and/ groups may act independently, their actions are interpreted against the backdrop of the entire network of activity systems.
- Activity systems are complex structures accommodating many different viewpoints, interests and histories; and the multifaceted nature of these, or the multi-voicedness of the system is amplified within networks of interacting activity systems (Engeström, 2001).
- Activity systems are shaped and transformed over time; therefore the activity and its components carry with them an accumulated history.
- A collective activity system is driven by a deeply communal motive embedded in the object of the activity.
- Contradictions give rise to change and development. Occurring as historically accumulated structural tensions within and between activity systems, they generate disturbances from which change and innovation arise.
- Opportunities for expansive transformation exist within activity systems. Expansive transformation is achieved when the object and motive of the activity includes many more possibilities than the previous mode of the activity did.

In the absence of ready-made techniques, or a clearly defined set of procedures for 'doing' activity theory research, Engeström's (1999) summary stands as a manifesto for its current form. Activity theory thus provides a robust but flexible conceptual tool that can be adapted to the specific nature and context of the object being studied.

3.2.4 Contradictions, Expansive Learning Cycles and Boundary Crossing

As has been described, activity systems undergo constant change and development, and for activity theory, change is associated with contradictions that develop within and between systems. Together with the role of contradictions in activity systems, the next section highlights the equally critical aspects of Expansive Learning Cycles and Boundary Crossing that play an important role in the use of activity theory as a tool specifically for analysing teacher professional development processes in the Cluster Project.

The concept of contradictions has been mentioned as central to activity analysis as a source of change and development. Contradictions include issues of conflict and tension occurring within an activity system, as well as those impacting from outside a system. Tensions, according to Yamagata-Lynch, Pamental and Smaldino (2007:5), can be seen as the catalysts for examining the status quo, and can instigate a series of changes.

For analysing the various sources of tension within activity systems Engeström developed four levels of inner contradictions, shown in Table 3.1 (Engeström, 1987, Yamagata-Lynch & Haudenschild, 2009).

Table 3.1: Engeström's four levels of inner contradictions in activity systems.

Contradiction Level	Engeström's Definition
Level 1 Primary Contradiction	When activity participants encounter more than one value system attached to an element within an activity that brings about conflict.
Level 2 Secondary Contradiction	When activity participants encounter a new element of an activity, and the process for assimilating the new element into the activity brings about conflict.
Level 3 Tertiary Contradiction	When activity participants face conflicting situations by adopting what is believed to be a newly advanced method for achieving the object.
Level 4 Quaternary Contradiction	When activity participants encounter changes to an activity that result in creating conflicts with adjacent activities.

Inner contradictions are disturbances that develop when activities interact with allied activities and are affected by issues related to such activities. In essence, interactions with other activities may produce imbalances in an original activity, leading to change. For instance, in the activity systems of teaching and learning, the assumptions underpinning the activities of various role-players working in the field, namely teachers, developers of teacher development programmes,

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universities, and school districts often differ. Where these differences become evident as contradictions, they can be the cause of (often productive) tension and conflict within and between the related activity systems.

Primary contradictions are said to occur when participants of an activity encounter more than one value system associated with an element in the system, producing conflict. An example put forward by Supovitz and Turner (in Yamagata-Lynch & Haudenschild, 2009) concerns the nature of professional development programmes and the opposing views of developers and teachers. While developers may regard sustained and intensive teacher development programmes as being of more value for advancing school reform agendas, this arrangement may be less appealing to teachers, who demonstrate a preference for one-day workshops or shorter term programmes to address their more immediate professional development needs. In this case, the object of improving classroom practice may be shared by a group (education district officials, universities, classroom teachers), but there may be less agreement on the type of programme that could best achieve the shared goal. In effect, this can create a conflict situation for developers of teacher professional programmes since teachers may ultimately choose not to participate in the sustained and intensive development programmes considered more beneficial by some of the programme developers for meeting sustained long-term educational goals.

Secondary contradictions refer to new encounters participants experience within an activity system. The process of accommodating new aspects / programmes / techniques / experiences can engender tension or conflict. For example, as mentioned by Yamagata-Lynch (in Yamagata-Lynch & Haudenschild, 2009), when a teacher becomes involved in a professional development programme, in addition to performing his/her daily work-related activities, the teacher may be challenged to adequately meet the demands, expectations and requirements of both sets of tasks at the same time. When the teacher is confronted with the challenge of assimilating the new rules and the division of labour imposed by the professional development programme into his/her everyday work routines, this situation can generate tension and conflict.

Tertiary contradictions occur between the object or motive of an activity system and the object or motive of a 'culturally more advanced' form of the activity (Beatty & Feldman, 2009:5). Yamagata-Lynch and Haudenschild (2009) reason this may arise when school districts impose

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new teaching and learning programmes for improving learner results upon teachers without prior in-depth research or consultation. Disconnect between the new and existing programmes may cause teachers to experience difficulty and resentment in assimilating the prescribed coursework into their daily programmes. Quaternary contradictions develop between an activity system and its related activity systems. This may occur when teachers are compelled to adjust their programmes and strategies to accommodate new plans or programmes forming part of a school district, provincial or national improvement plan.

Conflicts, dilemmas, disturbances, tensions and contradictions are not one and the same. Engeström and Sannino (2010:7) find that these are located at two different levels of analysis, and that there is a substantial difference between conflict experiences and developmentally significant contradictions. Conflicts, dilemmas, disturbances and local innovations may be investigated as manifestations of the contradictions. While conflict experiences are situated at the level of short-term action, contradictions are situated at the level of activity and inter-activity, and have a much longer life cycle.

Within the education domain, Engeström and Sannino (2010: 5, 17) describe various institutions as work organizations with their own histories, contradictions and zones of proximal development, and see contradictions within these organizations and their objects as being the driving forces for transformation. The zone of proximal development (ZPD), as defined by Vygotsky (in Findlay, 2003:1), is ‘the distance between the actual development level as determined by independent problem solving, and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers.’ In the current research the issue of contradictions related to the Cluster Project as a work organization is revisited in Chapter 6.

The ultimate test of learning theories, according to Engeström and Sannino (2010:1), is how helpful these are to practitioners working towards understanding and generating learning with respect to challenging critical issues facing humankind. Whereas a theory of learning as such is not contained within activity theory, activity-theory orientated pedagogical concepts feature in Engeström’s (2001) theory of expansive learning (Mwanza & Engeström, 2005). This next section considers Engeström’s (2001) concepts of ‘Expansive Learning Cycles’ and ‘Boundary Crossing’.

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Engeström's (2001) expansive learning cycle refers to the processes of learning and change resulting from ongoing tensions and conflicts within activity systems. He proposed the expansive learning cycle as an organizational learning theory, and activity systems analysis as the method for examining the changes that occur while organizations are engaging in learning activities (Yamagata-Lynch, Pamental & Smaldino, 2007: 5). Reviewing various studies Engeström and Sannino (2010:1) describe six important ideas related to the theory of expansive learning: expansive learning as transformation of the object, expansive learning as movement in the zone of proximal development, expansive learning as cycles of learning actions, expansive learning as boundary crossing and network building, expansive learning as distributed and discontinuous movement, and expansive learning as formative interventions. The authors maintain that these variations extend expansive learning analyses both up and down, outward and inward. Describing the movements, Engeström and Sannino (2010:1) see the up and outward movements as dealing with learning in fields or networks of interconnected activity systems with their partially shared and often contested objects, and down and inward movements as tackling issues of subjectivity, experiencing, personal sense, emotion, embodiment, identity, and moral commitment.

The theory of expansive learning cycles challenges traditional learning theories, which posit knowledge as stable, and there to be acquired by the learner with the assistance of a teacher who possesses the knowledge. This view interprets knowledge as a static stable commodity that survives through simple transmission from one generation of learners to the next, and is limited to what is known and understood by the teacher. Engeström (2001) takes a very different position on knowledge and learning, arguing that:

> *...people and organizations are all the time learning something that is not stable, not even defined or understood ahead of time. In important transformations of our personal lives and organizational practices, we must learn new forms of activity which are not yet there. They are literally learned as they are being created. There is no competent teacher (Engeström, 2001: 137-138).*

In terms of Engeström's views knowledge, understanding and meanings are co-created with others in a social setting, usually within an activity. Knowledge is not seen as a stagnant body, but evolves over time as it is continuously being modernized and as new knowledge forms through collaborative analysis and action.

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The basis for Engeström's (1987) theory of expansive learning is the expanded activity system model (Figure 3.5), in which one focus is the expansive transformation of the object in a collective activity system. The framework builds on Vygotsky's work, with the 'zone of proximal development' as its cornerstone. Engeström's (2008b:12-13) full cycle of expansive transformation represents a collaborative journey through the zone of proximal development of the activity. Seven expansive learning actions (Figure 3.6) together form an expansive cycle or spiral which Engeström and Sannino (2010: 5-6) explain as follows:

1. The first action involves *questioning*, criticizing, and rejecting some aspects of the accepted practices and existing wisdom;

2. The second action involves *analysis* of the situation. Analysis involves mental, discursive or practical transformation of the situation in order to uncover the causes or explanatory mechanisms. Analysis focuses on the 'why?' questions and explanatory principles. One type of analysis is historical-genetic: it seeks to explain the situation by tracing its origins and evolution. Another type of analysis is actual-empirical: it seeks to explain the situation by constructing a picture of its inner systemic relations.

3. The third action involves *modelling* a new solution to the problematic situation. This means constructing an explicit, simplified model of the new idea that explains and offers a solution to the problematic situation.

4. The fourth action involves *examining* the model: running, operating and experimenting on it in order to fully grasp its dynamics, potentials and limitations.

5. The fifth action involves *implementing* the model by means of practical applications, enrichments, and conceptual extensions.

6. The sixth action involves *reflecting* on and evaluating the process;

7. The seventh action involves *consolidating* its outcomes into a new, relatively stable form of practice.

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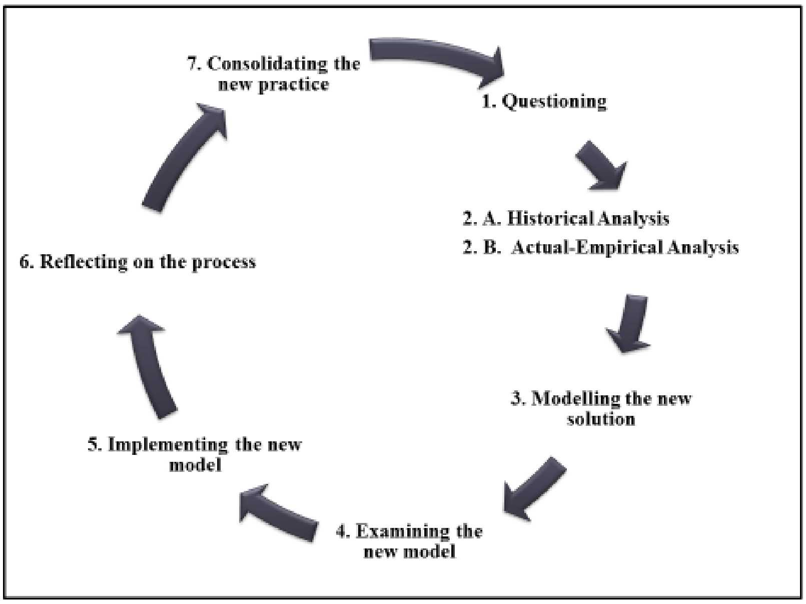

Figure 3.6: Engeström's Expansive Learning Cycle (Engeström, 1999)

Clarifying this expansive circle further, Engeström and Sannino (2010:5-6) see the theory of expansive learning as focusing on learning processes in which the subject of learning is transformed from isolated individual(s) to collectives and networks. Learning processes are initiated with individuals interrogating the existing organization and perceived rationality of a particular activity. As more participants become involved, collaborative analysis and modelling of the zone of proximal development are initiated and carried out. In time, the learning effort of implementing a new model of the activity involves all participating members and elements of the collective activity system.

Extending activity theory and Engeström's (2001) theory of expansive learning, Baudin, Faust, Kaufmann, Litsa, Mwanza, Pierre and Totter (2004:3-4) argue that the 'subjects' or participants (e.g. students and teachers) in a learning activity consciously and unconsciously engage in dynamic learning goals or object formation.

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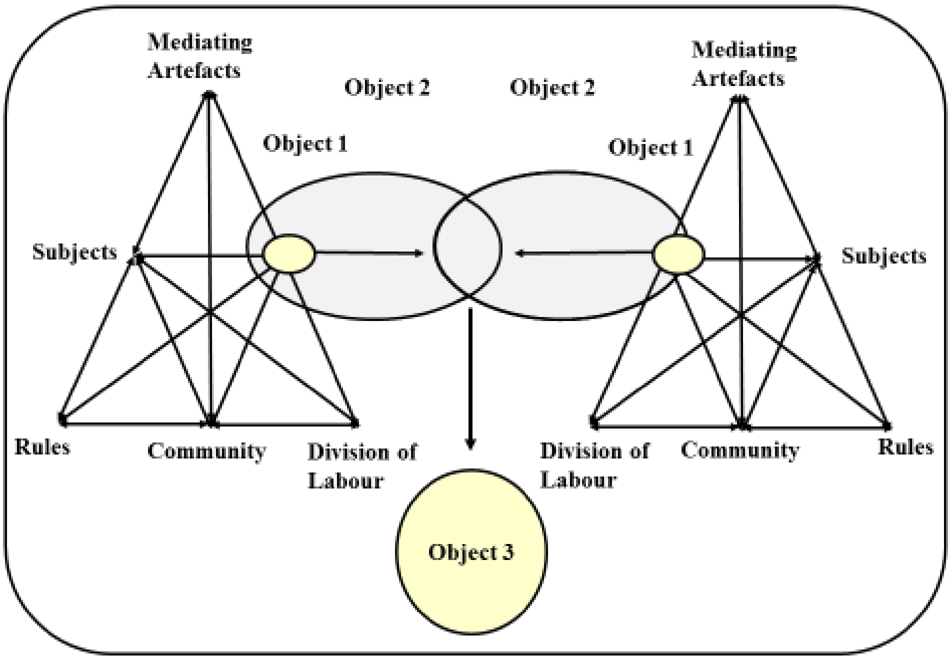

Figure 3.7: Two interacting activity systems as the minimal unit of analysis for third generation activity theory and the creation of a new object (Engeström, 2001:131).

For reasons already mentioned, the outcome(s) of the learning activity cannot always be predicted with certainty, remaining subject to a range of influences operating within the contextual environment or community in which teaching and learning is taking place. In this context, the pedagogical stance emphasizes the process of emerging knowledge developing from disturbances or conflicts in the learning activity. The new knowledge can generate novel practical activity systems and artefacts for use in real life contexts. Baudin et al. (2004:4) maintain that participants in a learning activity can develop new:

- learning activities,
- methods of learning and teaching, and
- tools for exploring and interacting with learning objects.

Contradictions within and between systems focus attention on the root causes of problems and facilitate collaborative analysis, a crucial precondition for the development of a shared solution. Thus, for practical application of activity theory, Baudin et al. (2004:4) recommend partnerships between all stakeholders or interested parties in a community of teaching and

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learning, and in this way being able to collectively challenge contradictions which can be exposed, and hybrid forms of teaching and learning activities in which learners and teachers become co-producers of knowledge can be explored.

While expansive learning is useful for promoting collaborative action, boundary crossing can be a powerful concept for fostering innovation in education. Engeström (2008b:14) explains that boundary crossing occurs as human beings engage in multiple activities and are regularly moving between these activities. He offers the example of a school student moving from home, to school to peer culture, and back home, arguing that such instances of boundary crossing are not confined to activities of the individual, but can also occur between collective activity systems and organizations in partnerships, and in mergers. According to Engeström (2008b:14), boundary crossing in these cases is said to provide material for double stimulation, promoting negotiation and the re-orchestration of activities. Boundary crossing can support collaboration beyond narrow boundaries of subjects and schools, and the advantage for science education, according to Hansen, Gräber and Lang (2012), is that it can promote collaborative learning inside and outside the school as well as teacher professional development.

The unit of analysis in boundary crossing is not the individual, but the interactions between acting persons and the spheres in which they act (Hansen et al., 2012). Further, that boundaries to be crossed can be identified as occurring between subjects such as the sciences, mathematics or languages, between in-service teachers, between initial and in-service teacher education and training, between theory and practice, between and inside schools, and between universities, museums, companies, and key policymakers and stakeholders. Hansen et al. (2012) regard boundary crossing and joint work in collaboration as beneficial for teachers as they develop a 'shared vision' of working and learning together, bringing more coherence in the overall curriculum and finding common ground in selecting what should be taught in schools. Ultimately, in the course of this process, there is potential for change in schooling.

Relating the concept of boundary crossing to a general view of learning, Engeström (2001:153) argues that learning and development are largely understood as vertical processes, and that in the process of learning an individual is elevated to higher levels of competencies. Rather than discarding this view, he proposes a complementary perspective, namely that of learning and development occurring as a horizontal or sideways process as well. He suggests boundary

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crossing as representative of the most obvious form of horizontal or sideways dimension of learning and development.

Moving between different systems, such as schools and communities of practice, participants cross boundaries, encountering new and different views, insights and ways of doing. The occasions generate conflict and tensions, followed by reflection on longstanding practices and notions, and change. Instances such as these provide opportunities for innovation, revitalisation and deep learning.

As with the issue of contradictions within activity systems, the concepts of ‘expansive learning cycles’ and ‘boundary crossing’ as these relate to analysing teacher professional development in this research are explored in Chapter 6.

3.2.5 Summary

The challenge for users of activity theory in research or in organising development programmes may be the absence of a clearly defined set of procedures of ‘doing’. Even though activity theory does provide a general conceptual framework for understanding and analysing human activity, it does not offer any clear methodology as to how such activities can be unambiguously distinguished, defined and examined. Researchers working in the domain of activity theory typically employ several methods of data collection, and extend investigation over a longer time frame for a full range of contextual issues to emerge.

Moreover, within the activity theory tradition, a range of diverse studies have emerged, some involving observation of activities, analysis of interactions or historical analysis of artifacts (Bannon, 1997). Although activity theory is not the only theory that considers development, one of its main research themes, according to Bannon (1997), is that activity theory as a research method for the study of development is advantageous in several significant ways:

- Development is not the only object of study, but it is also a general research methodology
- All practices are a result of certain historical developments under certain conditions and are continuously re-forming and developing processes.
- There is a strong emphasis on ‘development’ and evolution of activities and actions within settings.

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Activity theory is not applied as a research method in this research, rather it is used as a theoretical framework to describe and frame the Cluster Project, the case in this research.

Activity theory has a rapidly growing body of literature in related disciplines. The theory offers a broad conceptual framework for understanding the inter-relationships between different activities, actions, operations and artifacts, as well as subjects' motives and goals, and aspects of the social and organizational contexts constituting an activity system. An important aspect of activity theory is that it considers work, operations and activity systems in their entirety, extending the inquiry beyond just one particular actor, participant, tool, outcome or action. As a socio-cultural, socio–historical lens for analysing human activity systems (Jonassen & Rohrer-Murphy, 1999), activity theory takes into account, amongst others, issues related the environment, historical influences, cultural influences, and role of the tools, motivations and complexities of actions. It takes into consideration all aspects associated with the activity, the influences exerted by various components, as well as their interconnectedness and interdependence.

Engeström's (2001) contributions to it have become popular in activity theory, offering researchers a clear conceptual frame, and a well-worked out methodological frame, which he has termed the 'developmental work research'. Central to his activity analysis is the concept of 'contradictions', considered the main cause of activity systems developing and evolving. Some of Engeström's (2001) work, and other contributions in the field of activity theory with respect to the second and third generation activity theory models, the concepts of contradictions, expansive learning cycles, and boundary crossing are used in this research for a broad and in-depth understanding of the Cluster Project and its objective of improving primary science education through teacher professional development.

3.3 Complexity Theory

Complexity theory is young and evolving, one of a range of contemporary approaches. A new recruit to the field of educational research, it represents a radically different way of thinking, proposing alternate ways of conceptualizing and researching teaching and learning. Complexity, with its focus on components and their connectedness within interrelated networks, departs from the traditional 'simple cause-and-effect models, linear predictability and reductionist approaches' employed in the study of phenomena, respectively substituting

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these with 'organic, non-linear, holistic approaches' (Morrison in Mason, 2008:16). Philosophically, complexity theory takes a pragmatic position, leaning towards 'comprehension and explanation rather than prediction' (Mason, 2008:38). Complexity theory's rejection of the traditional emphasis on simplification and reduction, its fragmented historical and conceptual development, its emergent nature, as well as its disregard for the more traditional mathematical techniques usually employed in scientific works, have all motivated many scientists to question the whole basis of the theory, regarding it as too vague, too 'fuzzy', ungrounded, and inapplicable to be called science. Not discouraged by the opposition to its radical nature, some researchers (Doll, 1993; Richardson & Cilliers, 2001; Davis & Sumara, 2006 & 2008; Kuhn, 2008; Mason, 2008) have welcomed the novelty of complexity theory. Its appeal resides in the useful alternatives it provides to experimental and quantitative methods, and the new pathways for analysis at variance to traditional linear reductionist analyses. Thus, complexity theory has been allowed to persevere, evolving and growing substantially in various disciplines in the last decade as more and more researchers are keen to explore its potentialities.

Complexity theory has its origin in the 'hard' sciences of mathematics and physics. Its development can be traced through studies in physics, chemistry, biology, ecology, mathematics and economics. Its form not fixed by precise definitions (Davis & Sumara, 2008:33) to restrict and regularise implementation to specific research fields, complexity science was able to traverse the boundaries of a range of disciplines making its way into fields as diverse as archaeology, psychology and law. Its incorporation into the social sciences is understood to be a more recent phenomenon, making it a 'relative stranger' (Mason, 2008:2) to the field and accounting for an even shorter history in this domain. As a theory of 'change, evolution, development and adaptation' (Morrison in Mason, 2008:16) complexity holds much promise and finds application in many areas of the social sciences including education.

Mapping the conceptual and historical development of Complexity Science and Complexity Theory Castellani (2011) produced a timeline, Appendix A, charting key contributions in the field over six time periods. The timeline incorporates the contributions of leading scholars, and according to Castellani (2011) the synopsis 'provides a macro-level introduction to complexity science and complexity theory'; though he does acknowledge that the record is not final, fixed and exhaustive. The schema shows the emergence of Complexity Science and Complexity Theory can be attributed to a range of influences; some important ones appear to

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stem from Systems theory, Dynamic Systems theory, Cybernetics and Socio-Cybernetics. The shared focus is systems, their elements and the connections between them.

Complexity theory in this research gives attention to some of the critical concepts for expanding understanding of teacher professional learning in the Cluster Project, with respect to: learning as a nonlinear process; unpredictability; networking and connectedness; change by emergence and self-organization; changing environments; teacher development programmes as open, complex adaptive systems; pedagogy; and holism.

3.3.1 Teaching and Learning

There is growing interest within the educational research field for a theoretical paradigm that can capture more fully all the interrelated and constantly changing factors of complex learning situations. A qualitative paradigm of complexity, with its many and complex perspectives, language, and a way of working, has the potential to effectuate such a study, and therefore may be of interest and value to education and education research. However Mason (2008:13) cautions against the unexamined acceptance and use of this framework, for the reason that the theories and sciences of complexity are somewhat young, and their related phenomena are a long way from being well understood. Academics involved with complexity are therefore understandably cautious in advocating the wholehearted embrace of complexity in all aspects of education practice and research.

The usefulness of complexity for educational research lies in its potential for describing and making sense of ‘subject matter that cannot be studied by formal means only’, (Cilliers, 2000: 23). Similarly, Kuhn (in Mason, 2008:173-174) maintains that complexity as a ‘paradigmatic orientation for explaining novelty and evolution’ in education offers ‘evocative metaphors for making sense of that which is not bound to linearity and certainty’. On the other hand, both Kuhn (in Mason, 2008:169) and Cilliers (2000:23) emphasise that complexity has implications for the way we conceive of social interactions such as those involved with education; and the way we conceive of the structural, functional and organizational aspects of education organizations and their interactions with the broader context. In selecting a complexity perspective researchers have to clear on what they can and cannot learn through its use.

Citing two frequent objections to the use of complexity in educational research, Kuhn (in Mason, 2008: 173-174) indicates objectors state ‘complexity draws inappropriately on images

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and metaphors from mathematics and science'; and that many discourses in disciplines such as philosophy, arts, humanities, social sciences developed within constructivist, postmodernist, poststructuralist or critical perspectives can provide equally acceptable or more advanced approaches for explaining similar notions and insights derived from a complexity view; contending in effect that complexity is redundant. In her rebuttal to the first objection, Kuhn (in Mason, 2008: 175) argues that separating mathematics and science from the humanities, social science or sociology does not adequately acknowledge the complex interrelated nature of human society; and if complexity is considered inappropriate for use in the social domains because of its origins in the hard sciences of mathematics and science, then substantial quantities of quantitative and 'objective' research in other fields would likewise have to be rejected on the basis that they too make use of mathematics and science images and metaphors.

Responding to the second objection from those who argue for the redundancy of complexity theory, Kuhn (in Mason, 2008: 176) argues that what would and should be of greater interest is what can be learned from a complexity perspective that is useful to the problem or issue being investigated, and that the language and concepts associated with complexity theory can be useful for constructing different meanings, and thus complexity theory cannot be regarded as redundant. She concludes her line of reasoning by stating that it is only through critical thinking and wider discussion within the realm of complexity and complexity thinking that researchers can actively participate in developing or evolving research approaches for education research. Reflecting on what can be brought to light with a different approach and a different type of thinking should be considered of greater value to education and educational research than attempting to restrict theoretical frameworks for research to those which are tried and trusted. In spite of apparent difficulty associated with its application, Ramalingam, Jones, Reba and Young (2008: ix) recommend complexity for its set of useful and challenging 'fictions' that can contribute to a better understanding of real world complexities such as those associated with education.

Complexity theory, with its focus on the multidimensional nature of change, can be useful for 'understanding the dynamics of educational change' (Hoban, 2002:25). Rather than 'input-output, back-box causal modelling', a complexity perspective applies important concepts of 'connectedness, holism and non-linearity' (Mason, 2008:14) to understanding educational phenomena. Education and educational research can benefit from these perspectives, along with complexity theory's acknowledgement of diversity. Complexity theory acknowledges that

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human ability, interests, behaviours, habits, and the contexts within which human endeavour take place are very different, interpreting human activities and their settings from the micro level of the individual to macro level of international establishments as an intricate web of complex interconnections and interactions. Complexity theory is concerned not so much with attempting to isolate the parts of an organizational system as with understanding the relationships that give rise to the organizational whole (Stanley, 2009:2). Connectedness exists throughout dynamic systems, such as those in schools, for instance, where the connections between components are extensive; for example, children are linked to parents, care-givers, family, teachers, peers, religious organizations, and sports bodies, while teachers are linked to other teachers, support agencies, social services, teacher unions, education district offices, and so on. Understanding education as a whole requires understanding the separate components and their (inter)connectedness.

The school, along with its staff and learners, does not function in isolation, shut off from the community, but is connected with the external world through the staff and learners, and internally through administrative tasks, curriculum development and assessments, teacher-learner relationships, and a host of other forms. Detaching an individual element, event or experience from its embedded state, and examining only one of its features, will not in any way diminish the 'multi-dimensionality, non-linearity, interconnectedness, or unpredictability' of the phenomenon (Kuhn in Mason, 2008:174).

Complexity theory suggests that, to understand educational phenomena more completely, such phenomena ought to be studied holistically (Mason, 2008: 8). To atomize a phenomenon, and then to focus only on certain factors, implies a disregard of the scale of complexity at other levels of the environment or system, as well as excluding the dynamic interactions with other constituents and their influences, and ignoring the fact that a learner or the school represents and reflects a myriad aspects of the society within which s/he or it operates.

Complexity theory also acknowledges that a learning system is made up of different layers of agents (Morrison in Mason, 2008:27): the individual learner, the teacher, the classroom setting, the curriculum, the rules and regulations, and the lifestyle of the community. The system requires that each layer and its respective influence be analysed and understood differently. Educational research therefore needs to take into consideration that the outcomes of learning processes and development cannot be explained or understood by examining single issues in

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isolation, but requires a consideration of a range of influences situated within a continuously changing environment.

Complexity emphasizes “the process rather than the content of learning”, (Morrison, 2006: 6), interpreting learning as involving self-discovery, self-learning, and active participation. Further on the subject of education, Morrison (2006:6) explains that complexity suggests “a movement towards bottom-up development and change; local and institutional decision-making on educational issues; child-centred, experiential, and exploratory teaching and learning; a rejection of rigid prescriptions and linear programming of teaching and learning; and a move towards non-linear learning”. Teachers may develop lessons plan to guide events in the classroom, but teaching is more often than not a complex unpredictable activity. At any given time classroom events can change, careful plans unravel, needing teachers to redirect lessons, to improvise, to make creative impromptu adjustments to their original plans in relation to the feedback they receive from learners.

The complexity of teaching is widely acknowledged, challenging many aspects of a teacher daily. Teaching is intellectual and thoughtful; it is not simply a matter of sticking to a textbook, or implementing the instructional designs others have developed. Every day, a teacher is called upon to make crucial decisions, from designing and implementing lessons, to responding to learners’ questions, to meeting with colleagues, education department officials and parents. Teaching can be physically taxing; teachers are active all day long, moving between different contexts, from one classroom or part of the school to another, and on to other environments for professional interactions. Teaching can also be emotionally demanding, teachers are concerned about the well-being of children entrusted to their care. Teachers also encourage children to relate socially, helping them interact with others in socially acceptable ways.

Teachers create and manage conditions for children to learn, while managing time and other resources amidst a host of other responsibilities, all at the same time. To accomplish all of this a teacher must understand children as individuals, each with their own complex set of knowledge, skills, and aspirations. A teacher must also consider the range of individual personalities, attitudes, cultures, beliefs, values, and customs and traditions as they connect with diverse children, their parents and colleagues; demonstrating a sensitivity to multiple aspects of various personal, professional, and cultural relationships. Planning for a lesson for

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thirty or more individuals, successfully executing lesson plans, all within the context of numerous (and sometimes conflicting) demands from the school, district and community.

Teaching and learning are considered complex adaptive systems (CAS) and processes (Grisogono, 2004; Weichhart, 2013). Teachers need to continually reflect on their teaching and be ready to make changes as and when it is required. Knowing what and how to change would need teachers to examine their own effectiveness as teachers. This means teachers might be required to modify the learning objectives, content, structure, or format of a course, or otherwise adjust their teaching strategies from time to time. Above all, teachers must support all learners to achieve their learning objectives, preparing them for successful outcomes in externally mandated assessments, and supporting their becoming productive members of society.

The system consists of multiple agents (the speakers in the speech community) interacting with one another (Beckner, Blythe, Bybee, Christiansen, Croft, Ellis, Holland, Ke, Larsen-Freeman, Schoenemann, 2008:2). The authors explain further that the system is adaptive, that is, speakers' behaviour is based on past interactions (history), and current and past interactions together feed into future behaviour. A speaker's behaviour is the consequence of competing factors ranging from perceptual constraints to social motivations. New knowledge, skills and behaviour can emerge from interrelated patterns of experience, social interaction, and cognitive mechanisms. The CAS approach reveals commonalities in many areas of language research, including first and second language acquisition, historical linguistics, psycholinguistics, language evolution and computational modelling.

The goal of education is to provide children with learning experiences tailored to their needs. This means accommodating different abilities, initial knowledge bases, and learning styles in a way that supports and nurtures personalised learning. On the other hand, traditional schooling, schools and classrooms are rigidly controlled, strictly regulated with classrooms arrangements, schedules, curricula, standardized tests, and school bells, where content is "delivered" to children in much the same way, mostly in a linear fashion via mass produced textbooks. It seems there is a mismatch between the essential goal of education and the context usually structured for educational processes. Employing traditional teaching styles focussed on linear inputs and outputs in traditional highly structured classrooms, personalised learning might not always be achievable. Breaking with the traditional view, complexity theory instead

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considers teaching and learning in schools and elsewhere as nonlinear, often unpredictable processes, whether for children or adults. Elsewhere in this chapter Reid (in Fraser, et al., 2007) agrees that teacher learning is not confined to formal planned situations only, but can take place through informal and incidental interactions as well. Educating the whole person is an important goal of education in itself, and teachers and facilitators play their part in this process, by taking into account and responding to differences in the learning needs of individuals.

Teachers' work and its context are both multi-dimensional; this means changes imposed on a system can affect different dimensions of the system at different times. Studying any aspect of the multidimensional work and its environment would not be possible without studying the connections and relations between the different parts making up the system. Complexity's focus on interconnectedness and interrelatedness of systems and their constituent elements, and of learning, reminds of the Gestalt principle: "the whole is something other (and more) than the sum of its parts", (Blosser, 1973). Explaining the application of the Gestalt principle to classroom activities, Stenhouse and Watts and Taber (in Chu, 2012:2) write, "Gestalt ideas suggest the teaching-and-learning process should change from an injection of information to a more complex activity where students have a substantial part to play in integrating new intelligible, plausible, and fruitful concepts with their existing knowledge". The explanations links with complexity's view of learning, and highlights the importance of involving children / adults actively in learning, as co-constructors of knowledge, and for teachers / facilitators to find ways to integrate new learning with the initial knowledge base.

In contrast to linear models where all learners are expected to follow fixed pathways towards learning, a worthwhile pedagogical approach is child-centred or teacher-centred with opportunities for nonlinear or non-sequential learning which is more accommodating of diverse learning needs. Learning opportunities for children and adults should preferably include nonlinear, interactive, context-sensitive and active learning elements, and be flexible enough to accommodate diverse learning levels, different knowledge bases, skills, aptitudes, personalities and learning styles. For designers of professional development programmes, this means suspending the "one-size-fits-all" approach in favour of methodologies that accommodate differences amongst teachers in a way that acknowledges their academic and professional experience, and addresses their particular professional training needs in a way that contributes to their professional growth and development.

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Situated within a conventional mechanistic paradigm, educational change invariably becomes, or is perceived by those using such a framework as, a lockstep, linear process, accompanied by a narrow simplistic approach to teacher development. The fact that this approach is used regularly and on a regular basis does not yield promising or insightful results, is currently rarely considered, nor are more suitable alternative approaches to teacher development contemplated on the whole. A new mindset is needed for understanding the nonlinear dynamics of educational change and teacher learning. Hoban (2002:38-39) proposes complexity theory as a perspective for understanding why short-term approaches to teacher development are usually inadequate for promoting sustainable educational change. He argues that such programmes may be relatively unsuccessful because they do not accommodate the long-term, non-linear nature of change. He further emphasises two important aspects which should accompany educational change processes: long-term teacher learning, and teachers being prepared to reconceptualise their own views of professional learning, a shift that begins with sharing, collaboration, and developing as a 'teacher inquirer'.

In making use of and implementing a complexity perspective, this research interprets teaching and learning, teacher learning, and educational change as dynamic, multi-dimensional, interconnected, nonlinear, and unpredictable processes that necessitate flexible and extended teacher learning programmes and collaborations.

3.3.2 Implementing a Complexity Perspective

Complexity theory finds application in vastly different studies spanning a variety of traditional disciplinary boundaries, from which a range of understandings and its implications have developed. Distinguishing a strictly mathematical and computational (quantitative) perspective, developed via chaos theory, from a more critical understanding (qualitative) of complexity theory, Cilliers (2005:257) argues that, in terms of the critical understanding of the theory, 'complexity theory may not provide the particular tools to solve complex problems, but does show in a rigorous way precisely why the problems are so difficult'. Noting elsewhere that, although the 'lessons to be learnt from complexity theory may be rather oblique, important lessons can still be learnt' (Cilliers, 2000:23. Despite the sceptical tone of the criticism of the role of complexity theory, Cilliers (2000:257) points out that this view is based on an understanding in keeping with an accepted scientific characterization of complexity.

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Within a qualitative paradigm, complexity theory with its holistic perspective, supports case study methodology, action research, and participatory forms of research that include the viewpoints of as many participants and/or stakeholders as possible. This allows for the accommodation of multiple-causality, multiple perspectives and multiple effects. A single level analysis is insufficient for sense-making (Davis in Mason, 2008:51), and, in accordance with heterogeneity, Morrison (in Mason, 2008:25) argues that complexity theory suggests a substantive agenda as well as a set of approaches that supports methodological, paradigmatic and theoretical pluralism. The complexity insights and understandings discussed above are taken into account, and set the framework for data interpretation and analyses in Chapter 6.

To sum up, complexity theory has effectively captured the attention and imagination of researchers, bringing a new vitality to many areas of science where more traditional reductionist strategies have been relatively unhelpful. Complexity theory finds application in vastly different studies that span a variety of traditional disciplinary boundaries, such as neurosciences, meteorology, computer science, evolutionary computation, and earthquake prediction. The absence of an exact, static, and universal definition of complexity theory allows for a range of different interpretations, understandings and applications in the field of research.

An ever expanding range of applications produces its own set of challenges for researchers. To distinguish the many uses of complexity theory more clearly, Haggis (in Mason, 2008:156) refers to an overview developed by complexity theorists Richardson and Cilliers (2001), who, in this context, describe three themes or communities in literature; ‘hard, reductionist complexity science’, with its focus on ‘understanding the principles of complex systems’, ‘soft, complexity science’ which employs complexity theory or systems as a ‘metaphorical tool to understand organizations’, and ‘complexity thinking’, which considers the ‘epistemological implications of assuming the ubiquity of complexity’. The use of complexity in this research ties in with the second category, ‘soft, complexity science’, as the central focus of this research is the Cluster Project professional development model for teachers, for the purpose of understanding and evaluating its role in teacher development, and its contribution to science education more clearly.

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3.4 Activity and Complexity Theoretical Frameworks

The two frameworks, activity theory and complexity theory, with their related concepts of holism, dynamics, and interconnectedness, serve as complementary lenses through which the Cluster Project is examined with regard to the important concepts of teacher development and primary science education. In this research activity theory is used to analyse the Cluster Project with respect to its purpose, organization and function, while complexity theory is used to shed light on teacher learning and educational change, and the meaning and implications of education change for teachers and for teacher professional development.

The Cluster Project in this research is viewed as a system that interacts with other activity systems. Second and third generation activity theory models are used to identify important system components of the project model, and to reflect on the interactions of this activity system with other activity systems, such as the education district offices, schools and teachers. As entities given to dynamism, activity systems transform continuously. This process or model is applied to understanding and evaluating the Cluster Project, as well as the teachers involved with the project, and their professional development. In developing an understanding about teachers, their experiences and learning, and teacher development more clearly, reference is made to Engeström's (2001) important concepts of contradictions, expansive learning cycles, and boundary crossing.

Both activity theory and complexity theory conceptualize systems such as organizations or programmes and their environments as holistic units of analysis. Drawing on Cilliers' (2000; 2001; 2005) general framework, the analysis focuses on the Cluster Project as a system for enabling teacher development, as well as for accounting for influences from the context and their effects on processes intended to promote teacher professional development. These include the effects of curriculum change, the implications of this change for teacher's work, and the contribution of professional developers to the project. With regard to teacher learning, complexity theorists take the view that we can never predict precisely what those processes might become through interaction, emergence and self-organization. As has been described, in terms of complexity theory, teacher learning is seen in terms of dynamic, multi-dimensional, interconnected, nonlinear and unpredictable processes with regard to which there can be no absolute certainty about the outcomes of any teacher learning programme. Such complexity

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perspectives as these expand the analysis and investigation of the Cluster Project and its processes for promoting teacher professional development and primary science.

Activity theory and complexity theory are complementary, sharing a focus on "dynamically evolving social systems or collectives for understanding human knowledge and practices" (McMurtry, 2006), the interconnectedness and interdependence of constituents, the multitude of interactions amongst them, and reorganization and transformation as the outcome of activities. Though a number of parallels between the two theories can be distinguished, there are variances in their perspectives on human learning. Both theories take systems such as organizations or programmes and their environments as the holistic unit of analysis for understanding human knowledge and activities, (McMurtry, 2006). Both acknowledge that processes and outcomes of professional learning take place within a context, and agree that learning can therefore not be studied and understood in a vacuum. A critical difference between the two theories though is that activity theory considers activity systems together with issues of contradictions, conflicts and tensions as important for studying human learning and development, whereas complexity science considers all systems, relationships, movements, interactions and influences significant to human learning and knowing, (McMurtry, 2006). Relevant to this research is activity theory's view of learning which suggests that learning proceeds along a linear route towards an outcome. Rejecting an input-output view of learning, complexity argues that social behaviour, education and learning are instead emergent processes, marked by recursion, feedback, evolution, autocatalysis, openness, unpredictability, non-linearity, connectedness and self-organization (Doll, 1993).

3.5 Development of a Qualitative Analytical Framework

This section examines various teacher professional development frameworks and models for describing individual, organizational and systemic change which have been generated by other studies. The rationale for purposely selecting these studies is that important issues examined in each correspond closely with key aspects of this research. Drawing on some of the critical lessons learned from studies in this area, this research develops a separate analytical framework, contextualizing criteria for analysis to the purpose of this study, as well as accounting for realistic and relevant competencies in the light of actual teaching contexts.

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Frameworks and models reviewed for the purpose of developing a separate theoretical framework appropriate to the current study include Janse Van Rensburg and Le Roux's (1998) critical indicators of professional development, Bell and Gilbert's (1994) professional development framework, Reid's quadrants of teacher learning (in Fraser et al., 2007), Kennedy's analytical framework (2005), NCREL's Five Phases of Professional Development (1997-1999), Hackling and Prain's Primary Connections' professional learning model (2005), Clarke and Hollingsworth's Interconnected Model of professional growth (2002), and Loucks-Horsley, Hewson, Love and Stiles's Professional Development Design Framework (1998).

Each framework or model of teacher professional development is described separately, and analysis that follows informs the development of a separate set of criteria to guide the interpretation and analysis of data for this research.

3.5.1 Janse Van Rensburg and Le Roux

Studying teachers' participation in an environmental education training programme, Janse Van Rensburg and Le Roux (1998) emphasized the following as essential indications of teacher professional development: new ways of doing (skills / approaches), new understandings (content / environment), new understanding of context (school), and new networks (working with other teachers).

3.5.2 Bell and Gilbert's professional development framework

Bell and Gilbert's (1994) professional development framework (Figure 3.8) on the other hand deals with teachers developing their ideas and beliefs about teaching and learning, acknowledging their feelings about change, developing classroom practice, and collaborating with others. According to Bell and Gilbert (1994:493), teacher development should be viewed in terms of teachers learning rather than in terms of others causing teachers to change, acknowledging the critical role of teachers in their own professional development. The authors see development as a reflective inclusive process, and thus teacher learning includes purposeful inquiry where teachers enquire about or investigate aspects of their own teaching. In this way the enquiry focuses on those issues or practices that teachers are concerned about and wish to change.

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Tracking the professional development of science teachers in a three-year research project called 'The Learning in Science Project' in New Zealand, Bell and Gilbert (1994) monitored the development of science teachers as they learned new teaching activities that enabled them to consider their students' thinking and constructivist views of learning. One of the main implications of their research is the changed roles and activities of the teacher in the science classroom (Bell & Gilbert, 1994:483-484). They observed that science teachers in the project were challenged to alter their teaching, from transmitting, unmediated, a body of scientific knowledge, to helping their students develop their own (and often alternative) conceptions of, and attitudes towards, current accepted scientific concepts. Teachers were also challenged to view students' thinking differently, and to consider different ways and means of facilitating students' conceptual development, including their scientific conceptual development.

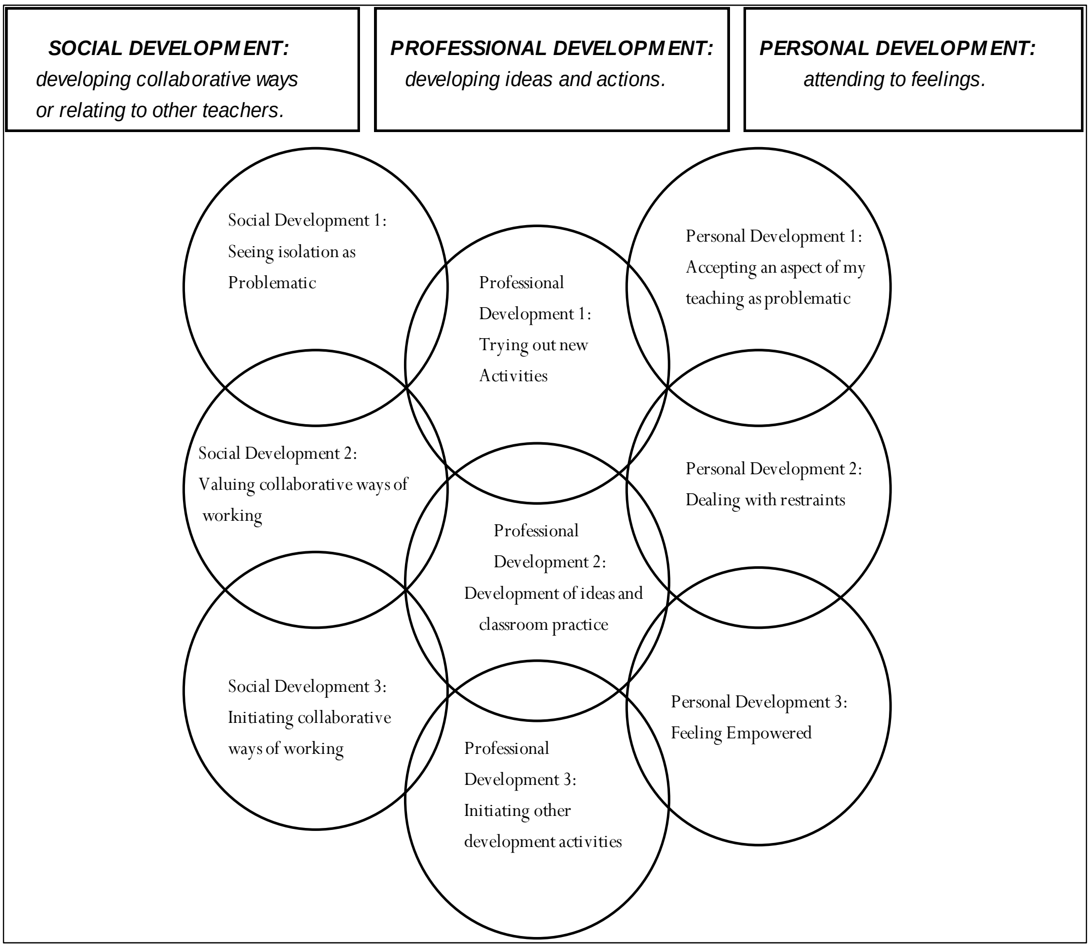

Figure 3.8: Bell and Gilbert's overview of teacher development (1994)

Bell and Gilbert (1994:48) summarized the key areas of teacher development:

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- *Personal development* which involves teachers' beliefs, values and attitudes, as well as teachers' interest and motivation, and attends to feelings about change, teaching in general, and science education.

- *Social development* which involves working with other teachers and engaging learners in new ways of learning and doing. Bell and Gilbert (1994) consider support in the context important for teachers' risk taking and new learning.

- *Professional development* which involves intellectual stimulation and professional relevance, establishing links between theory and practice, transforming concepts and beliefs about science education, and changing classroom practice.

The three aspects of personal, professional and social development are not separate discrete events; they are interactive and interdependent. A teacher's personal motivation and voluntary engagement is essential for development and for inspiring change in professional practice. The motivating effect of interest and 'ownership' of the learning opportunity means that the teacher willingly reflects critically on her or his own teaching practice and its outcomes, s/he experiments with alternative strategies, and changes his or her practice. For an individual teacher, additional personal development can either be boosted or curbed by a range of factors, internal and external to the individual. Since 'learning in isolation is seen as problematic' (Bell & Gilbert, 1994), the value of social interaction, social networking and learning from and with others within communities of practice plays an important role in the teacher's development.

Other aspects mentioned and advocated by the authors as being essential for the interrelated aspects of teacher development to occur include:

- Opportunities for differentiation should recognize prior knowledge, experience and expertise,

- Teachers' attitudes, beliefs, and values shape teachers' professional identity, and play an important part in determining self-efficacy and teacher confidence, and

- Support, feedback, and reflection should occur in a loose and flexible sequence.

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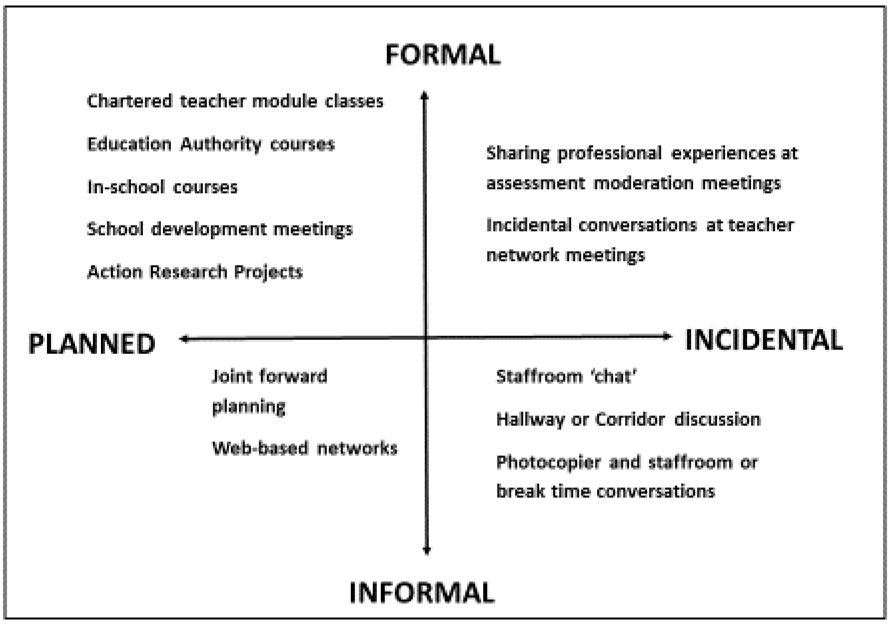
Bell and Gilbert's (1994, 2004) research and framework offer useful insights into teacher development for improving children's learning of science. They recommend that the process of science teacher development be ongoing, and include ample opportunities for experimenting with different teaching strategies, as well as reflecting on, and refining, teaching practice.

In addition, Bell and Gilbert (1996:173) advise that their professional development model should not be viewed as a recipe for improved learning and practice for teachers, since knowing what to do differently will not by itself bring about change. Further, teachers' context of work, including the wider political and social environment, and the nature of support teachers' receive, plays a defining role in how teachers are able to change and improve their teaching.

3.5.3 Reid's Quadrants of Teacher Learning

Reid's quadrants of teacher learning conceptualises the spheres of action in which teacher learning may occur. The different dimensions of formal-informal and planned-incidental learning opportunities for teachers are presented as polarized positions grouped around the intersection of two dimensions (in Fraser et al., 2007). Formal and informal learning are located at opposite ends of the vertical axis, while planned and incidental learning opportunities are positioned at opposite ends of the horizontal axis.

Figure 3. 9: Reid's quadrants of teacher learning (in Fraser et al., 2007)



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Formal learning opportunities are those usually developed and presented by external agencies, for example, formal courses presented at a university, by the education department or other independent bodies, such as non-governmental organizations. Informal learning opportunities are those which teachers seek out for themselves, for example, networking with other teachers, collaborating in communities of practice, and sharing ideas and experiences via social networks. In schools planned opportunities, which may be either formal or informal, are usually pre-arranged, for example, collaborative grade and phase planning sessions at schools. Incidental opportunities are usually spontaneous and unpredictable, for example informal teacher exchanges during the intervals in the staffroom or during corridor discussions. Reid's (in Fraser et al., 2007) framework acknowledges that there are many different approaches to, and varying opportunities for, teacher professional learning.

3.5.4 Kennedy's analytical framework

Kennedy's (2005) framework supports a comparative analysis of a spectrum of models for continuing professional development. The framework identifies nine models of development, further categorizing these in terms of their capacity for supporting professional autonomy and transformative practice.

The arrangement focuses on the perceived purpose of the model and on issues of power. Power is further described in terms of central control, individual teacher autonomy and profession-wide autonomy. The nine models are organized along a continuum according to two main criteria: the relative potential capacity for transformative practice and professional autonomy within each. Rationalizing the selection of criteria, Kennedy (2005:236) maintains that, for such conditions, teachers are required to articulate their own conceptions of teaching, and select and justify appropriate modes of practice. She adds that the circumstances in which each of the nine models of continuing professional development are adopted, and the form(s) of knowledge that can be developed through any particular model, are equally relevant for classification.

Models of continuing professional development have a specific purpose and nature. According to Kennedy (2005:236), professional development programmes are structured and organized differently for different purposes. Although a professional development experience might be considered as means of introducing or enhancing knowledge, skills and attitudes, it cannot be assumed that this is uncontested.

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Using the purposes underpinning each, Kennedy (2005) proceeds to categorize the models as either 'transmissive', 'transitional' or 'transformative' and elaborates on each category:

- 'Transmissive' models are those teacher development opportunities that are externally delivered, have a top-down unidirectional nature, are presented by 'experts' in the field, and focus mainly on technical aspects rather than on issues relating to values, beliefs and attitudes. This type of continuing professional development does not usually support professional autonomy, instead favouring replication, perhaps tending towards facilitating compliance. Continuing professional development models located in this category include the training, award-bearing, deficit and cascade models.

- 'Transitional' model: the continuing professional development supports either a transmissive agenda or a transformative agenda, depending on its form and philosophy. Types of models in this category include communities of practice and those models featuring elements of coaching and/or mentoring.

- 'Transformative' model: professional learning connects theory and practice, and encourages an internalization of concepts, reflection, construction of new knowledge and its application in different situations, and an awareness of the professional and political context. Models of continuing professional development located in this category have the capacity to support considerable professional autonomy at both individual and profession-wide levels.

The categorization and organization of continuing professional development models as presented by Kennedy (2005) in Table 3.2 suggests an increase in teacher autonomy as one moves from the transmission, through transitional, to the transformative categories.

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Table 3.2: Kennedy's nine models organized into three broad categories.

Model of Continuing Professional Development (CPD)	Purpose of model
The training model The award-bearing model The deficit model The cascade model	Transmission
The standards-based model The coaching/mentoring model The community of practice model	Transitional
The action research model The transformative model	Transformative

Increasing capacity for professional autonomy

While the capacity for professional autonomy is greater in transformative models, Kennedy (2005:248) cautions that this does not in any way suggest that professional capacity will necessarily be fulfilled at the same time. Nevertheless, the framework can assist with an analysis of continuing professional development in terms of:

- Issues of purpose and power within structures
- The manner in which continuing professional development for teachers is organized. This highlights the motivation for such structures on the part of both external agents and teachers themselves, and the nature of professional knowledge and professionalism.
- The various contexts in which professional knowledge is acquired and applied, be it in an academic context, an institutional discussion of policy or practice in the classroom (Eraut, 1994:20); all of these contexts are equally important considerations when reviewing programmes for teacher development.

Kennedy's (2005) model is useful for organizing and analysing models of teacher development with regard to clarifying their purpose, form, and the power dynamics inherent in each.

Applying Kennedy's (2005) categorization to the eight teacher professional development models described in Chapter 2, the to date widely used traditional and cascade models, with reduced professional autonomy, are situated in the transmissive category; the site-based and cluster models, with elements of coaching and mentoring, are transitional, and the self-directed,

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resource-based and teacher-leader models, with a greater degree of professional autonomy, are located in the transformative category.

3.5.5 NCREL's Five Phases of Professional Development

The North Central Regional Educational Laboratory (NCREL) (1997-1999), a US Department of Education teacher development initiative, distinguishes five phases of teacher professional development within a framework. The research-based framework was designed to promote ongoing professional development, individual reflection and group inquiry into teachers' practice. The NCREL (1997-1999) interprets professional growth in terms of five developmental and cyclical dimensions. These five dimensions of professional development include building a knowledge base, observing models and examples, reflecting on own practice, changing own practice and gaining and sharing expertise. These dimensions, or phases, and their non-linear, cyclical relationship, are represented in Figure 3.10 and each is explained in the following paragraph.

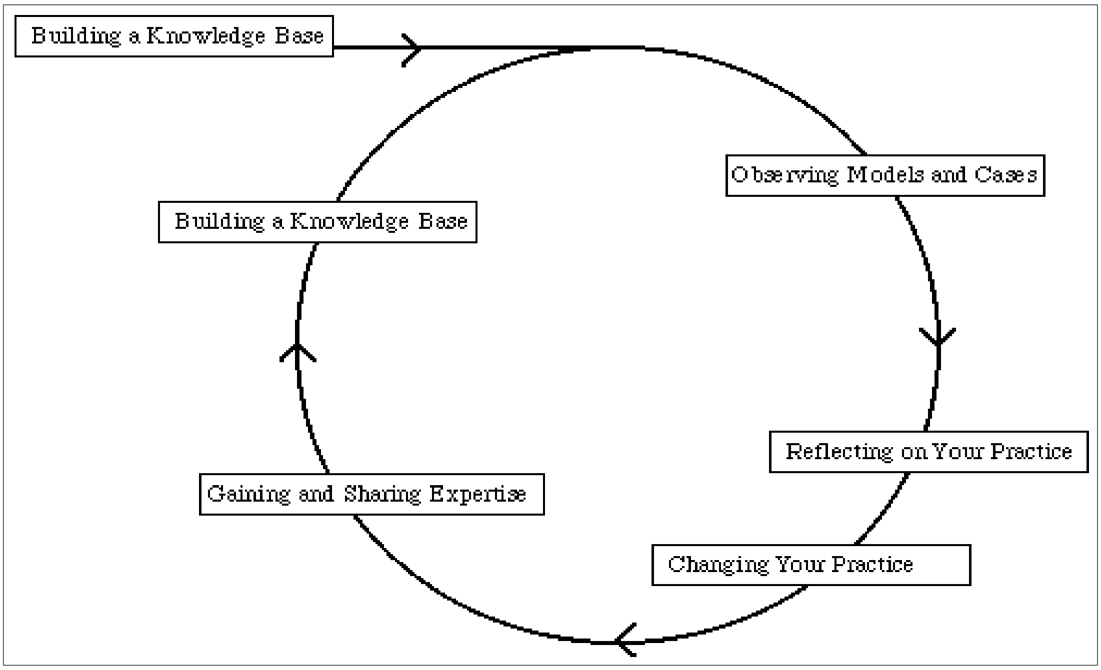

Figure 3.10: NCREL's Five Phases of Professional Development

- Building a Knowledge Base. The purpose of this phase is to acquire new knowledge, skills, and information in order to support and promote conceptual development and understanding. This phase might include activities such as goal setting, assessing needs,

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participating in interactive workshops, and the establishment of study and collaborative groups.

- Observing Models and Examples. This phase focuses on the study of different instructional examples in order to encourage a practical understanding of research and principles. Activities in this phase can include school and classroom visits, peer observation, using instructional artifacts, co-planning, and listening to or watching audio and video examples of best practice.

- Reflecting on Your Practice. The purpose of this phase is to analyse instructional practice on the basis of new knowledge, and to transform theoretical and practical knowledge into plans for instructional change. Activities in this phase might include the use of journals or teacher-authored cases for collegial discussion and reflection.

- Changing Your Practice. The purpose of this phase is to translate new knowledge into individual and collaborative plans and actions for curricular and instructional change, and to reflect individually or collaboratively and revise these if necessary. Activities in this phase might include action research, peer-coaching, support groups, and curriculum development.

- Gaining and Sharing Expertise. The purpose of this phase is to continue to refine instructional practice, learning with and from colleagues, while also sharing practical knowledge, understanding and experience with peers. Activities in this phase might include team planning, mentoring or partnering with a colleague, and participating in a network.

NCREL's five phases of professional development model usefully describes a series of interrelated activities teachers can engage in towards improving professionally. The five phases do not occur separately or sequentially, but are said to overlap and/or repeat, and certain phases can also occur at the same time. For successful professional development processes, Hassel (1999:9) advises strong content and effective processes as a sound basis for making initial and ongoing decisions. Hassel (1999) further recommends that professional development content, process, and activities all work together to achieve the goals of development.

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3.5.6 The Primary Connections' professional learning model

Primary Connections, illustrated in Figure 3.11, is a professional learning programme for teachers consisting of professional learning workshops, curriculum resources, opportunities for practising science teaching supported with resources, and reflections on practice linked with exploring principles of teaching and learning.

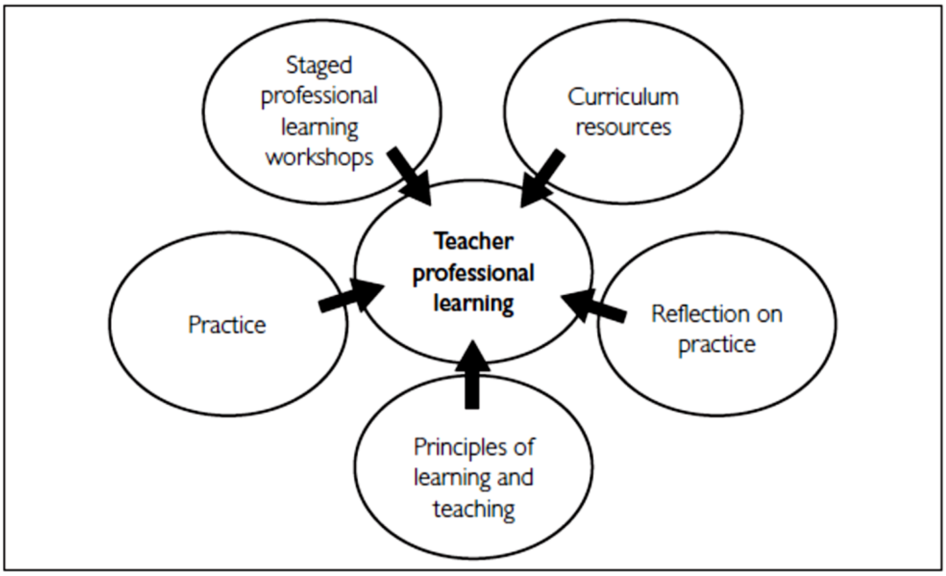

Figure 3.11: Hackling and Prain's Primary Connections professional learning model (2005:31)

Trialled in 56 schools throughout Australia in 2005, Primary Connections aimed to enhance learning outcomes for primary students in science and literacy through teacher professional development. The programme focused on improving teachers' confidence and competence for teaching science by developing their science pedagogical and content knowledge.

Primary Connections features a teaching and learning model based on the inquiry and investigative approach that allows learners to pose questions, undertake investigations, and develop explanations. The model in Figure 3.11, adapted from the 5Es inquiry model, is consistent with constructivist learning theory, which proposes that children actively construct knowledge and make meaning from their personal experiences. Hackling (2006:75) sees rich curriculum resources developed within the framework of the teaching and learning model as accompanying quality professional learning opportunities for teachers, for enhanced science

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learning outcomes and science literacies. The instructions guide teachers' interactions with children.

Table 3.3: The Primary Connections teaching and learning model (Hackling, 2006:75)

Phase	Focus
Engage	Engage students and elicit prior knowledge Diagnostic Assessment
Explore	Provide hands-on experience of the phenomenon
Explain	Develop science explanation of the experiences and presentations of developing understanding Formative Assessment
Elaborate	Extend understandings to a new context or make connections to additional concepts through student-planned investigations Summative Assessment of the investigating outcome
Evaluate	Re-represent understandings, reflect on learning journey and collect evidence about achievement of conceptual outcomes Summative Assessment of conceptual outcomes

Amending the 5Es pedagogical model, Primary Connections has integrated science learning strongly with:

- Literacy. By doing this Primary Connections acknowledges the importance of equipping children with science-specific and general literacies that allow them to engage with science phenomena, construct science understandings, develop science processes, and communicate ideas and information about science (Hackling, 2006:75),
- Assessment. According to Hackling (2006:75), the Primary Connections teaching and learning model embeds diagnostic, formative and summative assessment to connect lessons with students' prior knowledge and to monitor learning, and
- Co-operative learning was incorporated for a range of purposes. In this process teachers are encouraged to organize students into small interactive groups for projects, problems, tests, discussion, and for analysing case studies.

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Hackling and Prain (2005) report that Primary Connections for teacher development, with its 5E learning cycle and embedded enhancements, has made a substantial and positive impact on teachers' practice, students' learning, and the status of science in schools where it has been utilised.

Hackling (2006:78), in analysing data on the programme, noted strong indications that a combination of professional learning that involves teachers building their science pedagogical content knowledge, and being supported in their teaching with curriculum resources, enhances teachers' confidence and self-efficacy. Further, as a consequence of increased confidence and self-efficacy, and using the curriculum resources, teachers increased the amount of time they spent teaching science and thereby increased students' opportunities for learning science, which resulted in strong science achievement gains.

3.5.7 Clarke and Hollingsworth's Interconnected Model of professional growth

Four analytic domains are key features of Clarke and Hollingsworth's (2002) Interconnected Model (Figure 3.13). According to Clarke and Hollingsworth (2002:947), their model, adapted from those generated by others such as Guskey (1986:7) (Figure 3.12), is non-linear, recognizes professional growth as an inevitable and continuous process of learning, and identifies specific mechanisms by which change in one domain is associated with change in another. The interconnected, non-linear model identifies particular 'change sequences' and 'growth networks', giving recognition to the idiosyncratic and individual nature of teacher professional development (Clarke & Hollingsworth, 2002:947).

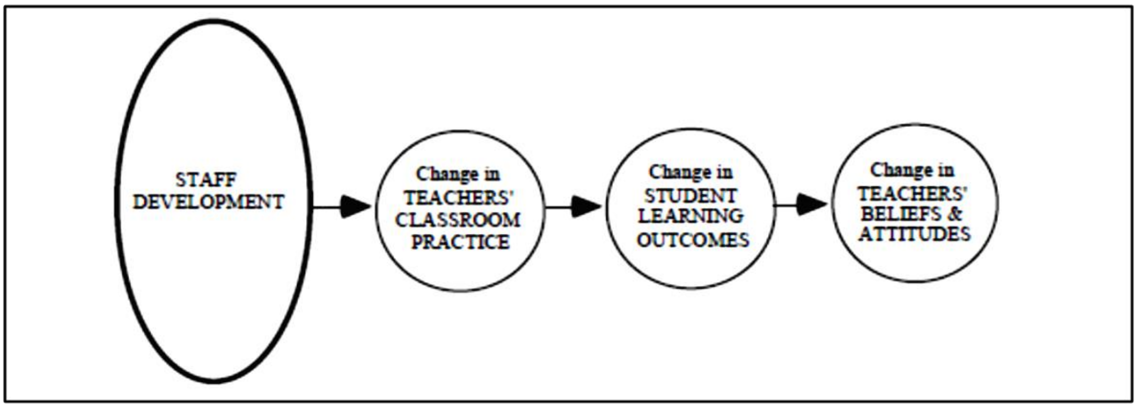

Figure 3.12: Guskey's model of the process of teacher change (Guskey, 1986:7)

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Clarke and Hollingsworth's Interconnected Model (2002:950) suggests that change in teachers and their practices occurs through 'reflection' and 'enactment' in four domains spanning the teacher's world: the personal domain (teacher knowledge, beliefs and attitudes), the domain of practice (professional experimentation), the domain of consequence (salient outcomes), and the external domain (sources of information, stimulus and/or support). Acknowledging the complexity of professional growth, the model identifies multiple growth pathways between domains. The external domain is the source of information and stimulus, and is located outside the teacher's personal world. The three domains of practice, personal and consequence constitute the teacher's professional world of practice. The domain of practice refers to all forms of professional experimentation, which are not confined to teaching practice in the classroom. Explaining 'change' experienced in all the domains, Clarke and Hollingsworth (2002:951) describe how experimentation with new teaching strategies resides in the domain of practice, new knowledge or a new belief resides in the personal domain, and a changed perception of salient outcomes related to classroom practice resides in the domain of consequence. Clarke and Hollingsworth (2002:965) conclude their study with recommendations that teachers be afforded ample opportunities to learn in ways that they find useful, and that their learning should not be constrained by prescriptive, predictable linear processes.

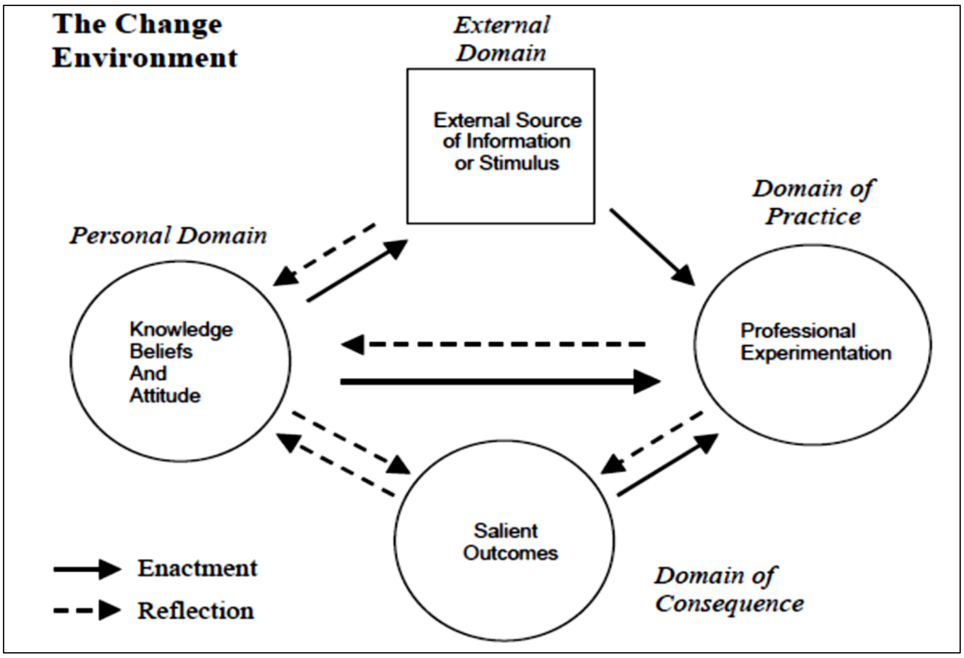

Figure 3.13: Clark and Hollingsworth's interconnected model of professional growth (2002: 951)

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3.5.8 The Professional Development Design Framework

As this chapter has shown, teacher learning and professional development is not a simple or straightforward process. In the late 1990s Mundry and Loucks-Horsley (1999:1) showed the process to be complex, necessitating continual reflection and adjustments, and requiring much more than a ‘plan and implement’ strategy. At the time they were advocating that programmes aiming to build substantial science and mathematics content knowledge and change and improve teaching should take into account a multitude of factors, such as the changing context of work of teachers and professional developers, the stages of development teachers’ move through as they acquire new knowledge and skills, and a host of other interrelated and constantly changing dynamics.

The Professional Development Design Framework is not a ‘model’ to be implemented, but was intended as a guide to inform the work of professional developers (Loucks-Horsley et al., 1998:15-16). Situated centrally in the framework in Figure 3.14 is the generic planning sequence, incorporating goal setting, planning, doing, and reflecting. Surrounding this plan are the important inputs of context, critical issues, knowledge and beliefs, and strategies that professional developers need to consider when planning a programme. Reflection can affect every input, with new designs emerging from reflective processes. Feedback loops emphasize the continuous and circular design of implementing professional development programmes. Continuous reflection on the outcomes of the programme promotes constant re-evaluation and further improvement. Multiple feedback loops from the ‘reflect’ stage are intended to show how programme development evolves as practitioners learn from their experiences and adapt processes.

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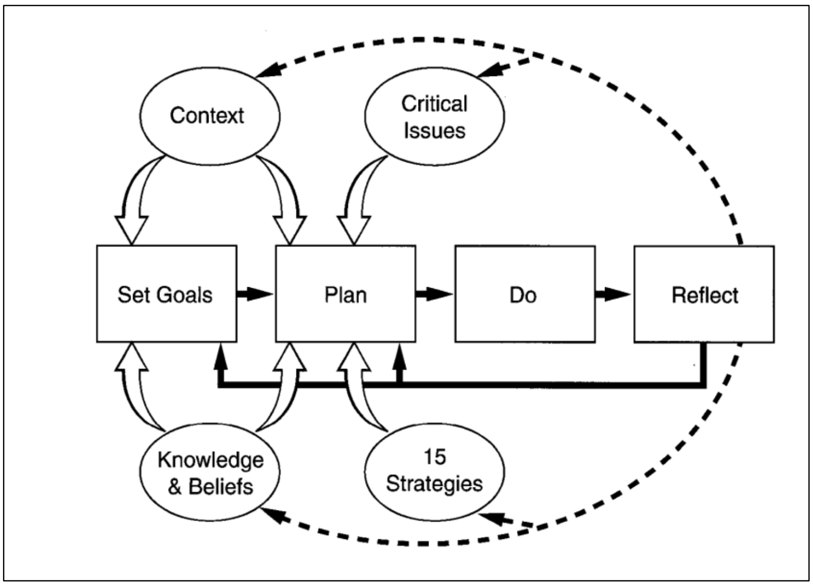

Figure 3.14: Loucks-Horsley, Hewson, Love and Stiles's Professional Development Design Framework (1998:17).

Loucks-Horsley et al. (1998) proposed that professional developers consider the broad knowledge bases that inform their work, understand the distinctive qualities of the context of their work, draw on a wide range of professional development strategies, and engage the critical issues that mathematics and science reformers in general encounter, irrespective of the context in which they work. They further recommended that the framework be used to surface key decision points and dilemmas that emerge in the course of teacher learning, and in so doing, their understanding of the tensions professional development designers struggle with as they form and provide learning opportunities for teachers. Attaching a disclaimer to the design framework, Loucks-Horsley et al. (1998:24) cautioned that it may not be perfect as it has the potential to create artificial distinctions among such components as critical issues and context, and that it may miss valuable feedback loops and other connections. Yet, they and other professional developers saw, and continue to see, it as offering a simplified view of an enormously complex process, and alerting planners to important aspects to give attention to and the obstacles to avoid.

The Professional Development Design Framework is appropriate for this section of this chapter dealing with critical indications of teacher development. The framework is significant considering the important role of professional developers and their goals, perspectives, knowledge, context of work and methods as they develop learning opportunities for teachers.

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I argue that any examination of the influence of a development programme on teachers' knowledge and skills would be incomplete without consideration for the views, objectives, decisions and strategies of professional developers. The framework's list of considerations also includes important aspects to take into consideration, such as the expectations of programme developers, the nature of their relationships with teachers, teacher involvement in processes such as topic selection, and monitoring and evaluation of teacher learning and growth. Of importance are the indications of what learning and development programme developers consider important for determining the success of processes, and the degree to which the objectives and expectations of programme developers match the expectations of the teachers involved and the learning outcomes achieved.

3.6 Qualitative Analytical Framework

From the above it is clear that teacher learning and professional development is understood differently by different researchers, as demonstrated by the various interpretations and models, each with its own emphasis. With the exception of Janse Van Rensburg and Le Roux (1998), who provide the only set of critical indicators for observing and analysing teacher professional development, the frameworks or models for the most part limit their descriptions to the processes of development, domains of influence or spheres of action for teacher learning and development, what it entails and what teachers and others ought to know and do to promote teacher learning and change.

The four-point summary developed by Janse Van Rensburg and Le Roux (1998) describes teacher development in terms of improvements in teachers' knowledge and practice with their use of the word 'new'. Although the guiding summary omits mention of important aspects, such as teachers' previous knowledge and experience, a clear definition and understanding of development, beliefs about teaching and learning, agency, and feelings about change, it offers a useful basis for developing a separate set of criteria for describing teacher professional development.

Distinguishing three domains of influence where teacher action, reflection and change occur, Bell and Gilbert (1994:494) also emphasize the importance of including in teacher development programmes new/up-to-date theoretical ideas and new teaching suggestions for professional learning and change to happen. They argue that teachers improve their teaching

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practice through experimenting with new ideas, evaluating and practising new theory and teaching ideas over an extended period of time in a collaborative situation, where they are able to receive support and feedback, and where they are able to reflect critically on their own development and professional practice.

Clarke and Hollingsworth's Interconnected Model (2002) likewise identifies analytical domains of teacher development, specifying reflection and action as essential processes for teacher change. The inclusion of consequence as a fourth domain acknowledges the important connection between improvements in teachers' professional abilities and children's learning. Equally important is the recognition that teacher learning is not a straightforward sequential process, but is a complex non-linear process in view of the fact that individual teacher's professional growth needs and teaching contexts differ. Multiple growth pathways between various growth domains accommodate diversity amongst teachers. Observing an innovative trend, Clarke and Hollingsworth (2002:948-949) note greater recognition on the part of researchers and designers of professional development programmes for teacher agency in professional development. With schools developing into 'learning communities', teachers are increasingly viewed more as 'learners' actively involved in owning and shaping their own professional growth through reflective participation in professional development, and in practice.

Reid's (Fraser et al.: 2007) framework usefully identifies and describes the nature of the wide range of learning opportunities for teachers. The design also focuses on the teachers and their perceptions of their needs, emphasizing teacher behaviour rather than the delivery style of continuous professional development opportunities. The framework can serve as a useful tool for determining the type of professional development pathways teachers frequently make use of, and the learning opportunities teachers themselves regard as worthwhile for changing and improving professionally.

Kennedy's (2005) model establishes a critical link between professional autonomy and transformative professional development. According to Kennedy (2005:236), professional development opportunities are structured and organized differently for different purposes, and, although professional development experiences might be considered as a means of introducing or enhancing knowledge, skills and attitudes, it cannot be assumed that this process will automatically happen. For this reason Kennedy (2005:236) encourages a thorough

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interrogation of professional development models with regard to their purposes, structure, circumstances and inherent power dynamics for a better understanding of the motivation for the structuring of these programmes, as well as the nature of knowledge and teacher professionalism the models promote. Reviewing Kennedy and Reid's (2011) relatively recent contributions to the field of teacher development, Reddy (2011: 14) suggests a mix of transmission and transformative opportunities for learning, and suggests that combinations of formal as well as incidental and informal opportunities would have a strong and positive influence on teacher learning. This suggestion points to the need for less rigid and more open processes for teacher learning.

NCREL's Five Phases of Professional Development five developmental and cyclical dimensions have already been described (see 3.5.5 above), its phases consistent with processes observed in Hackling and Prain's (2005) Primary Connections professional learning model, which also emphasizes building teachers' science pedagogical content knowledge and providing support for practice to enhance teachers' confidence and self-efficacy, in turn contributing to improvements in classroom practice and students' learning. The Cluster Project model incorporates the NCREL's Five Phases of Professional Development, and also features key elements of Hackling and Prain's (2005) Primary Connections professional learning model in its design.

Separated from the frames and models above is Loucks-Horsley's et al. (1998) framework with its focus on the role of professional developers and their goals, knowledge and methods as they develop learning opportunities for teachers. Of importance for the current study are the professional developers' objectives and expectations of a programme, processes to monitor changes in teachers' knowledge and practice, measurement of learning, and reflection on outcomes of processes. According to this model, already during the planning phase, developers of professional development programmes identify critical indicators to formally define those aspects of teachers' knowledge, actions or behaviour that should be evident as outcomes at the level of teacher, classroom or school as a programme concludes.

To arrive at this set of criteria or outcomes, professional developers apply themselves to questions such as: How would we know/what will indicate whether the programme has been successful or not? What would we expect to see at the end of this process? How could we determine whether participants' newly acquired knowledge and skills have actually influenced

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and improved their practice? Which specific actions or behaviours could be said to demonstrate the participants' effective use of new knowledge and strategies? Answers to such questions require a thorough understanding on the part of both the professional developers and the participants of the new ideas and inputs, together with thoughtful reflection, leading to the development of appropriate, agreed-upon, and relevant indicators for determining the effectiveness of programmes.

Accordingly, for the evaluation of the Cluster Project 2007 – 2009 conducted by an outside evaluator, Angela Schaffer (2009), the impact of the project with regard to participating teachers and schools was defined by the professional developers in terms of two broad indicators. The Cluster Project 2007 – 2009 proposed to improve:

- Teachers' knowledge and understanding of the scope and content of the Natural Sciences curriculum, and
- Teachers' and Natural Sciences teams' ability to plan the teaching and assessment of the curriculum in both an educationally effective and officially acceptable manner.

In line with the broad objectives of the project, the research brief given to the evaluator specified that she focus on the following specific criteria in her assessment:

- Teachers' attitudes to teaching Natural Sciences, Natural Sciences Planning, and Natural Sciences Assessment.
- Teachers' understanding of the Learning Outcomes required by the National Curriculum (the National Curriculum Statement (NCS) at the time of the research) , teachers' basic knowledge, teachers' scientific knowledge, teachers' knowledge of application of scientific knowledge, and teachers' knowledge of curriculum content across all four Natural Sciences strands of Life & Living, Matter & Materials, Energy & Change, and Planet Earth & Beyond.
- Teachers' individual planning, school phase and assessment plans.
- How teachers' are able to access to, and use, Natural Sciences and other resources.
- Schools' coverage of the curriculum.

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The set of criteria developed for the programme mainly concerns changes or shifts in teachers' attitudes in relation to teaching Natural Sciences, and improvements in teachers' Natural Sciences knowledge, planning and assessment, and collaboration at schools. Although the elements focused on are essential in any evaluation of a teacher development programme, the most critical components that deal with improvements in Natural Sciences classroom teaching and children's learning of Science appear glaringly absent in this evaluation. Since *teaching is* ultimately concerned with children's learning, the importance and evaluation of children's learning cannot be disregarded in an evaluation of a teacher development programme.

This thesis argues that the goal of improving teaching practices in order to improve children's learning lies at the heart of any teacher development programme. Thus the omission of these two critical aspects, teaching practices and children's learning of science, from the impact evaluation of the Cluster Project 2007 – 2009 conducted by the independent evaluator, in terms of Guskey's (1986) explanation renders the evaluation incomplete.

3.7 Qualitative Indicators of Teacher Professional Development for Primary Science Education

Drawing on the lessons of the spectrum of frameworks and models described and analysed above, the broad and specific criteria used for the impact evaluation of the 2007 – 2009 Cluster Project, as well as a set of performance indicators developed by Barge (2012), this research develops a separate analytical framework consisting of five key focus areas for analysing the professional development of primary science teachers in the 2007 – 2009 Cluster Project:

1. Professional autonomy
2. Professional knowledge
3. Professional practice
4. Professional collaboration
5. Continuing professional development.

The word 'professional' is purposefully connected to each focus area, emphasizing the important relationship between each component of autonomy, knowledge, practice, collaboration and continuing development, together with the professional activity of teaching. The criteria are expanded and explained in Table 3.4 below, on page 139:

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3.7.1 Professional autonomy

Professional autonomy refers to the independence of professionals such as teachers as they make independent decisions, exercise their professional judgement, and carry out work activities free of external supervision. During the course of their work teachers make autonomous decisions in a range of work situations, such as when they decide on the content, teaching methods, and resources for lessons, and design assessments to track and record children's progress.

However, for a teacher, there is more to teacher professional autonomy than simply making independent curricular and classroom decisions. Referring to a variety of different earlier applications, Smith (2003:3) shows that various education researchers have used the term in different contexts for different purposes, assigning different meanings and understandings to the term 'teacher autonomy' to refer to:

- (Capacity for) self-directed professional action, or
- (Capacity for) self-directed professional development, or
- Freedom from control by others over professional action or development (Smith, 2003:3).

Adding to the above dimensions of teacher professional autonomy, Smith (2003:4) strongly recommends noting that:

- Professional development could be considered as one form of professional action, but action and development are not necessarily the same thing (we may act (e.g. teach) in a self-directed manner, but do not necessarily learn from the experience);
- Allowance needs to be made for a distinction between *capacity for* and/or willingness to engage in self-direction and actual self-directed *behaviour*, and
- The term 'teacher autonomy' may be employed by different writers for one or more of the dimensions mentioned.

For the sake of clarity, Smith (2003:3) further advises that researchers communicate clearly which dimension/s they are referring to in their discussions, in order to avoid the danger of

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appearing to be talking about the same thing when in fact they are intending a different meaning. In the context of this research the term 'professional autonomy' is used broadly, and includes the three dimensions of 'professional action', 'professional development' and 'freedom from control' as described above.

While the policies and regulations of any profession impose limits on the extent of professional autonomy the profession allows, some researchers criticizing the poor quality of teaching and learning in the education system argue that teachers' professional autonomy appears more limited than that of other professions (Nash, Jones, Ecclestone & Brown, 2008:5) if one takes into account the regulated environment in which many teachers work. Some of the regulations referred to include implementing a prescribed centralized curriculum, maintaining specific sets of documents, and administering national or provincial assessments as prescribed (Naylor, 2011:2). Reduced teacher professional autonomy can have a number of negative consequences, such as poor learner performances, decreased job satisfaction, and higher attrition rates among teachers (Pearson & Moomaw, 2005:48). Rigidly applied regulations, increased administrative tasks, and time-consuming teacher evaluations reduce teacher professional autonomy considerably, and at the same time present fewer opportunities for teachers to exercise their professional judgement more fully, or to incorporate their creativity and innovation into their work.

Support for greater teacher professional autonomy is growing, and Melenyzer and Short (in Pearson & Moomaw, 2005:38) note that teacher professional autonomy appears to be emerging as a critical variable when examining educational reform initiatives, with some researchers arguing that granting teachers greater autonomy and empowering them is an appropriate place to begin in solving the problems in today's schools. This involves moving teachers beyond being mere technicians, restricted to implementing only what others consider important. Proponents of greater teacher professional autonomy argue that teachers know their learners and are therefore better placed to make informed decisions about the content and strategies they use in the classroom.

Teacher professional autonomy, together with some aspects of a rigidly regulated work environment and its effects on the professional autonomy of teachers involved with the 2007 – 2009 Cluster Project are discussed later in Chapter 5.

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3.7.2 Professional knowledge

Teachers draw on a body of professional knowledge as they respond to the learning needs of children in their contexts. Within professional knowledge Shulman (1987:7) distinguishes several domains of knowledge:

- Knowledge of content: 'deep' knowledge of the subject,
- General pedagogical knowledge: broad principles and strategies of classroom management and organization,
- Knowledge of the curriculum includes the materials and programs that serve as 'tools of the trade' for teachers,
- Pedagogical content knowledge: an amalgam of content and pedagogical knowledge,
- Knowledge of learners and their characteristics: a diversity of aptitudes and interests,
- Knowledge of education contexts includes an awareness of communities and cultures, knowledge of educational ends, purposes and values, and their philosophical and historical grounds.

From among these categories of knowledge, Shulman (1987:7) emphasizes pedagogical content knowledge as the distinctive bodies of knowledge for and about teaching, as representing the blend of content and pedagogy into an understanding of how particular topics, problems, or issues are organized and adapted to diverse children's interests and abilities. Professional knowledge requires that teachers, for the purposes of improving learning, merge subject matter knowledge, pedagogical knowledge, and an understanding of children and their learning processes. No one of these aspects is more important than any of the others, since together they affect the quality of teachers' lesson presentations and learning outcomes.

This research reflects on the various forms of professional knowledge and their development in the 2007 – 2009 Cluster Project.

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Context Awareness

Education and teaching are contextually situated, located within macro and micro level political, social, economic and cultural contexts. Besides the broader context, the school and the community surrounding it, represent separate contexts; the classroom is another locale, and learners and teachers have other social and learning contexts beyond formal school structures, such as their families and support networks, peer groups, extra-mural groups, religious groups, the wider society, and other institutions of learning. The challenge for education and teachers is presented by the fact that, as has been mentioned, the broader and local contexts, and their various facets, do not remain static, but change continually over time.

Teachers regularly work in diverse contexts in which they apply their knowledge and expertise in a professional autonomous manner, whether in the classroom or on the sports field. Understanding teachers' work requires a comprehensive understanding of their contexts of work. Citing three important aspects of the context to consider when evaluating teachers and their work, Fullan and Hargreaves (1991:32-33) mention the need to acknowledge the varying contexts in which they work, their realities and practicalities, and the particular contextual characteristics of class size, time, and curriculum which together set boundaries and constraints in terms of what teachers can or cannot do, and around realistic possibilities for innovation. These aspects significantly influence the kinds of teaching most likely to be taking place in classrooms, and the kinds of improvement targets that can be reasonably set (Fullan & Hargreaves, 1991:32-35). Thus, disregarding the context of teaching and its influences in an evaluation may yield an incomplete and distorted view of events in the classroom and of the teacher's work.

It is important that teachers themselves are also context aware as they construct their lessons for children, that they develop their understanding of the different aspects of the context, the influences that arise from it, as well as the changes that occur in it. Together with learner characteristics, context is frequently cited as one of the first variables to be considered when designing learning experiences (Ramsden in Benson & Samarawickrema, 2007:61). Referring to the social theory perspective, Benson and Samarawickrema (2007:62) maintain that, at the child's personal level, issues related to race, ethnicity, gender and sexual orientation, social and educational background, money, power, work or age, also form part of the context of learning. Greater teacher context awareness, and an understanding of links between the school, home

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and community enables teachers to develop adaptive, responsive, relevant and situated learning opportunities for children.

Given that impacts from the context can either support or constrain teachers' work, this research considers the school, teacher and learner contexts and their influences on the professional development of the teachers involved with the 2007 – 2009 Cluster Project, as well as teachers' contextual awareness and how they are able to adapt science teaching and learning to the particular living and family circumstances of the learners.

3.7.3 Professional practice

The complex domain of professional teaching practice combines professional knowledge, experience, and expertise to support children's learning. Within this domain, teachers respond to the learning needs of individuals and learning communities by creating and maintaining safe, inclusive and challenging learning environments in which they engage multiple tasks and goals simultaneously, and by being flexible as they implement curricula, learning programmes and lessons using appropriate pedagogy, assessment and evaluation strategies for monitoring progress and giving feedback, and using quality resources and technology.

Professional practice is an aspect of professional development which frequently not given enough attention in evaluations of professional development programmes. In their research in the early 1990s, Guskey and Sparks (1991) noted the usual focus in evaluations to be participant's satisfaction with the programme, or some indication of change in their professional knowledge, but that change in professional practice was rarely being considered, and rarer still was assessment of the impact of these programmes on student's learning. Wenglinsky (2002:1-2) agrees that teachers' practice is a dimension of schooling often neglected, especially in quantitative research; it is often treated as the 'black box', or not studied at all, and when it is, only the characteristics of teachers that are easily measured, but far removed from the classroom, such as the level of education attainment, are contemplated. He further notes that the quality of teachers' classroom practices has a marked effect on student achievement, and, together with other aspects of teaching, this effect is as strong in its impact on student achievement as is a student's social background. Supporting this observation, Hightower, Delgado, Llyod, Wittenstein, Sellers and Swanson (2011:5) find that the quality of teaching in practice has the largest in-school impact on students' learning outcomes. Research

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consistently emphasizes the significance of teaching quality, strongly advocating that special attention be given to teachers' practice, the actions and activities in which teachers engage every day to promote learning in their particular contexts.

This research pays close attention to teachers' classroom practice, using observation schedules, teacher interviews, and PSP facilitator reports, applying a range of criteria for tracking changes in teaching practice that can be attributed to teachers' involvement in the 2007 – 2009 Cluster Project.

3.7.4 Professional collaboration

Professional collaborations reduce the isolation of teachers and provide a supportive environment for professional learning. Working in isolation can have a limiting influence on learning. Fullan and Hargreaves (1991:38) note a ceiling effect in terms of just how much we can learn about our practice if we keep to ourselves. Collegiality and collaboration among teachers is part and parcel of sustained improvement in schools (Fullan & Hargreaves, 1991:6). Linking up with both local and larger professional learning communities can contribute to a teacher's professional growth since the supportive learning environment affords teachers the opportunity to share knowledge and experience, engage in professional discourse, and together teachers can develop workable solutions to common challenges and concerns.

Strong and viable forms of teacher collaborations and collegiality have several crucial benefits for both teachers and schools. Describing some of these, Fullan and Hargreaves (1991:45) refer to research done in the late 1980s by Rosenholtz (1989) which identified the most important contribution of teacher collaboration as being the reduction of uncertainty around the job. This was identified as a factor undermining teachers' confidence, and research done in the mid-1980s by Ashton and Webb (1986), which determined that working collaboratively with others reduces teachers' sense of powerlessness and increases their sense of efficacy. For meaningful collaboration, Fullan and Hargreaves (1991:101) advocate that schools and teachers engage substantial and ongoing issues pertaining to matters such as curriculum and instruction.

Teacher and school collaborations take place within the context of the 2007 – 2009 Cluster Project. The manner in which these happen, and their contribution to teachers' professional development, are examined in Chapter 5.

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3.7.5 Continuing professional development

Ongoing professional development helps teachers keep abreast of change in education, change which may be massive, as has been the case in South Africa over the last two decades, and affect an entire system, as is the case when national curricula are renewed and reorganized. Change may occur on a much smaller scale, such as when new materials are presented by publishers, as innovative teaching and learning theories are introduced, and the latest research on how children learn is made known to education departments and to teachers, and as new technologies to promote learning become available.

As key agents of change in education, it is important for teachers to remain reflective, self-directed lifelong learners who engage ongoing processes of learning with the purpose of developing, updating, and improving their knowledge and skills. Though often difficult and challenging, especially in the face of overload, limited time, and other external pressures, Fullan and Hargreaves (1991: 8,65) advise that it is essential that, for teachers, development and change be grounded in some inner reflection and processing, so that teachers have the space and opportunity to connect learning with their innermost needs and feelings. Just as professional collaboration means different things to different people, so does reflective practice, which also has weak and strong forms (Fullan & Hargreaves, 1991:67). For strong forms of reflective practice, Fullan and Hargreaves (1991:68) suggest teachers expand the field of data they reflect on beyond their own personal impressions and students' test scores, deepen and extend their reflections through collaborations with colleagues, and reflect critically on the purposes and principles that underpin their classroom judgement and actions.

Teachers' reflective practice and involvement in professional development processes within the context of the 2007 – 2009 Cluster Project are reviewed in this research.

Table 3.4 below presents a summary expanding on the five focus areas of professional autonomy, professional knowledge, professional practice, professional collaboration, and continuing professional development, detailing the specific criteria employed by this research for interpreting and analysing teacher professional development with respect to the 2007 – 2009 Cluster Project.

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Table 3.4: Five indicators of teacher professional development in the Cluster Project

Five key indicators	**Clarification**	**Criteria guiding interpretation and analysis of teacher professional development within the 2007 – 2009 Cluster Project:**
1. Professional autonomy	*The teacher demonstrates agency and 'ownership' of learning and development for primary science education.*	• The teacher: – Participates voluntarily and actively in all processes of the 2007 – 2009 Cluster Project – Is involved in decision-making – Implements new / alternate strategies / approaches – Reflects on and improves classroom practice – Engages in further formal or informal learning opportunities – Engages in opportunities for sharing professional knowledge, expertise and experience
2. Professional knowledge	*The teacher develops knowledge and understanding of the science curriculum and content, the pedagogy for science and the needs of learners.*	• The teacher develops and improves: – Subject-matter knowledge (Content to teach) – Pedagogical knowledge (How to teach) – Curricular knowledge (What to teach) – Learner knowledge (Whom to teach) – Knowledge of assessment for learning and of learning (Monitors learning) – Cultural / Community knowledge (is sensitive to context issues) – Learning experiences to support children's learning of science (constructing age-appropriate learning opportunities) – Knowledge and ability to extend children's science learning experiences
	The teacher develops context awareness, and develops knowledge and understanding of the	• The teacher adapts science teaching and learning to: – The needs of the school and its context

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	broader context of education, the challenges for science learning, and relating learning of science content to real-world experiences.	– Diverse learners' needs • The teacher relates science learning to everyday living • The teacher demonstrates awareness of the: – Wider political and socio-economic contextual issues affecting science education – Community context influencing science education – Changes in context impacting science education
3. Professional practice	*The teacher creates an encouraging and collaborative environment for promoting science learning.*	• The teacher creates an environment: – In which he/she encourages deep level learning, rigorous investigation of ideas, concentration and curiosity, perseverance and a deep desire to 'know'. – In which he/she establishes rapport with learners based on mutual respect and understanding, with appropriate discipline levels and effective classroom routines. – In which he/she demonstrates respect towards all learners, encouraging respect for diversity of ethnicity, race, gender, and special needs / disability. – In which the classroom learning culture is developed by teachers with learners so that they (the learners) are actively involved in making decisions, taking responsibility, learning from errors and realizing accomplishments.
	The teacher demonstrates improved pedagogical knowledge (PK) and pedagogical content knowledge (PCK) for primary science.	• The teacher: – Employs a variety of age-appropriate teaching strategies relevant to primary science content. – Implements new and improved ways of doing – Engages children in active learning to promote the acquisition of key science knowledge and skills.

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		– Implements inquiry-based and investigative approaches – Links new knowledge with learners' existing knowledge structure (Prior knowledge) – Scaffolds instruction and resources to help children achieve their learning goals (Scaffolding) – Implements a variety of classroom techniques and strategies to stimulate learner interest and participation (Variety) – Uses a variety of instructional materials, activities, strategies, and assessment techniques to enhance learning and to accommodate the needs of diverse learners (Differentiation) – Recognizes patterns of learning, identifies and addresses learning challenges, and adjusts the materials, learning activities, and assessment techniques to facilitate learning. – Provides in-depth explanations of science content and incorporates higher-order concepts and skills (Cognitive challenge). – Is supportive and persistent in keeping learners focused on task and encourages them to actively integrate new information with prior learning (Learner involvement and Prior Knowledge). – Uses multiple levels (particularly higher cognitive levels) of questioning to stimulate thinking and monitor learning (Questioning). – Ensures the learning processes and the outcomes of learning have authentic relevance with children's lives (Relevance) – Assumes responsibility for children's learning, sets high (but reasonable) expectations for all learners, and supports all learners in achieving them (Accountability).

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	The teacher develops knowledge and understanding of a variety of resources relevant to science teaching and learning.	• The teacher: – Uses relevant resources to promote cognitive development. – Draws on a range of appropriate materials and other resources to support learning. – Sequences materials and other resources in age-appropriate activities to promote learning.
4. Professional collaboration	*The teacher actively collaborates with others to learn from and share science knowledge and expertise*	• The teacher: – Maintains positive interaction with other professionals in the field – Serves as role model for other educators – Participates actively in professional associations
5. Continuous professional development	*The teacher demonstrates a commitment to science education and continuous self- professional development.*	• The teacher: – Incorporates learning from professional development into classroom practice – Is a reflective practitioner – Engages in ongoing professional renewal

3.8 Conclusion

For purposes of supporting analysis of data, and observations and reflections on teacher professional development for primary science, the qualitative framework developed in this chapter:

- Captures essential elements of effective teaching and translates these into critical reference points for reflection and discussion
- Helps with understanding what teachers should know and do by making explicit the competencies that characterize good teaching practice
- Provides a structure and language for distinguishing and explaining indications of / or positive shifts in teacher development and teaching practice

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- Draws attention to practices needed to support practising teachers along the path towards higher levels of performance

As regards the critical research question and sub questions, Chapter 5 presents the data on teacher professional development and primary science education in the 2007–2009 Cluster Project model within an activity theory framework, with data on the school contexts, teacher participants, the service provider (PSP), facilitators, and collaborations and sponsorship, and complexity theory. Chapter 6 utilises the research-developed qualitative framework to investigate empirical data on teacher professional development within the Cluster Project.

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CHAPTER FOUR: RESEARCH METHODOLOGY

4.1 Introduction

This interpretive case study examines the PSP's Cluster Project, originally developed and implemented to promote science education in primary schools. The Cluster Project targets in-service teachers, providing training workshops and classroom support to strengthen their professional capacity for teaching science. Tracing six teacher participants' professional development and teaching of science, this research examines the effectiveness of the PSP Cluster Project model and of the learning processes used by the Cluster Project for promoting primary science teaching and learning.

Working within two complementary theoretical paradigms, activity theory and complexity theory, this research draws on qualitative perspectives and technical methods for generating data for analysis. This chapter describes the research methodology, providing: (a) the rationale for a qualitative research approach, (b) a description of the research sample, (c) a summary of information needed, (d) an overview of the research design, (e) the methods used for data collection, (f) a brief description of data analysis (g) the ethical considerations observed, (h) the steps taken to ensure validity, and (i) the limitations of the study. A brief summary concludes the chapter.

4.2 Rationale for the Research Approach

The qualitative research design shaped by the research question, and the nature of the study designated the selection of methods for securing valid and reliable data. An interpretive case study research model constitutes the central approach in the qualitative design. The particular case in this study is a teacher development programme known as the Cluster Project, developed and implemented by a teacher development organization, the Western Cape Primary Science Programme (PSP). The Cluster Project model and its processes are detailed in Chapter 5. The study focuses an interpretive lens on the views and experiences of six in-service teachers participating in the Cluster Project, analysing data for evidence of their professional development within the project within five categories developed and explained in Chapter 3. An overview of the research design is provided as Appendix B.

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4.2.1 Qualitative Research

Qualitative research examines real-world phenomena, and is usually associated with research in the social sciences fields of, inter alia, sociology, psychology and education. With its 'many methodological practices' it may be viewed by some theorists as a 'soft science or ethnography' (Denzin & Lincoln, 2011:4). Two key aspects distinguish qualitative research: it is 'interpretive' (considers how people understand and make sense of their experiences and the world they live in) and 'naturalistic' (studies social phenomena in their natural environments) (Denzin & Lincoln, 2011:6). A qualitative research design using interpretive case study was considered better suited to the purpose of this research, and for investigating development processes intended to upgrade teachers' professional competencies for improved teaching, which would in turn improve children's learning of, and competence in, science and the application of scientific concepts.

Qualitative educational research usually focuses on important aspects related to understanding how learning takes place and how teaching practice ought to respond to this process in terms of a positive outcome, examining a multitude of interrelated aspects of this process, such as what happens in schools and classrooms, school leadership and its effects on teaching and learning, relationships, interconnections and interactions between teachers and their learners, teaching and learning activities in diverse locations, programmes for teacher professional development, and the use of the latest technologies and other resources for supporting teaching and learning. Also included in this enquiry is the range and complexity of influences residing in the individual and/or in the broader context and their impacts on teaching and learning.

The main focus for qualitative researchers is the study of the 'socially constructed nature of reality' (Denzin & Lincoln, 2011:8). Individual and collective social experiences and their complexities, how and why they occur and how these are given meaning, or interpreted by those living these, in a particular setting at a particular time, constitute the focus of qualitative studies (Bloomberg & Volpe, 2008:80). This kind of research is non-manipulative and non-controlling, searching for, identifying and describing emergent patterns, properties, and behaviours. Applying a purely quantitative approach, which may involve manipulation and control of variables in terms of certain educational issues may not necessarily generate the kind of insights suited to the objectives of social research. In such cases, a qualitative methodology, with its holistic and flexible approach, may prove more appropriate. For these reasons, a qualitative methodology is considered more suited to the purpose of enquiring into teacher

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learning within the context of a professional development programme, particularly as I was interested in teachers' experiences, feelings and perceptions about their own teaching contexts and the ways in which they, individually and collectively, saw their own professional development.

Qualitative research engages various approaches and research designs, such as narrative research, phenomenology, grounded theory, ethnography, and case studies that rely on field-focused detailed interpretive descriptions of 'people's experiences, perspectives and context' (Spencer, Ritchie, Lewis & Dillon, 2003:3) for forming an in-depth understanding of some aspect of social life, 'using words as data for analysis in its methods rather than generating numbers', (Brikci & Green, 2007:2). The objective is 'rich, thick descriptions' for a holistic and realistic picture (Denzin & Lincoln, 2011:9; Bloomberg & Volpe 2008:78) and for a comprehensive understanding of complex social phenomena, events, situations, insights, experiences, and interactions, such as those that can be found in education.

As a holistic approach, qualitative research is concerned with wholes rather than analysis or separation into parts, emphasizing the importance of the whole and the interdependence of its parts. Thus the approach situates the observer in the world (Denzin & Lincoln, 2000:37), requires him/her to become immersed in the world(s) of others, and to employ various, usually flexible, methods to observe and record experiences, views, interpretations and understandings of the world. Description and discovery, according to Bloomberg and Volpe (2008: 80), are key processes in qualitative research, in contrast to quantitative research with its focus on testing hypothesis, establishing facts or distinguishing relationships between variables.

The position of the researcher engaged in qualitative research is critical, as the approach calls for a special relationship between the researcher and the object of study, (Denzin & Lincoln, 2000:29). As a systematic subjective approach, qualitative research, with its focus on life experiences, is intended to assist the research to gain insight into, and explore the depth, richness, and complexity inherent in, real-world phenomena. By focusing on the 'what is', the 'why', and the 'how' of actions and behaviour, not only the what, where, and when (Hancock, 1998:1; Brikci & Green, 2007:4), a qualitative approach facilitates for the researcher a deeper understanding of human behaviour and the motives for human actions.

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In any research, understanding is developed via different processes such as dialectic and inductive reasoning (Spencer et al., 2003:3), shared and individual interpretations, and communication and observation, and concentrating on the unique subjective life experiences and interpretations of an individual or a collective. These aspects of qualitative research mentioned here align with those important aspects of the activity and complexity theory concepts, which also emphasize a holistic perspective in relation to phenomena and a 'bottom-up', rather than a 'top down', approach to analysis and reasoning in research (Johnson & Christensen, 2014:34).

Qualitative research methods are not always stringently specified or clearly defined, the aim being that the creativity and flexibility of the research are not limited. The researcher working in this field has a number of responsible freedoms, including the freedom to adapt the inquiry as understanding deepens, and/or the initial situation changes, and if necessary the researcher may decide or need to redirect the inquiry along new emerging pathways as and when the need arises. In this process the researcher bears the important responsibility of adhering to sound ethical standards throughout, a responsibility which includes gaining the consent of, informing, and protecting the respondents/participants, (Bloomberg & Volpe, 2008:85). Qualitative research therefore is used with smaller studies, in which focused samples are advisable instead of large samples which may prove impractical given the intensity and time-consuming nature of the methods applied.

Sampling and data collection involve selecting individuals willing to, and capable of, expressing their inner feelings and sharing their personal experiences. This involves the use of interviews for oral descriptions, the collecting of documents and written descriptions, direct observations, and audio and visual recordings. Data and findings are described from the subject's point-of-view, which the researcher interprets to identify themes or patterns emerging. Considering the critical importance of participants' particular experiences and interpretations, researchers are advised to avoid rigid designs that restrict participants' responsiveness, and a qualitative method, with its more flexible emergent design (Bloomberg & Volpe, 2008:88), satisfies these requirements.

The essential role of qualitative researchers involves 'understanding the multiple realities from the perspectives of participants' (Bloomberg & Volpe, 2008:9). In order to develop such a multi-faceted understanding qualitative researchers working in this paradigm draw on multiple

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methods and multiple sources in their research. During their research process they usually spend much time in the natural settings for fieldwork, are the main instruments of data collection, deploy a wide-range of interconnected interpretive practices, provide a framework within which people can respond in a way that represents authentically and thoroughly their points of view about the world, or that part of the world about which they are talking, employ expressive language in descriptions and explanations, employ wide-angle and 'deep-angle' interpretative lenses in data analysis, seek an in-depth perspective through ongoing analysis, sift through information and descriptive data to distinguish patterns, properties and behaviours, and work towards ensuring trustworthiness, coherence and logic within their interpretations (Denzin & Lincoln, 2000; Patton, 2002; Terre Blanche, Durrheim & Painter, 2006; Creswell, 2006; Bloomberg & Volpe, 2008; Johnson & Christensen, 2014).

Qualitative research with its particular aims and methods may appear imprecise and 'fuzzy' to a quantitative researcher. Common criticisms of this kind of research include: the samples are too small and not necessarily representative of the broader population, and thus it is difficult to know how far to generalize the result, and the findings lack rigour, and thus it is difficult to tell how far the findings are biased by the researcher's own opinions (Brikci & Green, 2007:2). In spite of these criticisms, qualitative research has been shown to have numerous advantages: it offers methods for examining phenomena in great detail, includes subjective information, blends in with natural activity, is not constrained by rigidly defined variables, examines complex questions that would be impossible with quantitative methods, deals with value-laden questions, can be used to explore new areas of research, and can be used to build new theories, (Denzin & Lincoln, 2000; Ospina, 2004). Comparing qualitative and quantitative methods, Mack, Woodsong, Macqueen, Guest and Namey (2005:3) see qualitative methods as being typically more flexible than quantitative methods, employing mostly 'open-ended' questions that may not necessarily be worded in exactly the same way with each participant, and allows greater spontaneity and adaptation of the interaction between the researcher and the study participants.

Since the research question required interpretive data with respect to teachers, their experiences, and their learning and teaching practice, a qualitative design with its fundamental assumptions, key features, and way of working is both useful and appropriate. Critical qualitative aspects relevant to this research which are compatible with activity theory and complexity theory include: (a) an emphasis on understanding events and actions in context, (b)

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an interpretive stance facilitating interactivity between researcher and participants, and a (c) flexible emergent research design, (Bloomberg & Volpe, 2008:80).

The qualitative elements and processes used in this research are detailed in this chapter, including interpretive case study research, and tools, such as questionnaires, interviews, observation, documents and journals, and photographic evidence. The rationale and application of these in this research are also provided. An overview of data analysis and interpretation follows. Thereafter, attention is given to issues of validity and ethics.

4.2.2 Interpretive Case Study Research

Case studies can be positivist, interpretive or critical. Interpretive case study research involves the study of cases within an interpretive perspective, whereby empirical evidence is drawn from observations of real people in real situations, and by recording the meanings they assign to their experiences. The particular concern with this approach is how and why people view and understand the world as they do, and how these notions and understandings influence their actions/behaviour. In the course of implementing an interpretive case study approach this research focuses on the views and experiences of a sample of teachers participating in the Cluster Project, to establish whether involvement with the project positively influenced their professional development and/or affected their teaching practices in their science classrooms.

An interpretive perspective supports the production of ‘thick descriptions’. Terre Blanche, Kelly and Durrheim (in Terre Blanche, Durrheim & Painter, 2006:273-274) describe the interpretivist paradigm as involving taking people’s subjective experiences seriously as the essence of what is real to them (ontology), making sense of people’s experiences by interacting with them, and carefully noting what they say and do (epistemology), and employing qualitative research techniques to gather and analyse information (methodology). According to the authors, by making sense of the individual’s feelings and experiences, and of social institutions and social phenomena, an understanding of the subjective reasons and meanings associated with social interactions can be formed. First-hand accounts which are full accounts, and as authentic rather than ‘accurate’ in any absolute sense, are therefore essential, necessitating a subjective and empathetic relationship between the researcher and the subject, (Terre Blanche et al., 2006:277).

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Identifying two key principles of the interpretive approach, Terre Blanche et al. (2006:274) mention the researcher as the primary 'instrument' for data collection and analysis, and the importance of understanding in context. A comprehensive and genuine understanding of human living, thinking and experiences involves, on the part of the researcher, an appreciation of important contextual issues such as social, socio-economic, linguistic, and historical factors that shape thinking, attitudes, and experiences.

4.3 The Cluster Project Case Study

The particular case for this research is a teacher development programme, the Cluster Project, implemented by the PSP, teachers' experiences of participating in the project, and evidence of professional development, and the depth and quality of this development which is described and analysed within five categories in Chapter 5.

Case study research as the most common type of qualitative research contributes to a deep understanding of real world phenomena, and is used for explanatory (to test, explain or compare), exploratory (to discover) and/or descriptive purposes. Other purposes described by O'Leary (2004:116) include the intrinsic value of case studies, that they can be used to debunk or revise a theory, they bring new variables to light, provide supportive evidence for a theory, and can be used collectively to form the basis of a theory. Cases may involve people, organizations, communities, cultures, events or critical incidences that are selected for study because they are 'information rich' and/or exhibit striking manifestations of the phenomena under investigation (O'Leary, 2004:117). The case study approach is often used to narrow down a very wide field of research to a reduced number of researchable cases. Case selection, according to O'Leary (2004:117), is generally non-random; cases are usually handpicked on a pragmatic and theoretical basis. Since sampling and case selection are aimed at in-depth insight about the phenomenon being studied, empirical generalizations from a sample to a population are not always be possible.

For a holistic understanding of the subject matter of the research, it is studied in context. All aspects connected to the object of study, such as historical and socio-economic background, development, conditions, and environmental interactions are observed, recorded and analysed (Denscombe, 2001:31). Multiple sources of evidence include direct observation and interaction with the subjects, together with in-depth interviews, and documents. Thorough, carefully

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documented descriptions are used to secure reliable data, and to ensure valid analysis and interpretation, researchers are required to suspend their preconceptions and biases. For researchers using detailed descriptions, analysis may involve synthesizing experiences, clustering and categorizing data, defining relationships between/ among concepts, and/or the search for themes or patterns.

Numerous advantages are associated with case study research. O'Leary (2004:116) indicates that on a practical level it offers one set of boundaries for the study, while on a strategic level relationships of trust promote understandings of greater depth and breadth. Although an individual case study may not be generalizable, useful knowledge, for example, in terms of causes and potential innovation can be derived through the approach. On the other hand, even though case studies have a distinctive nature, Denscombe (2001:30) maintains that many of its features are not unique to this particular research strategy, and can be found elsewhere. However, its most useful feature is that it permits the use of a variety of methods, depending on the conditions and the particular needs of the situation being examined.

Case studies are very different from analytical and controlled empirical studies, and are more concerned with understanding than with accurately explaining or predicting people's life experiences. However, there are certain challenges associated with this type of research. It can be time-consuming, the researcher's control over certain situations is limited, and sometimes it may be difficult to access participants to acquire the needed information in terms of perceptions and views.

Case study research has attracted much criticism for its limited potential for generalizations, and the possibility of researcher bias tainting findings. Responding to this kind of critique, interpretivists argue that the world is too complex to be reduced to set of observable 'laws'. For interpretivists and qualitative researchers, generalizability is less important than understanding 'reality' in all its complexity (Gray, 2004:31). Qualitative researchers regard the world as neither stable, nor coherent or uniform, and 'truths' about the world like those developed via quantitative research are in the end unattainable since perspectives and understandings differ from one group or person to another. Instead, interpretivists are more concerned with using and extending the power of ordinary language and expression for an understanding of the social world (Terre Blanche et al., 2006:274). Thus, relying on first-hand accounts and interpretations, interpretivists describe their observations in rich detail, and then

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present their 'findings' using engaging expressive language. Rich experiential data and meticulous observations form the basis for making sense of social realities (Terre Blanche et al., 2006). Supporting a qualitative case study design as being ideal for understanding and interpreting educational phenomena, Merriam (in Bloomberg & Volpe, 2008:80) stresses that the main interest of research of this nature is process rather than outcomes, the context rather than a specific variable, discovery rather than confirmation. She notes further that insights derived from case studies can directly influence education policy and practice, together with future education research.

The current study, framed by qualitative research, is an exploratory interpretive case study which facilitated an in-depth study of the particular perceptions, experiences and development of teachers involved with the Cluster Project. It facilitated an investigation into the contribution of the Project to the professional capacity of a sample of teachers in terms of their ability to implement the science curriculum in the primary classroom competently, efficiently and creatively. As has been mentioned, the 'natural setting' or context of work for teachers is a significant factor in this kind of qualitative research, and is duly noted and accommodated in this study, described detail in Chapters 5. The qualitative researcher is the primary instrument, and the research relies on his or her skills to receive information in its natural context for the purpose of uncovering new and valuable meanings using descriptive, exploratory, and explanatory procedures.

The various forms of data production provided multiple avenues through which the views and experiences of the teachers were recorded, and provided a variety of different opportunities for teachers to express their opinions and describe their particular learning experiences derived from involvement with the Project. Multiple sources of data were used, and included teacher questionnaires, interactive and semi-structured interviews with participating teachers, classroom observations, and various documents.

In addition to an interpretive case study, the qualitative design draws on documented narratives relevant to this research. One is a set of case studies compiled by the PSP entitled 'Inspiring Teachers' a compilation of stories of the teachers involved with the project, (Appendix C). Reference is made to parts of these records in the data analysis (Chapters 5 and 6), lending support to other observations and findings in the current and other studies.

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4.4 Research Sample

In qualitative case study research, sampling is aimed at providing insights about the phenomenon, rather than empirical generalization from a sample to a population; thus it permits the selection of a smaller number of participants in a focused in-depth study. This research employed purposeful procedures to identify participants for the study. Purposeful sampling, according to Bloomberg and Volpe (2008:80), is typical of case study methodology, and generates substantial information about the phenomenon being investigated.

The historical background, together with the purpose and scope of the Western Cape Primary Science Programme (PSP), from its inception in 1984, has been sketched in detail in Chapter 1 (1.4). For the 2007 – 2009 period the PSP' s Cluster Project involved 40 primary schools from the Central, South, North, East and Cape Winelands school districts, later reduced to 37 when 3 schools withdrew from the programme. Intermediate Phase science teachers (Grade 4-6) were the main targets of this project. Additionally, the project provided separate training and support for Grade 7 science teachers, and training and support for the Natural Sciences component of Life Skills for Foundation Phase teachers. The overall number of teachers accommodated by the Project during this period was 375. With an average of 4 teachers per school (3 Intermediate Phase teachers - one science teacher per grade for the 3 grades in the Intermediate Phase, and 1 teacher for the Senior Phase, Grade 7), the project accommodated an average of 148 teachers for the Intermediate and Senior phases, and 227 teachers from the Foundation Phase. Of this number, 11 teachers were approached, later 10 were selected and interviewed for this research. Tragically one teacher passed away in a car accident. During the final write-up, the research reduced the number of research participants further to 6, with 3 male and 3 female teachers, making this is a small-scale study. Referring to Kelly (2006:293), ideal respondent characteristics differ according to the purposes of the study. He indicates that if the study is to describe personal experiences of a phenomenon, the following criteria are important for participants:

- Personal experience of what is being researched.
- Good communication skills (ability to describe experience in detail).
- Openness and undefensiveness, and

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- Interest in participating, as well as the perception that it may, in some way, be of value to the project or field to participate.

In addition to the criteria proposed by Kelly (2006), participant suitability was determined against a set of criteria developed with respect to the research objective, focusing on primary science teachers who attended Cluster Project training workshops and who invited facilitators to visit their classes. The set of participants narrowed down to 6 for this study were identified in terms of the following:

- Voluntary and active participation in all aspects of the Cluster Project
- Regular attendance of all the PSP workshops offered as part of the Project,
- Using or having used various resources in their science lessons, especially those provided by the PSP,
- Accepted PSP facilitators in their classrooms to observe their teaching,
- Reflected on their work and progress with PSP facilitators,
- Preparedness to work in a collaborative process,
- An inclination to experiment with new ideas, and
- Having implemented new strategies for teaching science.

The research identified 6 experienced teachers to participate in the study. A delimiting time framework of five years teaching experience was decided on to ensure that each participant was sufficiently experienced and had a knowledge of basic teaching and learning practices. Most of the teachers reported that they started participating in the Project with very little experience of teaching Natural Science in the Intermediate and Senior Phases, citing their lack of experience and subject knowledge as reasons for participation in the Project. All demonstrated an openness and inclination to experiment with innovative teaching strategies with a view to improving their teaching practices. There are differences among them with regard to teaching qualifications, ages, gender, ethnicity and dominant spoken language (English, Afrikaans or isiXhosa) and the type of teaching posts (senior or junior) held.

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The value that their experiences brought to this study is significant. Their extensive experience, coupled with their enthusiastic approach to experimentation and innovation, served as an advantage. Their keen engagement in the Cluster Project and their willingness to communicate their ideas and experiences as authentically and fully as possible was critical. Due recognition is given to the fact that the sample size compromises generalizability of the main findings of this research.

4.5 Research Data Collected

The interpretive case study focused on six teacher participants located at five different schools; three schools are situated in the North school district, and two are located in the Central school district. In seeking to understand processes for teacher professional development more clearly and how these can modelled (designed and delivered) for enhanced efficacy, this research examines the Cluster Project with the purpose of distinguishing elements of the model that have in any way benefitted the participating primary science teachers in terms of their professional development with regard to improving their science content knowledge and teaching practices, in other words knowing what to teach in science and how to teach science effectively and creatively.

Four key focus areas were derived from the research question and sub-questions, namely teacher professional development, the Cluster Project model, primary science education, and the context of work. Bloomberg and Volpe (2008:67) distinguish four general areas of information needed for most qualitative studies as being contextual, perceptual, demographic, and theoretical information. Matching the four focus areas to these four general categories, information needed for this research includes:

- Critical issues residing in the context that impact teaching and learning with regard to the schools, teachers, learners, curriculum, educational reforms, teacher training and support, and resources,

- The Cluster Project model with regard to its design and delivery, the influence of the Project on science teaching and learning, and participating teachers’ perceptions and experiences of the Project,

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- Demographic information with regard to the teacher participants, including their teaching qualifications, years of teaching experience, science background, age, gender, and ethnicity. At the time of this research 'ethnicity' still appeared to be a factor distinguishing schools and the communities in which they were located.

- Teacher professional development with reference to relevant criteria / indicators. This includes ongoing review and reflection on the literature on the part of the researcher with respect to understanding teacher development, to guide data collection, and for the purposes of interpretation and analysis.

Table 4.1: Overview of the information needed for this research:

Type of Information needed	**What the research requires**	**Method and sources used**
1. Contextual. For information on context and background.	Background of the Cluster School Project, information about its history (including the broader historical background/context), structure, mission, vision, values, products, resources, services, culture, leadership, staff and description of location. Information about the location of schools, and their surroundings.	Documents and reviews, Photographs, Interviews & Observations
2. Demographic For information about the participants.	Descriptive information about participants such as age, gender, ethnicity, teaching qualifications and years of teaching experience.	Questionnaire & Interviews
3. Perceptual For information about the teachers' particular experiences and perceptions.	Description and explanations of participants' experiences as these relate to the main focus of this research	Interviews, Observations, Photographs, Documents

4. Central research question: Does the "Cluster Project" model contribute substantially to teacher professional development and primary science education?	Key points: • Teacher professional development model - Cluster Project • Teacher development - Teachers' Natural Sciences content knowledge - Science teaching practice - Teachers and their experiences of the Project - Changes in content knowledge and teaching practice • Science education - Primary school science - Challenges in the context that hamper processes.	Document analysis, Interviews and transcripts, Observations of practices, Reports of observations, Ongoing review of literature for theoretical grounding.

Each focus area mentioned in Table 4.1 is expanded in Chapters 5 and 6.

4.6 Data Collection Methods

A multi-method approach, coupled with triangulation for cross-checking in analysis, was used for an in-depth understanding of the phenomena investigated in this research. As mentioned above, the strategy involved a range of data-collection methods, including teacher questionnaires, semi-structured interactive interviews, classroom observations, document analysis, and photographic evidence. Supporting this approach, Gillham (2000:1-2) argues that making use of a multi-method approach to analyse real-life questions is an important strategy because one approach is rarely adequate, and when the results of different methods intersect (agree, or fit together), then we can have greater confidence in the findings. In the current study different methods were used to provide evidence for substantiation, thus adding rigour, and greater depth and breadth to the study.

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4.6.1 Interviews

Widely used by qualitative researchers amongst others, interviews are a powerful means of obtaining information and gaining insights. They are useful for getting to know 'what makes someone tick', providing a way of getting to know the person well. Through purposeful probing conversations the interviewer-researcher is able to develop a better understanding of how the person thinks and feels, becoming more familiar with the person's personality and motivations. 'Lived experiences', and the meanings assigned to such experiences, are at the heart of qualitative research, and thus interviews that involve interactions with people (talking to and listening to them) to capture the meaning of their experiences in their own words represent a legitimate way of generating rich qualitative data, (Bloomberg & Volpe, 2008: 82). Interviews as a data collection method were considered as the most appropriate method for examining teachers' particular perceptions and experiences of the Cluster Project.

The interviews as a data collection instrument represents a good fit with the interpretive approach since it is a very 'natural form of interacting with people' (Kelly in Hannan, 2006:297). Usually interviews, besides eliciting perceptions or views, collect facts about the interviewee, such as information about age, qualifications, number of years of experience in a field, and other important details. Questions posed to obtain this kind of information are often used as opening questions, setting the scene for the main substance of the interview. The greater part of the interview seeks to obtain information about attitudes and opinions, perspectives and meanings related to the topic under investigation.

Interviews can be highly structured, semi-structured or unstructured. Whereas structured interviews consist of the interviewer asking each respondent the same questions in the same way, semi-structured interviews (sometimes referred to as focused interviews) involve a series of open-ended questions, and unstructured interviews (sometimes referred to as 'depth' or 'in depth' interviews) have very little structure (Hancock, 1998:9-10). Qualitative research mostly involves semi-structured or unstructured interviews. Interview schedules that are too tightly structured may not enable exploration of the phenomena under investigation in any breadth or depth. Instead, the types of interviews most useful for such purposes in qualitative research are flexible and interactive utilizing mostly open-ended questions. These give the interviewees the space to elaborate on meanings of events and experiences and to give direction to the interview process. Even though the broad framework of the interview is predetermined by the researcher, the participants have the freedom to tell the stories they choose, helping the researcher

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understand participants on their own terms and in the many ways in which they make meaning of their own lives and experiences. The interview aims to gather information about the research topic, and as long as the discussion does not deviate too much from the focus of the study, all other detail shared during the session is acceptable in terms of qualitative research.

Critics of the use of interviews in research suggest that often the situations / interviews appear contrived and artificial, and sometimes the way interviewees respond reflects this (Hannan, 2007). While interviews may be a useful and direct way of getting to know about people's feelings and experiences, Kelly (in Hannan, 2006:307-308) is concerned that the interview usually comes 'after the fact': there is a reliance on the interviewee's recollection of the past experience. What is more, the human interaction between the interviewer and respondent poses its own set of problems. Describing various other limitations associated with interviewing, Bloomberg and Volpe (2008: 82) argue that not all people are equally cooperative, articulate, and perceptive; interviews demand particular research skills, and interviews are not neutral tools of data gathering since they are influenced by the interviewer-interviewee rapport and the context in which the interview takes place. Despite these challenges, Gray (2004:213) argues that a well-conducted interview can be a powerful tool for eliciting rich data about people's views, attitudes, and the meanings that underpin their lives and actions. Another advantage, according to Denscombe (2001:112), is that interviews lend themselves to being used in conjunction with other methods as a way of supplementing data, adding detail and depth.

During interactive, semi-structured interviews, participants in this research were requested and encouraged to verbally describe their views and experiences of the 2007 - 2009 Cluster Project. These descriptions were transcribed for the purpose of analysis. An interview schedule was prepared prior to the interview to focus the interaction on key aspects of the research question (Appendix H). The teachers were interviewed at school during their non-teaching periods (free time) and after school. The duration of each interview was approximately sixty minutes. All the participants indicated that they had no objection to the interviews being taped. The interviews were recorded while participants were being interviewed, and carefully transcribed for the purposes of data analysis.

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4.6.2 Questionnaires

A questionnaire is a useful information gathering device. According to Gray (2004:187), case studies utilizing a combination of data gathering tools sometimes include a questionnaire as one of the tools used for data production. Questionnaires can be used to add useful information when used in conjunction with other methods.

Questionnaires are considered quick and easy to distribute and use, but can take a long time to design, apply and analyse. Denscombe (2001:87-88) considers questionnaires as appropriate when fairly straightforward, relatively brief and when uncontroversial information is required. Questionnaires may vary in terms of their purpose, size and appearance, but, to qualify as a research questionnaire Denscombe (2001:87-88) recommends that they be designed to gather information relevant to the research, they must form part of the data for analysis, and they should be composed of a set of written questions which can be directly posed to participants in a study.

Elaborating on the advantages of using self-administered structured questionnaires delivered by hand, post via snail-mail, e-mail or the Web, Eiselen and Uys (2005:2) mention the following useful purposes:

- They are more cost effective to administer than personal (face-to-face) interviews,
- Most people are familiar with the concept of a questionnaire,
- They reduce the possibility of interviewer bias,
- They are less intrusive than telephone or face-to-face surveys, and hence respondents are likely to more readily respond truthfully to sensitive questions,
- They are convenient since respondents can complete them at a time and place that is convenient for them.
- The responses are gathered in a standardized way, so questionnaires are considered to be more objective than other data collection tools used in qualitative research.

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Highlighting the disadvantages of self-administered structured questionnaires, Eiselen and Uys (2005:2) point out that the response rate tends to be low, especially when the questionnaire is too long or complicated for many participants to complete, when the subject matter is either not interesting to the respondent, or is perceived as being of a sensitive nature. Most importantly though is the fact that the researcher often does not have control over who fills in the questionnaire even though it may be addressed or delivered to the intended participant(s).

In this research structured teacher questionnaires (Appendix F) administered by the researcher were used to obtain information concerning the participants that was specific to the research. A questionnaire was developed to obtain background information regarding each teacher involved in this study. The series of closed questions focused mainly on the following:

- Academic qualifications, in particular those related to science education.
- Professional experience, specifically in terms of teaching Natural Sciences in the Intermediate Phase.

The information from these questionnaires helped the researcher develop a clear understanding of the teachers' backgrounds and professional competencies, academic qualifications, and professional experience, with regard to science education.

4.6.3 Observations and Field Notes

Detail about the world is received through our senses, and we discover and learn through our sensory observations and our experiences of the world. However, observation as a method used to collect data for research is more systematic and analytical than simply looking and listening. As an important aspect of case study research, whether conducted by participants or outsiders, observations offer a distinct way of collecting data that does not rely on 'what people say they do or what they say they think' (Denscombe, 2001:139). Describing its use in research more clearly and in more detail, O'Leary (2004:170) explains that, while 'to observe' in everyday language means 'to watch or notice', and observation refers to 'the act of watching or noticing', observation in research should be viewed as 'a systematic method of data collection that relies on a researcher's ability to gather data through his or her senses'. Observation in research uses direct eye-witness accounts of events in their natural context as important evidence, providing the research with an opportunity to move beyond people's opinions and self-interpretations of

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their attitudes and behaviours towards an evaluation of their actions in practice (Gray, 2004:238). Two important aspects of this method are that it positions the researcher at the very site of action, at the very moment when things are actually happening.

Research gains ‘thick descriptions’, in the form of rich qualitative data, from careful observations of relevant phenomena and detailed field notes. The observation technique used in a study depends on the nature of the research undertaken. There are two ways of doing observations, one method being unstructured and requiring the observer to become immersed in the field first before generating categories for observation; the other method is more structured and uses a prepared research instrument for observation purposes. Hannan (2006) regards the former method as more appropriate for exploratory case studies, and the latter as more applicable to large-scale surveys, or as a means of providing wider reference points for other qualitative small-scale studies.

Observational techniques are most appropriate when visual or auditory data is required, producing information which cannot be collected in any other way. A number of advantages are associated with observational research. It is directly connected to the social phenomena being studied, avoiding the wide range of problems associated with reliance on reports from others within or outside of the phenomenon/case study being researched. Observations are flexible and adaptable; they can be applied to a wide range of contexts and used for an assortment of purposes. They are used to generate both qualitative and quantitative data since they can be applied in an informal and unstructured way, as well as in a highly structured standardized manner. Detailed recordings of observations provide a permanent record of events and behaviours. Observations can effectively complement other data collection approaches, providing data for triangulation and thereby enhancing and deepening the quality of evidence.

On the other hand, this approach, particularly when used on its own, has several disadvantages. It can be costly, time-consuming and resource intensive compared to other data collection methods. The human flaw of bias or prejudice on the part of the observer cannot be ignored, undermining the reliability and validity of the data gathered, particularly in the absence of some form of triangulation. To ensure the information gained is as valid and reliable as possible, and not selected to prove a particular point, it is important that observation is as objective as possible and the observer needs to be aware of her own interests and biases. Observation is also said to affect the behaviour and actions of the person observed; this

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phenomenon, known as the 'Hawthorne effect', refers to the way in which people tend to behave differently, or even perform better than they would otherwise when they receive attention and when they know they are being observed (Coombs & Smith, 2003). The 'observer effect' means that the presence of the researcher may influence the events or behaviour of participants in a study. Indirect or unobtrusive observation is a way of diminishing this effect, as well as possible bias and subjectivity. Observation mainly focuses on behaviour or actions, and therefore it cannot enhance understanding of why people behave as they do. Other important disadvantages of the approach cited by Gray (2004:239) include:

- The possibility of the interpretation of what is observed being influenced by the mental constructs of the researcher (including their values, motivations, prejudices and emotions). Consequently, the researcher may disregard phenomena that could prove important.

- While the data gathered from observation are often rich, extracting meaningful themes and concepts from the data can be quite challenging.

In this research, semi-structured descriptive observations of classroom interactions were used to gather information regarding participating teachers' science teaching practices (Appendix I). The observation schedule used by the science facilitators was designed by the researcher. Thus it served a dual purpose: serving this research on the one hand, and on the other, serving as a guide for teachers and facilitators to reflect on their classroom practices. Data derived from observations of teachers' science lessons are discussed in Chapters 5 and 6.

4.6.4 Document Evidence

All forms of qualitative research usually include a variety of documentary sources or written texts, such as reports, letters, newspaper articles, official documents, journals, and books. The method involves a considerable amount of reading about some aspects of the social world under investigation, and seeks information about the actions, events or occurrences in order to identify, describe, interpret and classify patterns in the data, often avoiding a host of ethical issues associated with methods that rely on human interactions, and is considered by scholars to be an important research tool in its own right as an invaluable part of most triangulation methods (Bowen, 2009).

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Documents generated by individuals and groups during the course of their everyday practices are developed for diverse purposes, and reflect the particular meanings and assumptions of the writers or compilers, and are presented in a particular style, depending on the intended audience, and which can differ from document to document (Mogalakwe, 2006:222). Hence, a researcher is advised to remain vigilant when using documents as a source of data, and to take into consideration the 'origins, purpose and original audience' of the document (Grix in Mogalakwe, 2006:222). Although not all documents are specifically produced for research purposes, they can reveal important information about the social world of the people who created them. Even though official documents are regarded as socially produced information, they were or are intended to be read as objective statements of fact. It is therefore recommended that, as far as possible, multiple pervious analysers and/or triangulations are used to confirm, or validate, findings when analysing documents (Grix in Mogalakwe, 2006: 222).

The use of documents in research has both benefits and limitations. Comparing the benefits of using documented evidence with the use of interviews for data collection, Kelly (2006:316) sees documents as sometimes being easier to use because one does not have to literally 'think on one's feet' as is the case in an interview, nor engage in the tiresome process of transcribing everything. Documents provide valuable insights into the views and experiences of others, and, according to O'Leary (2004:121) represent a valuable way of 'understanding the reality of the researched by examining the texts they produced themselves'. Other benefits of using documents in research include: their potential to show what people do or did and what they regard as important, behaviour is recorded in a natural setting, the data has strong validity, information can be acquired from different time periods, giving a broad historical view of events and experiences; perusal and analysis of documents does not interrupt any work programme in which participants may be involved or the schedule of the investigation; consulting documents is less invasive than other methods, is less prone to issues of bias, the information as such does not have to be re-produced as it already exists, documents are usually readily available and not always dependent on strict access or ethical constraints; they can be used to identify and describe trends, can provide useful background information, can be used to corroborate evidence, are inexpensive to access. Despite demanding extensive reading on the part of the researcher, analysis of data from documents is more straightforward than that required from interviews, and in addition fits well with both quantitative and qualitative research. However, in spite of the many advantages of using documents in research there are

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definite disadvantages of this method, particularly if documents constitute the only or main source of evidence and if the researcher is not alert to possible bias and to the context in which these documents were compiled, the use of these is labour intense and time consuming, the information recorded might be incomplete, the information may be presented from only one perspective, access to specific content may be restricted, the data could be quite out-of-date or irrelevant to the research question, and the main findings that could be derived from the data may already have been extracted.

The documents consulted and relevant to this research include:

1. PSP reports on the Cluster Project prepared for funders and the education district offices,
2. PSP facilitator reports on the progress of the Project in schools,
3. PSP facilitator school visit reports,
4. Teachers' lesson plans, learners' workbooks and assessments
5. Printed resources supplied to teachers,
6. Teacher evaluation sheets,
7. Workshop documents,
8. Impact evaluation of the project developed by an external evaluator (Angela Schaffer, 2009),
9. An impact study of the PSP's work (Professor Peter Hewson, (2007)), and
10. An impact study conducted by Professor Clifford Malcolm (2004) in collaboration with Kowlas and Steers of the University of Durban Westville.

A set of criteria for Document Analysis (Appendix J) was used to evaluate and guide interpretation of the above-mentioned documents:

- Authenticity: Is it genuine, complete, reliable and of indisputable authorship?

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- Credibility: Is the document free of errors or distortions?
- Representativeness: Is the document representative of the organization and its work with teachers?
- Meaning: What meaning can be derived from the document?

The various documents referred to in this research were analysed with the aim of understanding the Cluster Project model in terms of its design, its processes, including monitoring and evaluation, and its outcomes. The research was particularly interested in the findings of previous research studies and evaluations. These documents in the form of reports were briefly mentioned in Chapter 1, and are referred to in greater detail in Chapters 5 and 6.

4.6.5 Photographic Evidence

Along with texts, photographs and audio-visual material, such as sound, video and film recordings, are counted as valuable sources of qualitative data. Photographs enable the detailed recording of facts, presenting the lifestyles and the realities of living and working conditions of participants in a study in their natural form (Gray, 2004:326). Photographs provide certain data that would otherwise be overlooked, highlighting events and processes relevant to the research in a way that could not have been achieved using any other method. This strategy allows the researcher to access some of the ideas, feelings, and emotions of participants that are too subtle, too sensitive or evasive to be captured in words. Photographs/ pictures present ways to gather more information about participants, providing some glimpses into participants' lives, and showing bits of reality to either illustrate or to augment/support the research findings. Building on meaning via other methods, such as photographic records, adds a more 'life like', authentic element to a report.

Supporting the incorporation of photographs in research, Le Grange (2000:169-173) sees its use in case study research related to educational practices as representing a way of providing meaningful insights into, and clarifying, the particular contexts of teaching and learning. Similarly, Razvi (2006) points out that as narratives are powerful testimonials that project the voices of participants, visual data have the potential to corroborate and enhance narratives. Since photographs faithfully reproduce the reality in front of the camera's lens, Swartz, (1989:120) contends they are visual records that provide an unmediated and unbiased visual

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report. Careful consideration and planning of image-based methods has the potential to strengthen critical understanding, and to enhance research studies. However, in his questioning of the reliability of photographs to 'tell the truth', Gray (2004:327) is concerned that 'what the camera focuses on and what it leaves out is selective'. He also cites changes in the natural behaviour of participants in the presence of the photographer as a problem. A thoughtful researcher considers all arguments about the strengths and weaknesses of a particular approach, particularly if it is used as the main or only data collection method, and should thus be guided by such considerations when using photographs in her research.

With the above caution in mind, the research applied a set of criteria for photograph analysis (Appendix K) to guide the selection and analysis of the photographs used. The photographs are mainly intended to illustrate particular observations, and to support interpretations derived from detailed descriptions. The photographs used in this research are drawn from PSP records, and were not specifically captured by the research. These photographs form part of PSP's usual monitoring and evaluation procedures, and are used to add weight to the narrative reports developed for funders and education districts. The photographs record actual teacher and learner activities as well as the context in which teachers work, and do this more effectively than the verbal report. Ethical considerations regarding the use of the photographs were duly observed in this research, and permission for their inclusion was obtained from the PSP management.

4.7 Data Analysis

Data analysis in Chapter 5 focuses on the Cluster Project case study through the lens of the activity framework, and primary data from teachers within the Cluster Project is analysed in Chapter 6 using the activity, complexity and developed qualitative framework for interpreting and describing indications of teacher professional development for improved primary science education. Important concepts associated with both theories described in Chapter 3 guide the interpretation of the data on the Cluster Project model with respect to the critical research issues identified in Chapter 1, namely teacher professional development and primary science teaching and learning. Engeström's (2001) notion of activity systems as units of analysis provides a useful structure for presenting and analysing data on the Cluster Project and teacher professional development in Chapter 5, and Chapter 6 further expands the analysis, referring to the crucial concepts of contradictions, expansive learning and boundary crossing.

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Several authors, cited in detail in Chapter 3, have applied themselves to the task of scripting analytical frameworks to distinguish and explain evidence of teacher development in qualitative research, while others describe models or processes for effective teacher development. As mentioned in the previous chapter, a number of such works were consulted, following which a separate framework for this research was conceptualised and contextualized for this current study. Janse Van Rensburg and Le Roux's (1998) critical indicators of professional development, Bell and Gilbert's (1994) professional development framework, Reid's (2007) quadrants of teacher learning (Fraser et al. :2007), Kennedy's (2005) analytical framework , NCREL's Five Phases of Professional Development (1997-1999), Hackling and Prain's Primary Connections' professional learning model (2005), Clarke and Hollingsworth's Interconnected Model of professional growth (2002), and Loucks-Horsley, Hewson, Love and Stiles's (1998) Professional Development Design Framework were assessed and reworked for use in the current study.

In Chapters 5 and 6 data on the Cluster Project model, and evidence of teacher professional development, is analysed in terms of the analytical frameworks.

4.8 Research Process

1) The research proposal was developed and submitted to the Stellenbosch University Education Faculty Proposal Committee, and was successfully defended on the 26th January 2009. During the meeting the following concerns were raised:

    - Is the research an impact study? And if so, how would the impact of the project be determined?

    - How does the research intend establishing whether teachers have developed professionally?

    - How does the research intend applying an activity theory frame?

    Responding to the first inquiry, this research is not an impact study, but is exploratory research focusing on a particular set of teachers involved in one professional development project, and their perceptions and experiences of the Project. Regarding the second question, the researcher acknowledged the challenge of determining and describing teacher

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professional development, and expanded on the intention of employing sets of criteria, or 'professional development indicators', to guide the interpretation and analysis of the data. In response to the third question, the researcher elaborated on the theoretical framework to be used for the research (discussed in Chapter 3), and her intention to use Engestrom's (2001) interacting activity systems theory for explaining the Cluster Project as a system, and its interactions with other systems (schools, teachers, education districts, and learners), as well as Engestrom's (2001) notions of contradictions, expanded learning cycles, and boundary crossing as essential for making sense of teacher learning and development. The meeting concluded with a reminder by members of the committee to the researcher to adhere to stringent ethical procedures when conducting research of this nature. With permission granted, the researcher proceeded with the study.

Following the meeting with the Proposal Committee, the researcher applied to the WCED for permission to conduct this research, which was granted on the 29th April, 2009 (Appendix D). Ethical Clearance from the University for the Research followed on the 17th September 2010 with the reference number: 300/2010. Subsequent to approval being granted, instead of focusing on the work of the organization known as the Primary Science Programme (PSP) in a teacher professional development programme, the researcher redirected her focus towards one of the projects the PSP offered to teachers, namely the 2007 – 2009 Cluster Project. Since the key focus area of the research remained the same, which is in-service primary science teacher development in context, a separate application was not considered necessary.

2) The first chapter with the background to the research and to the PSP, the rationale, problem statement and challenges was formalized, followed by Chapter 2 with a selected review of relevant literature, in order to study the contributions of other researchers in the broad areas of science, science education and teacher development, and to relate developments in these areas to events and processes in South Africa. At this point, as a result of a discussion with the researcher's supervisor, complexity theory was introduced into the research process. Chapter 3 followed, in which the methodological approaches, activity theory and complexity theory, were described in terms of providing a theoretical framework for the research.

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3) Potential research participants were identified and recruited via personal interviews. Eleven teachers were initially approached, 10 (6 males and 5 females) responded positively, and 1 (female) declined, indicating that she was leaving the school and would not be teaching science in her new post. Of the remaining 10 teachers, one teacher passed away in a car accident.

   The initial interview with teachers involved presenting the research concept, explaining the participant's role in this research, and what this entailed, and giving participants assurances that strict ethical procedures would apply. Following this the consent form for participants was discussed and signed by each participant (Appendix E).

4) During the second interview with the 10 teacher participants, a teacher questionnaire (Appendix F) was distributed to acquire information about each teacher's background, focusing particularly on their qualification levels and teaching experience. In addition, a classroom checklist (Appendix G) was used to capture information about the teachers' contexts of work.

5) The third interactive semi-structured interview was used to record the teacher participants' views and experiences of the Cluster Project. These interviews were conducted after the Project with the set of schools was concluded. For these interviews, the researcher developed a set of guiding questions, contained in the interview schedule (Appendix H).

   In addition, two male principals of the schools involved with the Project were interviewed, and the same interview schedule used with the teachers was adapted for these interviews. These additional interviews helped to provide different perspectives of the Project.

   All the interviews were recorded and transcribed, and respondents were asked to verify the transcriptions.

6) The researcher obtained various documents from the organization that were helpful for this research. The set of documents provided included school visit reports developed by the Science facilitators, Reports of the Project compiled by the organization for education districts and funders, an 'Impact Evaluation of the PSP Cluster Project' conducted by an external assessor, Angela Schaffer, (2009) and previous studies conducted by other

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researchers – those conducted by Professor Clifford Malcolm (assisted by Kowlas and Steers) (2004), and Professor Peter Hewson (2007); these references are supplied.

The classroom observation schedule (Appendix I) the Science facilitators used to report on their school visits was developed and introduced into the Project by the researcher. The schedule was translated into Afrikaans by a facilitator who worked on the Project with the rural schools.

7) The various methods used for collecting data included questionnaires, interviews, observations and documents. This information was analysed for evidence of teacher professional development using the framework developed in Chapter 3.

8) During the final stages of the write-up, data was analysed against a set of criteria / indicators identified in Chapter 3 to identify and describe evidence of teacher professional development and improvements in science teaching and learning that could be connected to the Cluster Project. This led to the research findings, and the conclusion with recommendations for processes of teacher professional development and suggestions of topics that require further study.

4.9 Ethical Considerations

All researchers are ethically bound to an ethical code when conducting studies of any nature in a manner that does not cause harm, be it emotional, physical, psychological, or other, to those involved in the study. For this reason, all studies are obliged to include an ethical dimension in the research design, and this forms an integral part of all research processes.

Qualitative research in particular, with its flexible and emergent design, demands some unique ethical considerations. Bloomberg and Volpe (2008:76) advise researchers who use this methodology to remain vigilant in terms of these issues throughout the study, particularly with regard to the researcher–participant relationship, which is influenced by roles, status, and cultural norms. Essentially, ethical considerations create safeguards, protecting the rights of participants. Researchers should therefore make provision for informed consent, protection of participants from any harm, and clearly explain the ways in which confidentiality in the research is ensured.

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The relevant ethical issues pertaining to this research were observed accordingly. Formal application for permission to conduct this research in the identified schools was granted by the Western Cape Education Department (Appendix D). In addition, permission was also acquired from the relevant principals of the schools (Appendix L). The teachers involved in the investigation were informed of the exact purpose and nature of the investigation, after which their informed consent was obtained (Appendix E). Their voluntary participation in an interactive process which was to examine their professional development is a significant and essential aspect of this research. It was important that the teachers recognize and acknowledge the value – to the PSP as well as to science teaching - of their involvement in this form of research.

In accordance with the applicable ethical principles, the participants were to remain anonymous, and for this reason numbers were assigned to participants (1 - 6) to protect their identities. All information acquired via the questionnaires, interviews and other relevant documents were appropriately stored to guarantee protection of the confidentiality agreement entered into with the participating teachers.

The manner in which this research was carried out, was specifically planned so as to avoid any harm (or wrong) to any of the participants, or any other person directly or indirectly linked to the study. This research and its findings can indeed contribute to the improvement of the practice of all involved: the participants, teachers, professional developers, policy makers, and researchers.

4.10 Validity and Reliability

Within the quantitative research paradigm standards of validity and reliability are applied in a specific manner. Whereas validity refers to how well a test measures what it purports to measure, reliability is understood as the degree to which assessment generates stable and consistent results. These two principles are discussed in turn, and their application to this research explained.

Considerable debate surrounds the issue of what constitutes sound (valid and reliable) qualitative research. The challenge with this type of research is that it cannot be reproduced to arrive at compatible results, and therefore cannot be appraised in the same way as quantitative research. Although the importance of the concepts of validity and reliability to any research is

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acknowledged, there is wide discussion about how such concepts should be reformulated for applicability in qualitative research. Among the aspects of interest forming part of the debate Spencer et al. (2003:4) mention consideration for ‘rigour’ in research, the need for principles of practice to be made manifest, the importance of sound or ‘robust’ qualitative research evidence and the relevance and value of the evidence for the research. The authors emphasize the need for qualitative research to be evaluated on its ‘own terms’ within premises that are central to its purpose, nature, and the manner in which it is conducted (Spencer et al., 2003:4). Hence, in the broader research field, the concepts of validity and reliability as applied in qualitative research differ from their application in quantitative research.

Various interpretations of validity and reliability in qualitative research with different emphases are encountered in the literature. Validity in qualitative research as described by Guion, Diehl and McDonald (2011:1) refers to whether or not the research findings are ‘true’ and ‘certain’ – ‘true’ in the sense that the findings accurately reflect the situation, and ‘certain’ in the sense that findings are supported by sound evidence. The focus for Bloomberg and Volpe (2008:77) is on how well, comprehensively and convincingly the research has provided evidence that descriptions and analysis represent the reality of the situation(s) and persons studied. Similarly, in their explanation, Spencer et al. (2003:6) emphasize the quality of the evidence obtained and the quality of analysis that accompanies it. Van der Riet and Durrheim (2006:90, 91) describe validity in terms of the research processes and products, referring to the manner in which the research is conducted and the degree to which sound conclusions can be said to have been reached. Guba and Lincoln (in Bloomberg & Volpe, 2008:85) agree with Spencer et al. (2003:4) that trustworthiness in qualitative research should be assessed differently from that in quantitative research, proposing the use of terms such as ‘credibility’, ‘dependability’, ‘confirmability’, and ‘transferability’ for qualitative research. Briefly explaining each of these criteria, Bloomberg and Volpe (2008:86-87) link credibility with validity, and consider whether the research findings are ‘accurate’ and credible from the perspective of the researcher, the participants, and the readers. Dependability is linked with reliability and establishes whether the findings are consistent with the data generated, and confirmability corresponds as far as possible with the objectivity of quantitative research, and considers whether the findings are the result of thorough ‘objective’ research instead of the outcomes of biases and the subjectivity of the researcher. With regard to transferability, Guba and Lincoln (in Bloomberg and Volpe, 2008:87) argue that this deals with the ways in which

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the reader determines whether and to what extent this particular phenomenon in this particular context can transfer to another particular context(s). Regardless of the emphasis, Bloomberg and Volpe (2008:85) stress that researchers must continue to manage potential biases throughout the design, implementation, and analysis phases of their research. Taken together then, validity in qualitative research involves three important elements: sound research processes to ensure that quality evidence is generated from which sound conclusions can be formulated.

Triangulation, an approach that involves analysing and investigating a research question from multiple perspectives, is often used by qualitative researchers to establish validity in research. Material/data is collected in as many different ways and from as many diverse sources as possible. This allows the research to develop a more comprehensive and in-depth understanding of a phenomenon through the use of different avenues and methods of investigation. Its usefulness for research, according to Cohen and Manion (1986:254), is that it presents a way of 'mapping out, and explaining more fully the richness and complexity of human behaviour by studying it from more than one standpoint'. In this way, triangulation permits a 'more detailed and balanced picture of a situation' (Altrichter, Posch & Somekh, 1996:117). Triangulation for cross-checking data from multiple sources can be used to distinguish regularities in the data (O'Donoghue & Punch, 2003:78). Patton (in Guion, Diehl & McDonald, 2011:1) does not agree completely with the latter statement; in his view the search for consistencies in data presents a common misconception often associated with the goal of triangulation. He maintains that inconsistencies / irregularities may in any event be likely given the relative strengths of different approaches, and in his view such inconsistencies and irregularities rather than being seen as weakening or invalidating the evidence, should be viewed as an opportunity to uncover deeper meaning in and from the data.

Triangulation is understood to enhance reliability in qualitative research, providing multiple methods to produce corroborating evidence and enabling a comprehensive picture to emerge. Not only does the use of multiple methods assist with data triangulation, an additional usefulness, according to Gray (2004:33) is that triangulation helps to balance out any of the potential weaknesses in each data collection method. Weighing up the advantages against the disadvantages of this method, Thurmond (in Guion, Diehl & McDonald 2011:2-3) mentions the following benefits of triangulation for research: '… increased confidence in research data, it creates innovative ways of understanding a phenomenon, it reveals unique findings, and

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triangulation provides a clearer understanding of the problem'. Thurmond (2011) also maintains that triangulation can be challenging, and:

> *[triangulation can be] time-consuming, collecting more data requires greater planning and organization, resources might not be readily available to the researcher, as well as the possibility of disharmony based on researcher biases, conflicts because of theoretical frameworks, and a lack of understanding about why triangulation strategies are used* (Thurmond in Guion, Diehl & McDonald, 2011:3).

The main benefit of triangulation as recommended by Guion, Diehl and McDonald (2011:3) is that it can deepen the research's understanding of the issues and maximize confidence in the research findings of qualitative studies.

Issues of validity and reliability were accorded appropriate attention within this research. For these purposes, data triangulation, utilizing data acquired from different sources, and methodological triangulation, employing a combination of methods such as interviews, questionnaires, and observations, served this research.

4.11 Limitations of the Study

Limitations of a study refer to those conditions that can weaken or diminish the study and its findings, and no research is without its own set of limitations. Certain limitations in this research relate to the qualitative methodology, the sample size and traits of the teacher participants, while others can be identified within the research design itself. Such instances were duly noted and the strategies used to minimize their impacts are mentioned.

Limitations associated with qualitative studies relate to concerns about issues of validity and reliability, the fact that this type of research takes place in 'natural settings' makes it difficult to replicate (Wiersma, 2000: 211), interpretation can be time-consuming, and this type of research relies heavily on the descriptions and observations of an individual researcher. Researcher subjectivity and potential bias are also crucial limiting factors that require careful consideration and explicit acknowledgement in any qualitative study. Researcher subjectivity is a chronic issue for qualitative research, given that data analysis rests solely with the researcher and his/her experiences, thinking, understanding and judgement. With regard to

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researcher subjectivity, Patton (2002:40:41) makes some important comments: that in qualitative research an analyst owns and is reflective about his/her own voice and perspective, a credible voice will convey authenticity and trustworthiness; while complete objectivity is impossible, and pure subjectivity on the other hand undermines credibility. Patton (2002:40) advises that the focus should be on maintaining a balance between understanding and depicting the world authentically in all its complexity, while being self-analytical, politically aware, and reflexive in consciousness throughout the research study. Biases shaped by human interests, needs, insights and expectations can have equally important implications for the research. Issues of subjectivity and bias require careful attention, and these have been attended to in this research through the use of multi- methods, a variety of data collection tools, and triangulation.

Limitations also associate with the various data collection tools used, the ways in which they were used, and the type of information obtained from these processes. The biological questionnaire seemed to be the most convenient method of acquiring professional information about the teacher participants. With regard to the interviews conducted with teachers, it was not possible to standardise the interview situations as these were held at different schools and under very different conditions. The schools are also not all located in the same area or community, and getting to some of the schools involved extra travelling and expense. Some interviews were rescheduled several times as it was difficult to get to some of the teachers, their free time at school was understandably constrained by various responsibilities. Observations of lessons seemed the least problematic of the data collection methods involving interactions with people since the observations were conducted by the researcher during the course of Project implementation. Document analysis and analysis of photographs also proved less complicated.

The small research sample can be considered to be an additional limitation of this study. One critique of this research may be the limited possibility of generalizing findings to other contexts and programmes. Even though generalizability was not an objective of this study, the research attended to the issue of transferability of findings by providing rich descriptions about the context and background of the study, the PSP, the Cluster Project, schools and teachers involved, key elements and processes of the teacher development model, and by making careful recordings and analysis of teachers participants' particular experiences, views and interpretations. It was anticipated that these measures would permit the knowledge and insights

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presented in this research to be appropriately assessed for their applicability to other contexts and for other teacher development programmes.

A small scale qualitative case study is necessarily required to clarify the selection of participants and participant characteristics, and to relate selection criteria and procedures to the research purpose. An earlier segment of this chapter explained that eleven teachers were initially identified for study, later ten were interviewed and observed. During analysis, the number of research participants was further reduced to 6, including 3 male and 3 female teachers. This reduction was motivated in part by the need for this research to adhere to a length limit, as well as the need to streamline the presentation and analysis of data.

For this research the attribute of interest amongst participants was that they were primary school teachers who participated actively in the 2007 – 2009 Cluster Project. Thereafter, a range of personal differences such as age, personality, values, beliefs, life experiences etc., professional differences such as qualification levels, teaching experience, teaching styles, teacher-learner relationships, and the nature of teacher-learner interactions, etc., and detail pertaining to their contexts of work such as the location of the school, school ethos, dominant language and culture at the school, learner complement, etc. was distinguished. Additional differences have to do with the Science lessons the teachers taught, the learner grade levels, teaching and learning environments (Science laboratory or classroom) and the resources used. These differences are explained in more detail in Chapter 5.

The researcher's association with the Cluster Project and participating teachers is explained in Chapter 1. Reiterating, the researcher is employed by the PSP as a science facilitator, and one of the work functions has required involvement with the Cluster Project. To a certain extent, the position held by the researcher may have impacted the relationship between the researcher and the teacher participants. Participants may have experienced difficulty adjusting to the different roles assumed by the researcher, and therefore consciously or unconsciously elected to amend the way they interacted with the researcher. This is a phenomenon Maxwell (1996) calls 'participant reactivity'. Two instances of participant reactivity as observed by this researcher are mentioned:

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- In their eagerness to show their support for the researcher, participants may sometimes have modified their responses, perhaps motivated by a desire to appear cooperative and helpful.

- On the other hand, and in spite of the researcher's best efforts, some participants may have responded in a cautious manner, and may at times have been less inclined to offer more detail. This can be attributed to feelings of insecurity, fear of being assessed and assigned scores, so they tend to be less forthcoming, with the result that less information is acquired.

The research thus engaged various strategies to attempt to pre-empt and accommodate such limitations in this study. Some of these steps included explaining the purpose and nature of involvement to the teacher participants in advance, securing their voluntary participation in the study, developing the kind of relationships that fosters open and candid dialogue between researcher and participants, interviews were unstructured and recorded to encourage participants to talk freely, I followed responses with probing questions to encourage participants to elaborate on their responses, and I team-taught Science lessons with the participants to help participants and learners feel comfortable with my presence in the classroom as I observed their teaching.

Not being able to communicate with teachers in their mother tongue, isiXhosa, placed obvious limitations on my interactions with isiXhosa first language teachers involved with the Cluster Project, and especially the two teacher participants in this study who have isiXhosa as a first language. This is acknowledged as a limitation. I chose not to use translations, and conducted interviews with teachers, learners and school management teams for this study mainly in English. In some cases, and where it was possible, some questions were clarified in the language of Afrikaans during interviews with Afrikaans-speaking teachers.

A shortage of critical resources, such as, computers and Internet access, and textbooks and other printed material, and Science apparatus, was a further limitation observed at a number of schools involved with the Cluster Project. I observed that a lack of resources placed limits on what teachers could achieve at some schools in terms of practical Science investigations. Teachers were also limited in accessing additional means such as Internet access and well-stocked school libraries to improve themselves professionally through self-study.

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The final limitation mentioned here concerns a critical omission of this research. The impact evaluation of the Cluster Project 2007 – 2009 by the independent evaluator (2009) did not review and reflect on teachers' classroom practice and children's learning of science. According to Guskey's (2002) this represents a crucial oversight since evaluating the outcomes of teaching practice on children's learning is an important measure of the effectiveness of professional development programmes. The second evaluative study by the Centre for Educational Research, Evaluation and Policy (CEREP) lead by Professor Clifford Malcolm (2004) paid careful attention to both critical issues. Details about the two evaluative studies are provided in Chapter 5. Whereas, this research about teachers' professional development included a focus on teachers' practice in the classroom, it also did not review and reflect on children's learning of science. This omission is acknowledged as critical, hence follow up research is recommended to address this shortcoming.

4.12 Conclusion

This chapter presents a detailed description of the qualitative research methodology employed in this research, providing explanations about the perspectives, procedures and tools used, the ethical issues observed, as well as steps taken to ensure maximum validity of the study. The advantage of the qualitative method for the research, according to Patton (2002), is that it is well-suited to understanding programmes and situations holistically and in depth. Further, such a holistic approach assumes that any understanding of a programme or product depends on a clear awareness of its political and social contexts, and allows the researcher to pay special attention to particular nuances, settings, and idiosyncrasies.

I consider a multi method approach to have been an advantage for this research since it has contributed to an in-depth understanding of a complex process, and facilitated access to data for corroboration, expansion, and elaboration of the findings. The participant sample was made up of six purposefully selected individuals. Data were obtained via teacher questionnaires, interactive and semi-structured interviews with participating teachers, classroom observations, and a range of documents such as lesson plans, reports on training workshops, classroom visits, and project assessments. The data were reviewed against literature as well as in terms of emergent themes. Credibility and dependability were accounted for through various strategies, including source and method triangulation.

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An exploratory case study of the Cluster Project model focuses on acquiring an understanding of teacher development in terms of fostering primary science education. The study sheds light on the work of primary school teachers and on processes for their development for enhanced science teaching in their and other classrooms. Through this process, significant and valuable insights and understandings relevant to the nature of the relationship between enhanced teacher professional knowledge and skills, and improved science teaching and learning have been brought to light.

The next chapter discusses the Cluster Project model within an activity framework in terms of its purpose, design, implementation and outcomes. The chapter provides detailed information about the participants, the schools and their contexts, and the PSP facilitators.

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CHAPTER FIVE: ANALYSIS OF CLUSTER PROJECT CASE STUDY

5.1 Introduction

This chapter investigates the Cluster Project case study using collected data, focusing on key research issues. The analysis of the case study is performed according to the activity framework, complexity framework, and research-developed qualitative framework, as discussed in Chapter 3. The purpose is to determine whether the Cluster Project model can promote teacher professional development (TPD) for enhanced primary science education.

The key questions of this research which guide the analysis of the Cluster Project case study, as described in Chapter 1, are:

- What is the efficacy of the Cluster Project model for promoting in-service teacher professional development (TPD)?
- Does the Cluster Project model meet the professional training needs of in-service primary science teachers?
- What is the effectiveness of the teacher development model for fostering improved Natural Sciences instruction and learning in primary schools?

This chapter presents the data on the Cluster Project model, its objectives, structure, delivery and outcomes, together with data on the school contexts, teacher participants, the service provider (PSP) and facilitators involved, and the processes for monitoring and evaluation.

Thereafter, analysis of the Cluster Project is expanded through contrasting the structure and outcomes of the model with critical aspects of frameworks, models and processes described in 3.5; describing connections with Engeström’s Learning Cycles, Contradictions and Boundary Crossing; and elaborating on influences of the Cluster Project on teacher development within a complexity framework.

Each focus area and its subset of criteria was applied separately to the body of data acquired from semi-structured interviews, classroom observations, various records such as facilitator

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workshops and school visit reports, Project reports and lesson plans to locate and describe indicators of professional development.

5.2 Background to the Western Cape Primary Science Programme's Cluster Project

To address the need for TPD that accompanied the introduction of the new national curriculum, the Western Cape Primary Science Programme (PSP) was established in 1984 in Cape Town; later the organization became a subsidiary of a national PSP body. A funding shortage led to the collapse of the national body in June 1999 following which, the current operation re-established itself in the Western Cape as an independent non-governmental, non-profit organization, developing as a service provider in the field of TPD.

The organization undertakes to provide training and support to primary school teachers to promote science teaching and learning for the most part in previously disadvantaged schools. This is achieved through the professional development of teachers by way of workshops, mentoring and coaching, classroom observation and support, establishing support networks; and by developing and supplying resources to teachers. In providing all of these services, the PSP endeavours to attend directly to the need for teachers to develop their professional capacity, while at the same time indirectly serving the needs of the learners for quality science teaching and learning.

As a mature NGO the PSP has a long history of involvement in in-service TPD and support in the Western Cape. Positioned thus, it has observed and engaged with curriculum change processes over time, as well as observing the impacts of these reforms on teachers and their work. Curriculum change events brought with them the demand for innovative approaches to teaching and assessment, and changed teaching and learning roles. In responding to the exigency for change, the PSP adapted its programmes accordingly to maintain the alignment of its support with the needs of the teachers and a changing curriculum.

While its focus area is the Natural Sciences and science teaching, it has extended operations to offer development opportunities for teachers in language, mathematics, environmental education and social sciences. Operating within national education policy frameworks, and collaborating with various official structures and partners, the PSP assists teachers with curriculum interpretation and implementation through the professional development

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programmes it offers, and by producing a range of teaching and learning resources for teachers. The PSP has over the years strengthened its position in the field of education through active engagement at all levels, from curriculum policy development to interpretation and implementation of the curriculum in the classroom. Furthermore, the PSP works closely with the Western Cape Education Department (WCED) and other education groups to support science teaching and learning in primary schools, thereby ensuring the legitimacy of its work with teachers and the with education authorities.

The PSP offers several concurrent teacher development projects, often independently or in collaboration with the WCED and other allied organizations. Some of these projects include the Innovation Project, Zenex Sparks Project, Hands-on Environmental Project and the Cluster Project. The Cluster Project offers guidance and support to teachers on how to plan, teach and assess the Natural Sciences curriculum for Grades 4-7. Special provision was made in the 2007–2009 Cluster Project to include the Grade R and Foundation Phase teachers in the programme. This addition to the Cluster Project model was retained in subsequent cycles of the project. The Cluster Project is a collaborative one conducted over the years in partnership with the WCED North, South, East, Central, Overberg and Cape Winelands education districts, and involves small clusters of schools within each of these districts. The district offices identify the schools located within each region that may benefit from the kind of support PSP offers, but the science teachers at each school are required to voluntarily commit themselves to involvement with the programme.

Following a review of its previous one-year and two-year cluster projects in 2006, the PSP decided to extend its programme of support for teachers to run over a three-year period. The intention being to intensify the professional development and support offered to all the Natural Sciences (NS) teachers and to the school management who elected to join the 2007-2009 Cluster Project. Since this was the first cluster of schools to receive extended professional support over a three year period, the PSP elected to have the impact of the first two years evaluated against the projected outcomes. Angela Schaffer, an independent evaluator, was contracted to collaborate with the PSP Natural Sciences facilitators on an impact study. It was agreed that the focus of the evaluation conducted by Angela Schaffer (2009) would be the teachers' knowledge of the Natural Sciences curriculum, their understanding of its professional requirements, as well as its implementation in the classroom.

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5.3 The Cluster Project Model within an Activity Theory Framework

The Cluster Project model offers teachers training and support on how to plan, teach and assess the Natural Sciences curriculum at small clusters of primary schools in urban townships and in rural areas, in collaboration with the Western Cape Education Department (WCED) and Project donors.

Prior to the introduction of the Cluster Project, the service provider (Primary Science Programme) implemented the project model for five years in four education districts across greater Cape Town and the Boland/Breede River region, and assisted the School Management Teams and Natural Sciences teachers at 140 Western Cape primary schools. Earlier project implementation, consisting of one and two year training and support programmes, was organized to improve teachers' understanding and implementation of the official planning requirements of the National Curriculum Statements (NCS). Following a review, which showed the minimal impacts of the shorter training programmes on teaching practice, the service provider adapted the model to run over a three-year period with the aim of strengthening, deepening, and sustaining the impact of the programme.

Activity theory provides a useful framework for interrogating a teacher development programme for improvements in primary science education, by situating practices and processes in context. Employing Engeström’s (1987) third generation activity theory, the Cluster Project model is interpreted as an activity system, with system components represented graphically in Figure 5.1, and explained below.

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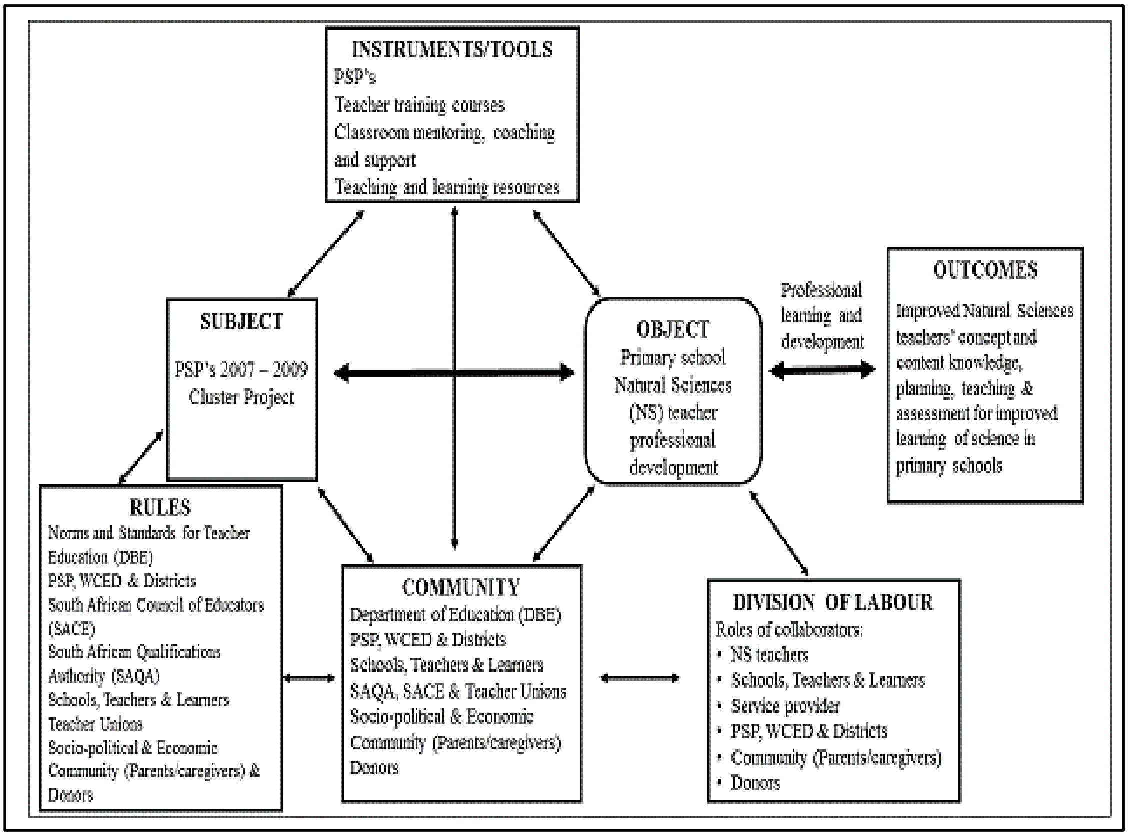

Figure 5.1: The 2007–2009 Cluster Project model as an activity system

Applying the activity theory framework to the Cluster Project model provides the components: Subject, Object, Instruments/Tools, Community, Rules, Division of Labour, and Outcomes.

5.3.1 Subject

The unit of analysis is the Cluster Project; its organisation and agency. Situated as an exploratory case study, this research examines the goals, configuration and implementation of the Cluster Project model in relation to the objective of TPD and outcomes of improved primary science education, taking into consideration the mediating instruments and their purposes and functions, the various members making up the community, the roles and responsibilities of those involved, and the rules regulating the activity.

The Cluster Project retained important components of the original design, offering Natural Sciences training, classroom and resource support to all teachers at 40 schools. Schools in need of this kind of training and support were identified by the WCED education districts and, once the school management and teams of teachers committed to participating in the project, a memorandum of understanding was drawn up with the teachers and the schools.

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Over the three years teachers received training courses of six-hours each term. Aligned to the curriculum, the courses focused on activities that develop Natural Sciences content and concept knowledge as well as hands-on teaching methodologies – "how to teach" science practically in the classroom. Training courses also integrated various teaching strategies for promoting language and mathematics development together with the teaching of Natural Sciences, where this could be integrated naturally. Some of the exercises for language development included developing lists of new words, integrating shared reading and shared writing exercises, and using a writing framework for investigative reports. For mathematics development, some lessons included representing data using bar and line graphs, naming and describing two-dimensional shapes and three-dimensional objects, and developing children's measurement skills which included using the appropriate units and apparatus.

Training courses were followed by individual visits each term where teachers were offered in-classroom coaching and assistance. Support during these visits took the form of demonstrations, team-teaching, observations and reflection sessions that allowed facilitators to assist teachers with implementing key practical lessons at the appropriate level in their contexts. In addition to the training and classroom support components, project implementation also included the supply of classroom focused resources developed by the service provider.

Forty primary schools across 5 Education Management and Development Centres of the WCED participated in the 2007–2009 Cluster Project: 6 schools in Metropole South, 7 schools in Metropole Central, 8 schools in Metropole North, 8 schools in Metropole East, and 11 schools in the Metropole Cape Winelands District. Early into the project 3 schools opted out, with reasons not specified. The project involved a total of around 375 teachers, of which about 227 were Foundation Phase teachers. Although the project provided training and support to Foundation Phase teachers to assist with the teaching of the Natural Sciences component forming part of the subject Life Skills in this phase, the main focus of the project was training and support for Intermediate and Senior Phase (Grade 7) Natural Sciences teachers.

Allowing for an average of 4 science teachers per school – 1 teacher per grade for the Grades 4 – 7 – the project involved around 148 Intermediate and Senior Phase (Grade 7) teachers, and 375 overall. This research examines indications of TPD with regard to 6 Intermediate and Senior Phase (Grade 7) teachers who participated in the programme – about 4 % of the group of Natural Sciences teachers. Selection of teacher participants was guided by voluntary

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participation and candidate suitability, and schools were selected automatically based on the selection of the teachers. Although female teachers dominated the group, an effort was made to recruit an even number of male and female teacher participants for this research.

5.3.2 Object

Engeström (in Hardman, 2008:72) interprets the object as the "the raw materials" or "problem space" at which the activity is directed and which is moulded and transformed into outcomes using physical and symbolic, external and internal mediating instruments, including both tools and signs. Hardman (2007) explains the object of an activity as the collectively shared problem space that community members act on and transform during the unfolding activity. In the case of the Cluster Project, the professional development of primary school science teachers occupies the object space. With the aim of generating improvements in Natural Sciences teaching and learning in schools, the project presents opportunities for teachers to upgrade their science knowledge and understanding, knowledge and implementation of the national curriculum, and capacity for teaching science.

The Cluster Project employed various means of tracking and evaluating the achievement of its objectives; using written pre- and post-tests to monitor science content and concept knowledge gains; observation schedules to monitor improvements in classroom practices; and reviewing lesson plans, learner books and portfolios to record and monitor teachers' science teaching and coverage of the curriculum.

Improvements in science learning at the primary school level is an objective shared by the community, the service providers, the WCED, schools, teachers, and donors. Commitment to the object and outcomes is demonstrated in various ways, through schools and teachers undertaking a memorandum of understanding, education districts and schools supporting project implementation, teacher attendance at training courses, teachers allowing facilitators into their classrooms, teachers implementing new learning and practices in their contexts, and through donor financial support of the various processes of the project.

5.3.3 Instruments/Tools

In the Cluster Project the mediating instruments for TPD are the training courses, on-site school and classroom support, the facilitators providing the training and support, and the various

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resources provided, such as printed materials and science equipment. Although the service provider decides on the training course content and forms of in-classroom support provided to teachers, these decisions are influenced by terms and conditions determined by components of the larger education community; that is the national Department of Basic Education (DBE), the Western Cape Education Department (WCED) and its district offices, the South African Council of Educators (SACE), and the various teacher unions.

5.3.4 Community and Rules

These exert influences on the selection of training course content, and the manner in which classroom support is provided to teachers. For example, course content is aligned to the national curriculum to assist teachers with its implementation, and the service provider reports on their work in schools to the education district offices who monitor processes through departmental officials and curriculum advisors assigned to Natural Sciences. Visits to teachers' classrooms are influenced by conditions determined by the education department in conjunction with teacher unions. Teacher unions have agreed to facilitators' visits to teachers' classrooms since these are intended to offer teachers support rather than evaluate them.

Community: The community in the activity system is that group of people with a shared objective. Several levels are identified within the community involved with the Cluster Project. At the macro level the community consists of the Department of Basic Education, the WCED and its different education district offices, SACE and teacher unions, science teacher associations, various project donors, as well as the larger socio-political and economic community; and the micro level community includes the school, colleagues, parents and caregivers, the teachers' own classroom and learners. The analytical lens is focussed on the Cluster Project, the teacher participants and the service provider presenting the teacher development programme, as well as others such as the school principals, School Management Teams and education district officials who play a lesser, but important role in the programme.

Rules: Rules regulate the use of time, organization and implementation of the training and support components, mediates interaction between teacher participants, facilitators, district officials, and donors, determines the nature of support provided to teachers and the criteria for monitoring and evaluating outcomes of development processes. A critical aspect of Engeström's systems thinking, according to Hardman (2008:69), is that it enables one to

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conceive of pedagogical practices as playing out in a rules-bound context in which power and control influence practice. In the context in which the Cluster Project is presented to teachers, power and control is lodged with several separate institutions such as the WCED, its education district offices and schools, teacher unions and teachers, and the donor communities. Each unit imposes separate sets of rules and regulations with respect to various aspects of the project and its delivery, and complicates project implementation.

5.3.5 Division of Labour

This component deals with the decision-making powers, and horizontal and vertical allocation of roles and responsibilities to the various participants. In the case of the Cluster Project, this includes the service provider, teachers and project facilitators, the principals and School Management Teams, education district officials such as the curriculum advisors, and project donors. The service provider's project facilitators prepare, coordinate and evaluate training and support, and produce learning support materials; the teachers attend the training workshops, implement learning in the classroom with support, and use the learning support materials in their lessons; the principals and School Management Teams support the programme at schools by making sure that teachers are informed when training and school visits are organized, and they also arrange that the required resources are available to teachers; the curriculum advisors support the implementation of the development programme, collaborating with the facilitators and offering advice to project facilitators and teachers; and the donors provide the funding for the project.

5.3.6 Outcomes

The object of the Cluster Project is enhanced teacher professional development (TPD) for improvements in Natural Sciences learning outcomes. Improvements in science learning in primary and secondary schools is at the top of the national, provincial and local school improvement agendas. For improvements in science learning outcomes, various approaches, activities, pedagogies and resources have over the years been developed, implemented and assessed, with varying degrees of success. The Cluster Project model with its focus on improved science teachers' knowledge and teaching practice represents another strategy towards achieving improvements in the Natural Sciences learning outcomes specified in the National Curriculum Statement (NCS). The intended outcomes of the Cluster Project in terms

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of TPD are measurable according to the NCS outcomes for the Natural Sciences. These NCS outcomes are described in more detail in the following section.

The NCS (2002) for the Natural Sciences learning area contains four major components:

1. Critical and Developmental Outcomes
2. Learning Outcomes
3. Assessment Standards
4. Content for Natural Science

Critical and Developmental Outcomes

The NCS bases its Learning Outcomes on the Critical and Developmental Outcomes that were inspired by the Constitution. Some examples of the seven Critical Outcomes require learners to be able to:

- identify and solve problems and make decisions using critical and creative thinking;
- work effectively with others as members of a team, group, organisation and community;

And, some of the five Developmental Outcomes require learners to be able to:

- reflect on and explore a variety of strategies to learn more effectively;
- participate as responsible citizens in the life of local, national and global communities.

Learning Outcomes

For the second component, the NCS (2002: 8 - 12) identified three important Learning Outcomes for Natural Sciences, summarised as follows:

Table 5.1: Learning Outcomes in Natural Sciences

Learning Outcomes	**Title**	**Statements**	**Components**

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1	Scientific Investigations	The learner will be able to act confidently on curiosity about natural phenomena, and to investigate relationships and solve problems in scientific, technological and environmental contexts.	- Planning investigations - Conducting investigations and collecting data - Evaluating data and communicating findings
2	Constructing Science Knowledge	The learner will know and be able to interpret and apply scientific, technological and environmental knowledge.	- Recalling meaningful information - Categorizing information - Interpreting information - Applying knowledge
3	Science, Society and the Environment	The learner will be able to demonstrate an understanding of the interrelationships between science and technology, society and the environment	- Understanding science and technology in the context of history and indigenous knowledge - Understanding the impact of science and technology on the environment and people's lives - Recognizing bias in science and technology which impacts people's lives

The first of the outcomes with a focus on the process of science is Scientific Investigations. Two reasons offered in support of this type of outcome in the science curriculum are: science studies natural phenomena and the processes of inquiry are an essential part of the nature of science, and; when children interact with natural phenomena in a "hands-on" way a widely-held view is that it stimulates greater interest, and; practical work allows children the opportunity to "discover" the science for themselves. Though there is general support for the inclusion of the outcome, in practice teachers have often found it difficult to meet the spirit of this outcome, citing access to a science laboratory and basic equipment for investigations, and finding the right balance between openness and specification for investigations as common problems.

The second outcome focuses on Constructing Science Knowledge, which children are required to develop through schooling over time. It is considered a primary goal in science education in

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view of the authoritative nature of scientific knowledge, and its influence on and applicability to everyday life.

The third learning outcome, Science, Society and the Environment, is a more recently formulated goal in science education, and is more challenging to implement since it requires a certain quantity of curriculum development to be linked to local circumstances. The third outcome elicited extensive debate since the links to human society introduces a level of subjectivity that some see as a contradiction of the supposed objectivity of science.

Assessment Standards

The third component for Natural Sciences identifies sets of Assessment Standards, which are associated with each of the Learning Outcomes and their components. Assessment Standards reflect the skills, knowledge and values required to achieve the Learning Outcomes. These are intended to inform teaching and learning, guiding teachers' work. Assessment Standards are specifically tied to a particular Learning Outcome component and grade level, and their content varies from one component or grade level to another.

Across grade levels for a particular component, the Assessment Standards become progressively more demanding. Some Learning Outcome components are not assessed in the earlier grades, and these therefore do not reflect Assessment Standards. Examples of the Assessment Standards and their progressions are detailed in Table 5.2 for two components of Learning Outcome 2.

Table 5.2: Assessment Standards for Learning Outcome 2 in Natural Sciences

Grade	**Comp. 1**	**Assessment Standard**	**Comp. 2**	**Assessment Standard**
4	Categorizing information to reduce complexity and look for patterns	Learner sorts objects and organisms by a visible property	Interpreting information	None
5		Learner creates own categories of objects and organisms, explains own rules for categorizing		None

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6		Learner categorizes objects and organisms by two variables		Learner, at the minimum, interprets information by using alternative forms of the same information

The NCS (2002:14) states that: “Assessment Standards describe the level at which learners should demonstrate their achievement of the Learning Outcome(s) and the ways (depth and breadth) of demonstrating their achievement. They are grade-specific and show how conceptual progression will occur in the Learning Area. They embody the skills, knowledge and values required to achieve the Learning Outcomes.” Further describing three main purposes for Assessment Standards as follows: to help teachers to know when learners have achieved a Learning Outcome; to show the minimum levels which learners should achieve in a specific grade; and to show learners’ level of achievement and progress in a specific grade.

Natural Sciences Content

The last component of the NCS details the Natural Sciences Content for each grade level. Four content strands are specified, these are: Life & Living, Energy & Change, Planet Earth & Beyond, and Matter & Materials. Each strand has two or three sub-strands, and a number of topics are specified under each sub-strand within each phase. In the intermediate phase, the sub-strands, number of topics, and examples of topics for each of the strands are detailed in Table 5.3.

Table 5.3: Content specified in NCS for Natural Sciences

Strands	Sub-strands	Topics	Examples of Topics
Life & Living	Life processes and healthy living. Interactions in environments. Biodiversity, change and continuity.	12	Photosynthesis. Water in ecosystems. Fossils in South Africa.
Energy & Change	Energy transfers and systems. Energy and development in South Africa.	8	Systems for storing energy. Electricity and safety.

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Planet Earth & Beyond	Our place in space. Atmosphere and weather. The changing earth.	13	Earth's rotation. The water cycle. Erosion and deposition.
Matter & Materials	Properties and uses of materials. Structure, reactions and changes of materials.	6	Boiling and melting points. Changes brought about by heating.

In his assessment of the NCS for the development of the Natural Sciences, Hewson (2007: 7) writes it is multi-strand and overly complex, demanding much of educators, learners, and school systems. Although sound arguments can be made that each of the NCS's components represents current educational thinking, combining them into a coherent whole in his view represented no small undertaking for even the most competent educator (Hewson, 2007: 7).

Furthermore, putting the NCS into practice is a difficult task, not only because of the complexity and detail embodied in each of the components, but also because the NCS says little about how the various components could fit together to become a coherent curriculum. Therefore, achieving the goal statement of helping teachers develop a coherent understanding of the NCS within the context of their practice at the time represented a significant undertaking (Hewson, 2007: 9).

Elaborating on various components of the activity system, the following sections describe the Cluster Project (*Subject*) in terms of the teacher participants involved with this research and their professional development (*Object)*, Cluster Project components and methods (*Tools)*, aspects of the schools and context into which the project is inserted and collaborations established (*Community, Rules and Division of Labour)*, as well as processes for identifying and describing influence of the Cluster Project on TPD (*Outcomes)* with reference to internal monitoring and evaluating processes.

5.4 Cluster Project Object (Teacher Professional Development)

5.4.1 Teacher Participants

For the reason that the study is qualitative and seeks to establish the implications of teachers' participation in the Cluster Project with respect to their professional development as primary science teachers, the sampling strategy used was non-probabilistic case studies. A group of 11 teachers were initially identified and interviewed for this research, later the group was reduced to 6 teachers. The 6 teacher participants, relevant information is contained in Table 5.4, are formally recognized as exemplary educators at their schools.

Table 5.4: Teacher participants

Participant (by pseudonym)	Age (2007)	Gender	Ethnicity	Post Level	Language	Professional Education & Training	Main subjects	Education & training for science teaching	No. of years teaching	No. of years teaching science	Main teaching subjects	Phase
Teacher A	42	Male	Coloured	1	English & Afrikaans	College	Geography & History	Workshops only	> Than 10 years	> Than 10 years	Natural & Social Sciences	Intermediate & Senior Phase
Teacher B	35	Male	Coloured	1	English & Afrikaans	BA & B.Ed. with distinction	Geography, Human Movement	Workshops, self-taught	> Than 10 years	> Than 10 years	Mathematics, Natural & Social Sciences	Intermediate Phase
Teacher C	42	Male	Black	1	English & isiXhosa	College	isiXhosa & Science	College, CTLI & Workshops	6 – 10 years	1 – 5 years	Mathematics, Natural & Social Sciences, and Technology	Intermediate & Senior Phase
Teacher D	35	Female	Black	1	English & isiXhosa	BA Degree	History & isiXhosa	CTLI & Workshops	5 years	5 years	Natural Science & Technology	Intermediate Phase
Teacher E	32	Female	Black	1	English & isiXhosa	College	Social Sciences & Natural Sciences	College & Workshops	6 – 10 years	6 – 10 years	Natural Science & Technology and Economic & Management Sciences (EMS)	Intermediate Phase
Teacher F	43	Female	Coloured	2	English & Afrikaans	College	Biology & Language	College & Workshops	> Than 20 years	6 – 10 years	Language (Afrikaans), Mathematics & Life Orientation	Intermediate Phase

The 6 teacher participants are located at 5 different schools, with 2 teachers stationed at 1 school. Two schools are located in the Central education district, and 3 are in the North education district. The study includes 3 males and 3 female teachers. With regard to racial and home language demographics, of the 6 teachers 3 are Black and fluent in isiXhosa (home language) and English, and 3 are Coloured and fluent in Afrikaans and English. With the

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exception of 1 teacher who is at a school where the learner demographics is a combination of Coloured and Black population groups, 5 teachers are at schools where the learner demographics is reflective of established communities surrounding the school, either predominantly Black or predominantly Coloured. Two teachers live close to the school, 2 live in the same area as the school, and 2 teachers live in a different area.

Five teachers are post level 1 teachers, and 1 teacher, Teacher F, holds a post level 2 post as Head of Department (HOD). Teacher F attended all the Cluster Project training courses, but only taught science in the third year of the project, and was then selected as a teacher participant for this research. The inclusion of participant 6 allowed the research to draw on the perspective of a senior member at a Cluster Project school.

Four of the teacher participants received their initial professional training at teachers' training colleges, and 2 teachers obtained university degrees, a Bachelor of Arts (Majors are Psychology, History and isiXhosa) and a Bachelor of Education degree (Majors are Geography and Human Movement). Both teachers acquired their teaching qualifications at the University of the Western Cape. Two teachers received initial teacher training at colleges in the Eastern Cape, and 4 were trained in the Western Cape.

Four teachers received education and training for science teaching through universities, colleges and workshops, and two received their training for science teaching mainly through various workshops. In addition to receiving science teacher training through the Cluster Project, 4 of the teachers also attended short science courses provided by the PSP in its Innovation / Wide-net Project, 2 teachers attended science training courses offered at CTLI (Cape Teaching and Leadership Institute) also presented by PSP at the time, and 1 teacher, participant 2, indicated that much of his knowledge of science and science teaching prior to involvement with the Cluster project was acquired through independent research, mainly referring to the Internet in his search for information, science teaching ideas and activities to do with learners. Teacher B is well qualified with two degrees and is the youngest male member of the group. Amongst all the participants, he appeared most comfortable and familiar with the latest available technology and research, and acquired information for science lessons independently.

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Three of the teacher participants taught for more than 10 years, and 3 teachers taught for less than 10 years. Teacher D indicated that she studied part-time for a number of years while working in an entirely different field before becoming a teacher, hence the shortest teaching period at that time. Two teachers taught science for more than 10 years, and 4 teachers taught science for less than 10 years. Except for the post level 2 teacher, a Head of Department, 5 teachers taught science for the duration of the Cluster Project. Teacher F later taught science in the third year of the project. The 6 teacher participants taught in the intermediate phase, and 2 teachers also taught in the senior (Grade 7) phase.

In addition to the 6 participants interviewed for this research, one school principal was also consulted for a senior member perspective. This allowed for a comparison of perspectives of two senior members at separate schools interviewed for this research. The principal heads a large urban school situated in a recently established poor community. The school is fairly large with over 1,000 leaners, and a Coloured and Black teacher and learner demographic. The principal is highly regarded by the Education District, other principals in the area, and his colleagues. The principal was selected for interview because he participated actively in the project, attended training workshops with the teachers of the school, and with the Heads of Department (HODs) monitored implementation of the project at the school. With knowledge and experience of the project, the principal provided insight from a senior perspective as to whether or not implementation of the project contributed to noticeable improvements in the professional growth of teachers and science teaching and learning at the school.

Teachers A, B, D and F were at schools which were fairly stable in terms of the management and support within the school. The principals encouraged and supported the science teams of teachers in their professional development. Two teachers, Teachers C and E, were at the same school. The school did not appear to be very stable and organized, and appeared affected by a lack of proper leadership which contributed to a fair amount of animosity and disunity amongst staff members. While Teacher E did not appear affected by the instability within the school, Teacher C seemed affected by a poor relationship with the principal and the Head of Department (HOD). However, Teacher E later moved to another school in the same area, while teacher C remained at the same school and was promoted to Head of Department several years later.

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The teachers were considered au fait with a variety of teaching strategies employed in Natural Science teaching, used the learning support materials supplied, and regularly experimented with an assortment of strategies. For these reasons, they were considered ideal candidates for this research. Informal conversations with some of the management of the school, confirmed that senior members at schools also considered all 6 teacher participants skilled professionals, and this view was readily shared by their colleagues.

The 6 teacher participants demonstrated an openness and inclination to experiment with innovations with a view to developing and improving their Natural Sciences teaching practice. Their enthusiastic approach to experimentation and innovation benefitted the study. Their keen engagement in the project, and willingness to communicate their ideas and experiences as accurately as possible was critical to this research. However, any project work or research in schools with teachers and/or learners required sanction from the authoritative body, the WCED (Appendix D).

5.4.2 Science Facilitators

Some reference to the science facilitators employed by the service provider to deliver the project is necessary in analysis of the Cluster Project, contributing to understanding the inputs and processes of the Cluster Project. The following section describes some of the credentials and roles of the science facilitators involved.

Successful science TPD depends to a large extent on the ability of facilitators to interest, excite and inspire teachers by presenting concepts and content in an interesting and lively way. Well-co-ordinated training courses are required to maximise learning, and to ensure teachers receive the kind of support and guidance they need to develop their science knowledge and teaching ability. Expert in-classroom support allows teachers to gain confidence and trust their own ability to teach and evaluate their teaching, and to cope with the challenges they encounter with implementing learning in their teaching contexts.

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Table 5.5: Summary of information about 5 Cluster Project science facilitators

Facilitators	Age (2007)	Gender	Ethnicity	Languages	Professional Education & Training	No. of years teaching, and science teaching experience
1 (Project co-ordinator)	45	Female	Black	isiXhosa, English & Afrikaans	• BA (Languages and Psychology) University of the Free State • STD (Secondary Teachers' Diploma) University of Cape Town	23 (3 years at a high school, and 20 years involved with science teacher development nationally and provincially)
2	33	Female	Coloured	English & Afrikaans	• Higher Diploma in Education (Hewat Training College) • Advanced Certificate in Education (Technology) (Rhodes University)	20 (9 years at a primary school, 4 years with South African Innovative Learning Intervention (SAILI), and 7 years as facilitator involved with science teacher development)
3	44	Female	Coloured	English & Afrikaans	• Teachers' Diploma (Hewat College of Education) • Higher Diploma in Education (Roggebaai Teachers' College) • BA Degree (University of South Africa) • Honors B Ed Degree (distinction) (University of South Africa) • Masters Degree cum laude (Curriculum Studies) (Stellenbosch University) • Doctor of Philosophy (current)	23 (23 years at a primary school)
4 (Rural)	43	Female	White	isiXhosa, English & Afrikaans	• Higher Teaching Diploma (Wellington Teachers' College)	21 (12 years at a primary school, 4 years as a facilitator for Institute for Mathematics and Science Teaching at Stellenbosch University (IMSTUS), 5 years involved with teacher professional development)
5	53	Female	White	English & Afrikaans	• BSc (University of the Witwatersrand) • PGCE (London University) • M Phil (Education) cum laude (University of Cape Town)	33 (4 years of Scientific work experience, 6 years school educator experience, 23 years as senior science facilitator involved with teacher development)

Table 5.5 above shows the science facilitators involved with the Cluster Project were all female, and held various qualifications; two with Teaching Diplomas, one with a Bachelor of Arts Degree, and two had Master's Degrees in Science Education. One facilitator had over 30 years' experience in working in the educational field, while the remaining four each had over 20 years' experience. The facilitators are highly regarded, consummate professionals, with extensive experience from primary to high school level. Four facilitators had 10 years or more experience in teacher development, and one had only 23 years teaching experience at a primary school. All were fluent in English, and the team accommodated the three languages dominant in the Western Cape.

The science facilitators were responsible for Project delivery, to develop the training workshops, provide in-classroom support, co-ordinate the supply of materials, and arrange the various monitoring and evaluation procedures used to track Project progress. The facilitators designed all aspects of the training courses and support for teachers. They decided on the content and activities to be presented, and developed the research instruments such as the pre-

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and post-tests. They planned school support and lessons with teachers; following up with visits to teachers' classrooms for demonstration or observation lessons, or to team-teach with them; transported material and other resources to schools for teachers to use, and wrote reports to document all their interactions with teachers.

Facilitators managed sound professional working relationships with teachers, demonstrating sympathetic awareness of the conditions under which some teachers worked, and were welcomed into teachers' classrooms. Skilful in evoking participation and creativity, they encouraged teachers to participate actively in their own learning process by using, for example, structured hands-on practical activities, investigations, and open-ended questions in training workshops. They demonstrated various teaching strategies such as active listening and inviting discussion, modelling good science teaching practice in training workshops, offering teachers practical suggestions for particular contextual teaching and learning challenges.

All demonstrated a keen interest in, and passion and commitment to science education and development, very aware of the responsibility that the quality of their collective input determined whether science teaching and learning would improve in the schools they worked with.

5.5 Cluster Project Tools

This section explains Project implementation, (the *Tools* component of the activity system), and details the training courses, classroom support and materials provided to teachers, and offers some information about the science facilitators involved with the Cluster Project.

The 2007–2009 Cluster Project incorporates three main components: the teacher training courses, classroom support for teachers, and the supply of essential teaching and learning materials. The Cluster Project proceeded from the identification of schools in collaboration with the Education Department Districts and, once the management and teams of teachers at each school committed to the three-year project (Appendix L) a memorandum of understanding was drawn up between the service provider (Western Cape Primary Science Programme), the schools and the teachers (Appendix M).

Prior to Cluster Project implementation at the schools, the principals and teachers were asked to complete a Natural Sciences questionnaire for each strand (Appendix N). The questionnaires

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are designed to assess teachers' knowledge and understanding of basic science concepts within each strand. In addition, leaners' Natural Sciences workbooks from a sample selection of teachers were examined according to curriculum coverage, concept development, and assessment to compile a profile of teaching in terms of NCS requirements (Appendix O). Data derived from these evaluations informed the delivery of the Cluster Project. Upon conclusion of the Cluster Project sets of learners' workbooks from the same sample of teachers were again examined using the same tool to identify and describe improvements in the three areas mentioned.

In agreement with WCED districts, schools and teachers, Project Outcomes were identified as:

1. Teachers improve their curriculum knowledge.
2. Teachers improve their Natural Sciences concept knowledge.
3. Teams of science teachers and school management teams within each school collaborate to draw up good teaching and assessment plans that meet the requirements of the NCS.
4. Natural Sciences is taught as required by the NCS: curriculum coverage is appropriate, concept development is evident and a range of assessment strategies is in place.
5. The Cluster Project will gather robust information on learners' Natural Sciences knowledge in schools.

5.5.1 Teacher Training Courses

Each term over the 3 years, all the Intermediate Phase (Grade 4 – 6) and Grade 7 Natural Sciences teachers at the Cluster Project schools were invited to attend a six-hour training course which focussed on activities that develop Natural Sciences concept and content knowledge, as well as practical teaching methodologies – the "how to teach". In addition, each term two-hour Life Skills training courses with a focus on the Natural Sciences component were presented to the Foundation Phase teachers.

Training courses, usually held at the beginning of a term, were presented on different days in different districts. Whereas in the South, East, Cape Winelands, and Central Education Districts

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training workshops were conducted in two-hour sessions over three consecutive weekdays, in the North Education District it was presented as a six-hour course on a Saturday morning. The teachers decided on the arrangement that best suited them. Preference for training on a Saturday morning in the North Education District was supported by the following reasons offered by teachers: "*there are fewer school distractions", "so that we can focus better", "we can benefit from an undisturbed training session", "we can attend the full session"* and *"we are less tired, and less stressed on a Saturday morning".*

In other districts where training workshops were held in the week, some teachers appeared tired in the afternoons; others were distracted, often called out of the training venues for various reasons; and a number of teachers did not attend the 3 afternoon sessions, missing out on parts of the training course. When asked which training sessions they preferred, a facilitator's comments was, *"... we know some teachers are reluctant to give up a Saturday for training, but it is harder working with teachers in the afternoons when they are exhausted and/or preoccupied. You somehow can't get as many activities done with them as you would on a Saturday."*

Training courses had three main objectives, namely to acquaint teachers with the specifications of the curriculum, to develop teachers' Natural Sciences concept and content knowledge, and to engage teachers in practical activities that demonstrate how the content can be taught to learners to help them learn. This is achieved by taking groups of teachers from the main concepts in the curriculum, through to lesson planning and activities for classroom implementation, and then finally dealing with assessment of learning. Content for the training courses was drawn from the curriculum, the NCS at the time, and focussed on the Natural Sciences content for each strand of Life & Living, Energy & Change, Matter & Materials and Planet Earth & Beyond, one strand per term. The arrangement was purposeful, and allowed the facilitators to assist teachers with preparation of the content they had to teach in each strand for the term. *Appendices P - Q* contain course outlines used at the time. These show the course topics and the practical activities conducted with Foundation, Intermediate and Senior Phase teachers in separate training courses.

From these samples (Appendix Q) it appears most training courses adhered to a particular arrangement, commencing with references to the curriculum to orient teachers to the concepts and content they were required to teach at the different grade levels for each Natural Sciences

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strand, lesson planning, and integration of content with 30% "own context" and application of Natural Sciences knowledge in line with specifications contained in the NCS (2002:7) which reads, "The core knowledge statements in Chapter 5 of the NCS represent a time allocation of 70% of the time for the Natural Sciences Learning Area in a Phase. Teachers are encouraged to use the remaining 30% of the time for extending the core and for curriculum development around the economic, environmental, and social or health contexts which are significant to learners and the local community." To further assist teachers with this requirement of the NCS, the service provider developed a list of suggested activities for teachers to use for 30% "own context" for each strand. Appendix R contains suggestions for 30% integration of own context for the strand Planet Earth & Beyond and the strand Life & Living.

Guidance for teachers with the 30% "own context" requirement was also supported with the "Out of the Box" (OOTB) resource supplied by the Old Mutual Foundation to all the Cluster Project schools at the time. The OOTB resource comprised a kit of instruction materials for teachers and a manual of lesson plans for promoting Environmental Education (Appendix S). At each training course teachers were guided on the use of OOTB equipment and the integration of suggested activities into lesson plans.

The main focus of the training courses were the practical Natural Sciences activities teachers were required to do with learners for the different grades. The Cluster Project combined the need for teachers to develop their Natural Sciences concept and content knowledge with the need to develop their science practical skills, as well as with the need to develop teachers' understanding of strategies for teaching specific content. The practical learning opportunities allowed teachers to become familiar with the purpose and use of the science apparatus, addressed deficits in practical skills, and allowed teachers to reflect on the learning of science through practical activity. As teachers were presented with some activities using local materials, and experienced using them, they began to have their own ideas about other local materials as alternatives, or which were even better for particular purposes. At the next training session teachers would share their ideas about the improvisations used in their particular contexts. These improvisations were also observed and reported on by facilitators as they did their school visits.

Training courses actively promoted "hands-on" practical science and aspects of inquiry-based science teaching and learning where this could be reasonable implemented in the different

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school contexts. Motivating for this approach facilitators cited the following, that good quality practical science activities can engage children, stimulates greater interest, builds on children's natural curiosity, helps them develop important skills, helps them understand the process of scientific investigation and conducting fair tests, helps them develop an understanding of important science concepts, and helps them develop an awareness of safety in science.

An important aspect of inquiry-based teaching and learning is that it places learners' questions, ideas and observations at the centre of the learning experience. Teachers were encouraged to incorporate guided investigations, creative problem-solving and critical reflection into their teaching of science. A "hands-on, minds-on, words-on" (PSP, 2007) approach was recommended for developing science learning experiences for children (Appendix T). The approach guided teachers with developing learning activities where children "do something active and physical", "use their thinking skills to solve problems and gain knowledge", and where they "talk, draw or write what they are thinking and learning". At first, the teaching methods recommended appeared challenging for some teachers who were not accustomed to working with learners in this way in their science lessons.

To support teachers develop confidence with the approach science facilitators modelled how teachers can engage children in inquiry-based learning experiences, and how to play an active role throughout the learning process helping children move from a state of wonder to a state of enacted understanding and further questioning. Using practical activities and modelling lessons with teachers helped them learn how to be responsive to the learning needs of the children, and to know when and how to guide learners forward in their inquiry.

Facilitators noted that teachers who attended the training workshops and experienced practical activities themselves were more inclined to take the learning back to the classroom and to implement science lessons. This observation was confirmed during facilitator visits to schools as they monitored teachers' work in classrooms. It also became clear that teachers who had not attended the training courses regularly were at a disadvantage, and were challenged with implementing certain practical lessons, especially where investigations were required. Teachers' engagement in various practical activities is best illustrated with photographs (Appendix U) taken during some of the training courses over the three years, and photographs (Appendix V) taken in teachers' classrooms shows the follow through as they applied their learning in classrooms.

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Exciting teachers about science through practical activity may be important, but it is not sufficient. Even when inspired, teachers need to understand the ultimate purpose of practical activities, and not to lose sight of the science being taught. Setting up practical activities requires some knowledge of basic science concepts, at least a reasonable understanding of the important concepts and principles related to the topics being taught. It was therefore necessary to go through as much of the concepts and content specified in the curriculum as possible to help teachers develop a broad understanding of the content, to carry out the activities recommended in the curriculum, to reflect critically on the outcomes, and to discuss the theory and relevant teaching points with teachers, offering suggestions for alternative activities and materials that could be used for teaching the same concept. These important requirements were accommodated in the science training workshops, and allowed teachers to draw on their own experience and creativity in their teaching. At the end of each training workshop teachers were provided with evaluation sheets (Appendix W) giving them the opportunity to reflect on the quality of the training they received, whether their particular professional training needs were met, and to suggest topics for further workshops.

From the course outlines (Appendix Q) it can also be observed that training courses actively promoted the integration of language and mathematics development in Natural Sciences teaching and learning. For learners to become scientific literate, this would require them to develop knowledge of science content and practice scientific habits of mind, and this would not be possible without knowledge of science vocabulary. Language development in science lessons was promoted through integrating strategies such as: compiling vocabulary lists, building a word wall, incorporating dictionary exercises, reading stories, role-play, reading and presenting research, debates, shared reading and shared writing, developing questions, using graphic organizers such as mind-maps, Venn diagrams for describing similarities and differences, and using writing frames for report writing, etc.

The Cluster Project introduced teachers to a range of teaching strategies for fostering language alongside science learning, and emphasized the importance of integrating writing, reading and speaking activities purposefully into science lessons (Appendix X). The following strategies for supporting science and language learning were included in training workshops, and teachers were further supported with implementation during classroom visits:

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- "Shared reading" engages children in an interactive reading activity. With the guidance and support of the teacher children join in or share the reading of a book or text. The strategy builds children's sight word knowledge and reading fluency;
- "Shared writing" involves teachers composing text with learners, and teaches children about the writing process. The strategy is useful for compiling summaries with learners, helps children reflect on what they learnt, and in this way it reinforces learning;
- Word lists help children build their science vocabulary;
- Writing frames guide children's writing, for example to record observations or to develop a science report;
- Tables of comparison and posters, or other graphic organizers such as mind-maps and Venn diagrams helps with summarizing essential information.

This researcher records an occasion where a teacher integrated science alongside language learning to good effect. At the time, the teacher was at a school piloting a programme which mandated home language isiXhosa as the language of teaching and learning (LOLT) for mathematics and the content subjects in the Intermediate Phase (Grades 4 – 6), whereas previously the LOLT was English. The Grade 7 classes of learners continued to receive instruction through English in mathematics and the content subjects. For the Grade 4 – 6 learners and their teachers, making the transition appeared not quite as easy and uncomplicated as educational authorities anticipated. For Intermediate Phase teachers the switch required extra effort since they were additionally required to develop new lesson plans and assessments in isiXhosa. The task was further complicated by a shortage of appropriate texts to guide teachers. Science teachers found translating material for lessons a difficult task, some seemed not to be aware of isiXhosa equivalents for particular terms used in science. To help children's learning though, the teacher mentioned developed a two language, English and isiXhosa, word list with his Grade 6 learners. In preparation for science lessons, learners guided by the teacher practiced reading and writing the words in both languages. The teacher noted that linking words in the two languages in this way improved children's learning and understanding of science concepts and content, and the strategy produced improved results. The teacher then proceeded to apply the same approach in his teaching of mathematics and technology as well, noting similar improvements in learning.

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The Cluster Project also introduced teachers to a practical tool to use in their science lessons – the KWL chart, with the questions: What do we know? What do we want to know? What have we learnt? (Appendix Y). Teachers find the tool useful for linking new content with prior knowledge, organizing information, and reflecting on and consolidating learning. Adapting the KWL chart with teachers, facilitators added the questions: How can we found out? What other questions do we have? Teachers were encouraged to expand the chart as they saw fit with new questions for science lessons, such as: What (tools/apparatus/equipment) would we need? What safety precautions do we need to bear in mind? Teachers mentioned that they used the chart with other subjects as well.

Science activities often require children to draw on mathematics knowledge and skills, to do basic calculations, to measure, and to reason out scientific relationships (Appendix X). Developing science learning experiences, teachers were encouraged to provide opportunities for children to use mathematics knowledge and skills, for instance for: identifying and describing 2-D shapes and 3-D objects; using instruments to measure the characteristics of height, weight, and temperature; and drawing graphs; etc. Integrating mathematics with science ensures a process approach is used, promotes children's conceptual understanding of science and mathematics, and helps children get to know the bigger picture of why and how things work in science and mathematics. In addition, the mathematics taught through science activities is presented in authentic situations, and these opportunities help children strengthen their mathematics knowledge and skills.

Training courses for Foundation Phase teachers also encouraged natural integration across the disciplines of language, mathematics and Life Skills (Beginning Knowledge, Creative Arts, Physical Education, and Personal and Social Well-being, with science forming part of the Beginning Knowledge component of Life Skills).

Additionally, training courses offered suggestions of strategies to use for certain contextual and learner challenges; for example:

- With large classes, a strategy suggested was to get learners to work in smaller groups;
- In classes where teachers had to accommodate more than one language – a suggested strategy was to use two-language word lists in lessons, for example an English and isiXhosa word list, and to integrate speaking, writing and reading activities into all lessons; and

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- In classes where teachers had to accommodate specific learning difficulties – strategies suggested included: using concrete objects in lessons (where possible), simplifying tasks for learners, scaffolding lessons and assessments, allowing children to read and write shorter pieces of text, and allowing children in work in smaller groups to support each other.

And finally, guidance with assessment of learning formed an essential part of training courses. In this segment of the course, the facilitators referred teachers to the "The Big Eight" (Appendix Z), adapted from Dr Howard Gardner's multiple intelligences (Gardner & Hatch, 1989) by the service provider. Teachers were guided on how to use the "The Big Eight" for developing assessment tasks appropriate for assessing knowledge and understanding of the Natural Sciences concepts and contents being dealt with, for the age / grade level of the learners, and developing assessments that include a variety of communication modes. They were also guided on how to form instructions for assessment tasks, with developing appropriate assessment criteria or rubrics for tasks, and with weighting the mark allocation (Appendix AA) is a sample assessment task. Developing assessment tasks and generating assessment criteria for the tasks appeared to be an area of general concern and a challenge for most teachers. The independent evaluator, Angela Schaffer, corroborates this observation in her report.

The training courses appeared to be very thorough, covering the main areas of support primary science teachers needed at the time: assisting them with interpreting the Natural Sciences curriculum, building their knowledge and understanding of important science concepts and content, helping them develop their practical skills, guiding with teaching strategies appropriate for the content and learner age and grade levels, helping teachers connect science learning with language and mathematics development, and guiding teachers with assessing learning.

Whole school development, teamwork and sharing of ideas and lesson plans among schools and teachers was encouraged, the purpose was to establish a community of practice for teachers to connect professionally, and to share resources, teaching ideas and strategies.

School visits where teachers were supported with the implementation of science lessons in their context of work followed the termly training courses.

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5.5.2 Classroom Support

Training workshops were followed by individual classroom visits for teacher mentoring, coaching and support each term. For this component of the Cluster Project facilitators guided and assisted teachers in their contexts to implement key practical lessons with their learners. School visits were arranged in such a way so as to cause minimal disruption to school programmes.

Prior to the school visits, teachers and facilitators decided upon the lessons that would be supported and the resources teachers needed. An observation schedule (Appendix I) was developed to record classroom activities for the purpose of reflecting with teachers, and for reporting on their progress. On the day of the school visit, facilitators carted basic equipment to schools for teachers to use, especially where these were not available at the schools. Providing the equipment teachers needed was a way of ensuring teachers had the necessary resources to present their lessons. Some basic science apparatus supplied for each strand were:

- Life & Living – magnifying glasses, specimen jars (to examine plants and animals closely), iodine solution, medicine droppers, and beakers (for testing for the presence of starch in foodstuffs),

- Energy & Change – sufficient cells, small globes, connecting wire, motors, buzzers for groups of children, different types of light bulbs, 3pin plugs etc. (for lessons on circuits, the effects of electricity, conductors and insulators, energy efficient lighting);

- Matter & Materials – enough beakers, tripods, burners, gauze wire mats, thermometers, a variety of equipment for measuring for whole class investigations (on solubility, boiling points); red and blue litmus and universal indicator, test-tubes and test-tube stands (for Grade 7 lessons on Acids & Bases);

- Planet Earth & Beyond – sufficient beakers, plastic filter funnels, filter paper, different soils and measuring cylinders (square) (for investigating the water-holding capacity of different soils)

Demonstrations where only the teacher handles the science equipment and learners observe what the teacher does was discouraged. Teachers were rather encouraged and supported to

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conduct investigations where all the learners are actively involved in the lesson, and where they are encouraged to handle apparatus themselves.

Classroom visits were organized differently for different teachers. Teachers decided on one of three forms of classroom support. They could decide on a demonstration or observation lesson, or to team-teach with the facilitator. For demonstration and observations lessons, an observation schedule (Appendix I) was used by both teachers and facilitator to focus on aspects of a lesson the teacher needed guidance with. For demonstration lessons, the facilitator taught the science lesson, demonstrating "how to teach" the lesson and the teacher recorded his/her observations on the schedule. For observation lessons, the teacher taught the lesson and the facilitators recorded his/her observations. And, for a team-teaching lesson, the facilitators and teachers planned and taught the lesson together, with the facilitator supporting the teacher's effort. In cases where teachers appeared uncomfortable about allowing facilitators into their classes, facilitators arranged consultation with teachers, these were usually held in the staffroom of the school. At the end of the school day, facilitators collaboratively reflected on the lessons with the teachers, the principal and the School Management Teams; advised on the challenges for science teaching and learning at the school, elaborated on teaching strengthens and weaknesses, and discussed ways in which science teaching and learning at the school could be strengthened further.

Team-teaching acknowledges the teachers and facilitators as equals in the classroom, and was the form of support preferred by the facilitators and most of the teachers. The collaborative, safe, non-threatening environment created through this partnership put teachers at ease as they interacted with their learners and the facilitators. This arrangement also did not appear to disturb the natural flow of classroom activities, and teachers and learners seemed not to be intimidated by the presence of a stranger in their midst. The mutually beneficial arrangement presented facilitators with an opportunity to observe and support the teacher's practice, and at the same time teachers observed facilitator's teaching, benefitting from being able to observe expert teaching. The learners also appeared more at ease with this arrangement as they still had their teacher with them and were not left alone with a stranger.

Team-teaching provided learners with rich learning experiences. It provided opportunities for facilitators and teachers to share ideas, insights and strategies as they collaborated to deliver strong creative lessons. Among the many benefits of this arrangement for the children was that

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they could engage with different personalities, benefit from different teaching competencies in a lesson, it allowed more interaction between teachers and learners, it allowed opportunities for small group and one-to-one learning, and children observed team-work in action as facilitators and teachers modelled behaviour and positive peer-to-peer interaction.

All too often, issues that individual teachers struggle with in their context are not sufficiently acknowledged. So too is individualized feedback and constructive in-classroom support seriously lacking in most schools. In-classroom support in the Cluster Project focused on improving science teaching practice in context, thereby directly addressing teachers' need for individualized, constructive, practical support and guidance.

Critical benefits of team-teaching for teachers observed in the Cluster Project are that: it takes place within the context of a relationship of mutual trust and respect, there is a shared vision of what matters in the classroom, there is immediate and constructive feedback, there are ample learning opportunities, it reinforces teachers' strengths and they develop greater confidence in their own ability, it acknowledges that teachers' professional needs are different and presents a way of providing individualized attention and support, it creates a safe supportive environment for teachers to test ideas and strategies, and teachers directly observes expert science teaching strategies / techniques they can incorporate into their repertoire of strategies.

Improving teachers' classroom teaching of science was identified as a crucial objective of the Cluster Project. The main purpose of supporting teachers in their classes was to help them develop into highly effective teachers capable of providing the kind of science learning experiences that can meet the learning needs of all children. This component most illustrated teachers' learning as they implemented what they learnt from the training in the context of their daily work with children. And, while training courses are important for building teachers' concept and content knowledge, support in the classroom appeared to be a critical Project component for improving science teaching practice and ultimately children's learning of science.

5.5.3 Teaching and Learning Support Materials

In addition to the training and in-classroom support provided in the Cluster Project, all the teachers (Foundation, Intermediate and Senior Phase) were supplied with a range of classroom focused teaching and learning materials to enhance their work with leaners.

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Originating out of collaborations with teachers, the materials draw on local experiences, culture and knowledge. To ensure suggested activities can be used in a variety of teaching contexts, the materials were trialled extensively in TPD programmes – on courses, in workshops and in classrooms with teachers. The materials take into account particular contextual and professional training needs of South African teachers. The research observed that the materials can be especially helpful to teachers who do not have a science background, and useful to those teachers who are not able to access good quality science textbooks.

The main benefit of the series of science focused books, (Appendix BB), for teachers is that these are closely aligned with National Curriculum, and offers guidance with its implementation. These materials also offer practical classroom guidance to teachers while enriching their understanding of the curriculum. They include examples of innovative and effective classroom activities and assessments appropriate for the primary school levels, Foundation Phase and from grades 4 – 7. Activities contained in the set of teacher support books were trialled extensively in classrooms. Suggested activities focus on the creation of learning experiences that allow children to engage, explore, examine, evaluate and explain the world through practical "hands-on" learning activities. Aspects about the materials teachers find particularly useful are that they are available in two languages, English and Afrikaans, have a three language glossary (in English, Afrikaans and isiXhosa) at the back of the book, include the learner task cards and assessments, and can be freely copied for use in the classroom.

Over many years the service provider developed a range of resource material for teachers in the Natural Sciences, Social Sciences, Literacy (Reading and Writing), and Curriculum Management and Planning. The following resources relevant to science education were added to its collection during the 2008-2009 periods:

- The re-developed Indigenous Plant and Animal Cards (32 Plant and 62 Animal) with a Teacher's Guide were produced in partnership with the City of Cape Town. In addition, the Teachers' Guide contains a glossary in three languages – English, Afrikaans and isiXhosa, and

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- Investigations in Natural Sciences, a booklet containing nine science investigations in the Foundation Phase. It has been translated into Afrikaans (Natuurwetenskappe Ondersoeke), and was translated into isiXhosa as well.

In addition to the science focused series of books, learner resources such as Southern Skies Astronomy Cards, Planet Earth & Beyond lesson plan book with a DVD containing snapshots of the lessons taught in classrooms, a Water Cycle poster, and Indigenous Plant & Animal Cards, (Appendix CC) were supplied to all teachers in the Cluster Project to enhance their science lessons, at no cost to the teachers or the schools. Training usually accompanies the issue of materials, and training modelled how the materials can be meaningfully integrated into science lessons to promote learning.

5.6 Cluster Project Community, Rules and Division of Labour

This section describes aspects of the schools and context into which the project is inserted, and the teacher participants involved with this research.

The Cluster Project is impacted by other systems such as individual teachers and schools, influences from broader activity systems such as the WCED and its education districts, teacher unions, the socio-political and economic and donor communities, which have an effect on project structure, content and training and support activities. Figure 5.2 shows that the field in which the project is implemented consists of a variety of separate but interrelated dynamic activity systems bound by a common objective of improved teacher capacity for Natural Sciences teaching and learning.

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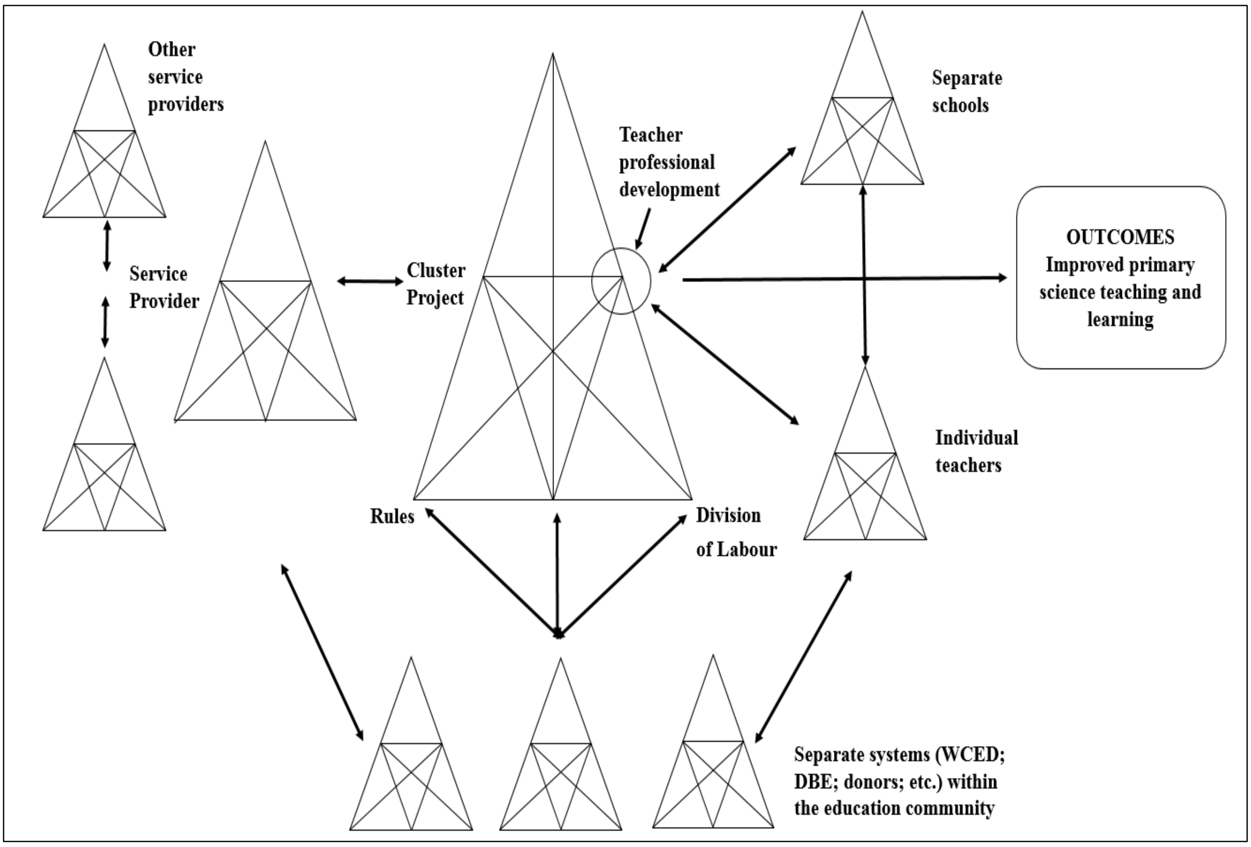

Figure 5.2: 2007–2009 Cluster Project interrelation with other systems

Following the withdrawal of three schools early in implementation, the project proceeded for 37 primary schools (27 mostly urban, a few peri-urban, and 10 rural) across five Education Management and Development Centres of the WCED. The schools who participated in the project are located in various Western Cape municipal districts; in the urban districts of Steenberg, Retreat, Grassy Park, Kensington, Maitland, Surrey Estate, Mitchell's Plain, Manenberg, Delft, Mfuleni, Lwandle, New Crossroads, Khayelitsha and Elsies River; and the rural districts of Witzenberg, Worcester, Tulbagh, Rawsonville, Breede Valley and Langeberg. Most of the schools are located in disadvantaged communities. For the reason that the school and its environment cannot be separated from the academic agenda, attention is now given to describing these with respect to schools' quintile and funding status; the basic structure and availability of additional facilities such as science laboratories, computer rooms, libraries; the learners at the schools; aspects of the surrounding communities; and school management and collegial spirit within the school.

All ordinary South African public schools are categorized into five groups, called quintiles, mainly for the purpose of allocating financial resources by the state, in accordance with

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financial status of the community. Quintile one is the "poorest" quintile, while quintile five represents the 'least poor". These poverty rankings are determined nationally according to the poverty of the community around the school, as well as certain infrastructural factors. The quintile ranking of a school determines the funding it receives each year and, whether or not the school is permitted to levy parents with school fees. No-fee schools may not charge fees; instead, funding allocations are adjusted to ensure that the poorest schools receive the largest per-learner allocations. While the allocations differ significantly between quintile 4 and 5 and quintiles 1-3. Quintile 4 and 5 schools charge school fees to obtain the funding needed to run the school.

Appendix EE summarizes important aspects of the Cluster Project schools; some aspects are illustrated by Appendix FF. While many of the schools are located in the lower categories, quintile 1 and 2, a few are categorized as quintile 4 – 5, thus the set of schools in the project receive varying levels of state support. Given the circumstances of a few schools, their quintile ranking of Quintile 4 and 5 does not appear to work in their favour. This is because, as Hall and Giese (2009) reports, the national data used to determine the poverty status of schools does not take into account the actual learner demographics of specific schools. These few schools do not appear to draw their majority enrolments from the local area, where there may not be children of school going age living in the area. Since these schools draw learners from neighbouring poorer communities, this means these schools educate significant numbers of children from families who cannot meet the fee arrangements, and it seems the erroneous allocation of quintile status becomes a significant source of financial pressure for these schools.

Schools in the Cluster Project are moderately resourced receiving either state support entirely or partially, and most schools and their learners benefit from the National Schools Nutrition Program. Poorly resourced schools with minimal state support have to survive on funding received through various other sources such as school fees. Since most families connected to the school are often in the low-income economic bracket, they are not in a position to contribute much towards school fees. Where parents cannot afford school fees, they apply to be exempted from payment of school fees. These factors contribute to a much reduced revenue and, with increased financial pressures these factors severely constrain the efforts of some schools.

Most of the project schools are built of brick, except one which at the time used metal container classrooms. Container classrooms can be very noisy at times, are not very comfortable, and are

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cold in winter and hot and stuffy in summer. For several older schools with brick buildings, the infrastructure did not appear very sturdy and needed regular and costly maintenance. Mould, leaking ceilings, extreme temperatures, poor lighting and instances of poor sanitation contributed to unhealthy and unsafe conditions. At the time too, one tap at a school provided water to over 500 learners, though conditions have since improved. Such conditions however, coupled with overcrowding in some classes can contribute to more children taking ill, injuring themselves, and diminished productivity in the school.

Thirty-three schools have computer laboratories, 22 have libraries, and 4 have specialist rooms. Although 6 schools boast science laboratories, at the time the rooms were not always used for science lessons, some were being used as classrooms. This applied to libraries and specialist rooms as well, especially where space is limited at certain schools. In some cases, a roster allowed teachers and leaners regular access to the computer laboratories and libraries, while in other cases access was limited for various reasons such as, teachers were not trained to conduct lessons using computers, only a few teachers were permitted to use the computers, and computers were not functioning and needed repairs.

The average number of learners at the larger urban schools is 1000, and the smallest rural school had fewer than 50 learners. Three languages dominate the Western Cape Province, namely English, Afrikaans and isiXhosa. The dominant language of all the rural schools is Afrikaans, while urban schools feature combinations of languages such as Afrikaans and English or isiXhosa and English and others have the three languages. Learner demographics at a number of urban schools feature a combination of Coloured and Black population groups and largely reflects the demographics of recently established communities, whereas at older schools learner demographics is mainly reflective of older more established predominantly Black or predominantly Coloured communities. As mentioned earlier, most of the schools, 34 of the 37, are located in areas generally considered disadvantaged communities, and for the rest learners come from some of the most deprived and depressed rural and urban communities of the Western Cape.

A number of schools are located in formal settlements, whereas others are situated in densely populated informal settlements. Those living in the latter face harsh living conditions. Homes without the proper services such as, sewage, electricity, roads, and clean water, make life very difficult for residents. Densely populated areas provide difficult, narrow access, few communal

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water points and banks of chemical toilets on their peripheries. An array of electrical wires, identified as illegal connections, crisscrossing overhead allow limited access to electricity, but also indicates very dangerous living conditions. Heaps of garbage in some areas, blocked drains, flooding in winter, stagnant pools of polluted water, polluted canals and rivers, dumps of industrial waste, coupled with the high density of people, poor access, and services contribute to extremely unsanitary and unhealthy living conditions. The burdens of poverty, hunger, and poor housing have definite serious impacts on children's learning, and create difficult and challenging conditions for schools, teachers and learners.

The above living conditions provide fertile ground for serious crime and abuses to thrive. Many of the communities are characterized by high levels of unemployment, crime, violence and abuse. Within the dismal physical environment, high levels of alcohol and drug abuse, foetal alcohol syndrome, dysfunctional family interactions, child-headed households, a general lack of support for education within the home, insecurity and hostility in the home and the community, and breakdown of local community structures is rampant. These factors fuel gang activities, so much so that violence and abuse appears an accepted way of life and culture in communities, and the schools located there.

Schools and teachers operating in the midst of all this are sorely challenged to accomplish their mission of educating children. Stresses within the community cannot be separated from children as they enter the school and the classroom, infiltrating and affecting school processes and the teachers' daily work. With the factors above collectively weighing heavily on the efforts of schools and teachers, they engender a great deal of distress amongst the teacher population. The level of anxiety and desperation amongst teachers in some of the schools is best illustrated by the following note (Appendix GG) in a project facilitator's school visit report in which she recorded a teacher's serious concerns at the time. It appears the teacher's general training and education had not sufficiently prepared her for the difficult and challenging working conditions she experienced at the time, contributing to her feeling overwhelmed, unprepared, and ill-equipped to deal with the many challenges she faced. It also appears that working conditions such as these are more keenly felt by teachers when they feel isolated in schools. Such feelings of isolation can develop from managerial factors such as poor leadership, poor school ethos and poor collegiality, contributing to a general lack of cohesion and support within the school.

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The school culture is an important aspect of the school, and refers to the climate or "ethos" which permeates all school activities, affecting the way teachers interact with each other as they work towards educating the learners at the school. A complex web of norms, values, beliefs and assumptions, and traditions and rituals, the school culture, is built up over time as teachers, learners, parents, and school management work together, deal with crises, and develop unstated expectations for interacting and working together (Deal & Petersen, 1990). The school culture in all the Cluster Project schools appeared vastly different. Few schools showed strong collegial support and team work. In these instances, a positive collegial spirit associated with strong school leadership. Encouraged and supported by the principal, teachers attended training courses together, shared resources, and supported each other with lesson planning and presentation. Their collective action supported implementation of science at their schools through each grade and phase.

For a greater number of schools, collegiality and collaboration appeared reduced. In these schools, the atmosphere was characterized either by very little interaction amongst colleagues, and in some instances a great deal of hostility. The project recorded an incident of open hostility at one school, involving a fist fight between two female teachers in the school corridor in full view of a group of learners. Also, though not overt, racial tension and strained relationships was observed amongst teachers and learners and the school management in three urban schools with a Coloured and Black demographic, whereas this was not evident at two schools in the same district with a similar demographic of teachers and learners.

Poor collegiality in a few schools appeared to associate with, in some cases autocratic, and in others cases difficult and inadequate school leadership. In these schools, teachers very much kept to themselves, worked in small groups or worked alone in their classrooms, and preferred to keep classroom difficulties and challenges of practice to themselves. Tensions within the schools and with teachers had definite effects on teachers' commitment to the project, affected their attendance at training courses, and implementation of the science programme at the schools.

Collectively, the factors mentioned raise the complexity of the context into which the Cluster Project was inserted. While acknowledging the wide range of complex contextual and learner factors impacting teaching and learning in Project schools, this research is confined to the

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influence of Project work on teachers since they are the primary audience of the project not the learners, and direct project objectives relate to teacher change and development.

5.6.1 Western Cape Education Department

Close collaborations were formed with the various officials of the education districts in which the Cluster Project was implemented. The service provider met with District Directors, Chief Curriculum Advisors, the General Education and Training (GET) coordinators, and the curriculum advisors responsible for Natural Sciences in the GET phase to acquire authorization for its work. The Cluster Project only proceeded in the district with their sanction and support.

The education districts were regarded as best placed to direct the service provider to schools they considered in need of the kind of support provided through the Cluster Project. In doing so, targeted training and support provided through the Cluster Project was aligned with district development plans.

Following initial consultations with officials for authorization of the Cluster Project, districts invited school principals to their offices where the service provider presented the programme. The principals were then requested to discuss the Cluster Project and implications of participation with the teachers at the schools, and to thereafter express commitment to the Cluster Project via a memorandum of understanding.

Natural Sciences curriculum advisors in the GET Phase in each district were requested to participate in various aspects of the Cluster Project, such as the training workshops and the school support. Their participation in the training workshops was particularly sought, so that they could be aware of the nature of the training and classroom support rendered and the materials provided to teachers. This way, they could further support Project implementation in schools.

Each year, the service provider reported on Project activities to relevant officials of the education district office to share progress, and discuss challenges and concerns.

5.6.2 Additional Collaborations

Collaborations with various other bodies, which benefitted schools in the Cluster Project. These collaborations included with the Wildlife and Environment Society of South Africa (WESSA),

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the Two Oceans Aquarium, the Table Mountain National Park, the City of Cape Town, the South African Astronomical Observatory (SAAO), Iziko Museums, the West Coast Fossil Park, Kirstenbosch Gardens, and the Old Mutual Foundation.

The Old Mutual Foundation provided “Out of the Box” (OOTB) kits of instruction materials and a manual of lesson plans to promote Environmental Education. An environmental project was attached to the supply of the OOTB kits, (Appendix S). The OOTB equipment and suggested activities from the manual were incorporated into training courses, and teachers were offered guidance on how to use the resource effectively for science lessons.

The Cluster Project also became a conduit for resources developed by other organizations, such as the EnviroKids magazines which is produced by WESSA. The service provider, the PSP, provides training with any new materials issued in order to improve uptake and use of the resource. New materials are not distributed to schools and teachers without mediation. The course outline (Appendix Q) makes reference to such an occasion where the EnviroKids magazines on sharks were used with teachers that year. Work sessions of up to two hours were held at each Project school with all the Natural Sciences teachers. The purpose of these sessions was to acquaint teachers with the methodology of classroom *work stations,* and focused on a variety of topics from the magazines such as past and present fishing practices and ocean highways / currents. Facilitators visited schools during October and November of that year to further support teachers using the magazine in their lessons.

EnviroKids magazines focused on important topics such as “Global Warming” and “Climate Change” presented information in interesting easy-to-read ways, and offered many practical activities for teachers to use with learners. Teachers found the magazines useful, and these were especially helpful to them for certain events such as Marine Week, usually celebrated during October of each year. Facilitators also encouraged teachers to use the regular supplies of various magazines such as the EnviroKids in their class libraries (Appendix HH).

In 2007, Wildlife and Environment Society of South Africa (WESSA) negotiated the following opportunities for Project schools:

- Table Mountain National Park sponsored ten bus outings to allow learners to visit the Rocky Shore in Kalk Bay.

- The Two Oceans Aquarium sponsored ten of its outreach school visits to Cluster schools.
- The City of Cape Town sponsored two bus outings for learners to visit the Rocky Shore at the Wolfgat Nature Reserve.

A range of specialists were often consulted for science edits of material resources such as, the palaeontologists connected to the Iziko Museum and the West Coast Fossil Park, and astronomers and education outreach officers with the South African Astronomical Observatory (SAAO). In 2008, as part of a roadshow to generate awareness about the "2009, International Year of Astronomy" Kevin Govender of the SAAO presented a new software "Celestia" to Project schools in the Cape Winelands at their Planet Earth & Beyond celebration, demonstrating how the software can be effectively integrated into teachers' science lessons on Astronomy.

Facilitators drew on strategic collaborations such as those mentioned above for the benefit of schools, teachers and learners, to enhance science teaching and learning in Project schools.

5.6.3 Project Donors

Donors do play a direct role in development projects. Apart from providing the financial resources for various aspects of development programmes, donors can assume various other roles as well. Monitoring through site visits for instance demonstrates interest, can improve understanding of the work being done, and can contribute to improving quality and accountability.

Financing social, economic and educational programmes means donors do have some leverage; however, it is important that they use their influence wisely and responsibly. Awarding funding merely for self-serving purposes of improving an organization's image, as a marketing strategy to gain public support, and lax or careless sponsorship can contribute to system-wide under-performance. It is more important for donors to put their collective potential to good use, and insist on and support better performance and constructive change.

As a recipient of donor funding for the Cluster Project, the service provider is held accountable for how funding is spent. For this reason, careful monitoring and evaluation processes are

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integrated into all aspects of Project delivery, for its own reflection to improve the model, and to provide detailed reports on Project impact and progress to donors. Complying with confidentiality agreements, this research is not permitted to make known the list of donors for the Cluster Project.

5.6.4 Cluster Project Conference

Two celebrations concluded the 2007–2009 Cluster Project. A ceremony was held in each district to present "Certificates of Participation" to teachers, reflecting the time (in hours) spent in workshops and for class visits; and a conference was organized for teachers to share their science teaching practice.

For the conference, selected teachers prepared lesson plans and PowerPoint presentations (Appendix DD), and engaged participants in practical lessons on various science topics. For most of the presenters, this was their first experience sharing their teaching practice in this way. A survey amongst attendees regarding their impressions of the conference showed they generally felt they gained from the practical nature of the presentations, and the opportunity to learn teaching ideas and strategies from colleagues working in similar contexts, dealing with similar teaching and learning challenges.

5.7 Cluster Project Outcomes

5.7.1 Internal Project Monitoring

Monitoring and evaluation processes built into training courses and school support served various purposes. These processes tracked the progress of the project, helped facilitators reflect on teachers' learning, and data derived was used in the preparation of reports for Project donors and the WCED. A variety of tools used to monitor various aspects of project progress and teacher learning include:

- Written tests and memoranda were used to monitor improvements in teachers' knowledge of Natural Sciences content and concepts. Appendix II are test samples.

- Teachers' Natural Sciences lesson plans were reviewed using checklists.

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- Observation Schedules were used for monitoring teachers' classroom practice, and their confidence in implementing the curriculum in the classroom (Appendix I).

- Individual teacher evaluations which allowed teachers to rate courses in terms of how their professional development needs were met (Appendix W). These were used to reflect on how teachers received the training course.

- Facilitators compiled regular reports documenting their interactions with teachers during school visits (Appendix JJ) to reflect on their work.

As part of project monitoring, course attendance and materials distribution was recorded onto a database. Attendance at courses was monitored through registers and captured onto a database, and teachers were awarded certificates of attendance for the number of hours they committed to training in the project over the three years. During the courses and school visits facilitators further reflected with the teachers on how the teaching ideas and activities were implemented in classrooms.

5.7.2 Two-year Impact Evaluation

An impact evaluation conducted by an independent researcher, Angela Schaffer (2009), formed the fourth component of the 2007–2009 Cluster Project. The impact evaluation sought to establish whether the Cluster Project achieved its intended outcomes and by implication, whether the achievements of the Cluster Project justified the resources invested. The evaluation focussed on assessing and explaining changes in Natural Sciences teachers' knowledge, and teachers' planning and classroom practices after two years of training and support. The impact evaluation did not include the third year of Project delivery. The following section extracts critical information from the evaluator's report (Schaffer, 2009) for analysis and review for this research.

The evaluation commenced with a baseline (pre-delivery) research phase conducted during the last term 2006 and the first term of 2007. The organisation's impact tools and familiarity with evaluative research was used as the basis for the impact study, for both pre- and post-Project measures. For the baseline phase, Project science facilitators conducted the assessment of 375 Natural Sciences teacher participants from 40 primary schools on a range of intended outcomes.

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Science facilitators conducted the field research for the reason that, as Project insiders they would be more likely to obtain rich and reliable research data with minimum disruption to the implementation programme and to participating schools than would be the case with unfamiliar researchers. Their knowledge of the Cluster Project and its contexts would enable them to identify important developments which external field researchers might overlook. The evaluation team acknowledged the arrangement increased the potential for biased data. Compensating for this weakness in the design the independent evaluator moderated all research processes, materials and raw data as well as developed the final analysis of impact data and prepared baseline and summative evaluation reports.

According to the evaluator, overall, the Cluster Project had a significant positive impact on all sample schools and teachers' performances in relation to the Cluster Project objectives, (Schaffer: 2009).

The review notes three important contextual factors which may have affected impact of the Cluster Project on Natural Sciences teaching and learning:

1. The instability of the teacher population.

Constant changes within education, the teaching profession and the movement of teachers between schools and grades contributed to a great deal of instability. This was shown to have a strong impact on the Cluster Project participation findings.

2. Teachers experienced poor conditions of service, including a lack of opportunities for specialization, and excessive non-teaching workloads.

These factors were said to result in poor staff relations at certain schools and they contributed to teacher passivity and general fatigue.

3. Teachers' own generally poor education, resistance to reading and lack of foundational "general knowledge".

These handicaps made it unlikely that teachers were able to extend their scientific knowledge beyond the confines of what they remembered from a Project session or had seen in their curriculum guides.

The evaluation concluded with two important observations, (Schaffer, 2009):

- Although there was a significant mean improvement on all four curriculum strands, the actual post-test scores were lower than ideal for Project exit scores.

- Regular participation in Project and other training courses together with the involvement of an HOD or School Management Team member in the Cluster Project impacted significantly on the quality of schools' coverage of the curriculum.

Within the domain of TPD, the independent impact evaluation concentrated on crucial areas of concern, such as teachers' attitudes towards Natural Sciences teaching, knowledge of the subject, planning and assessment, and collaboration at school level. But, as previously mentioned, the critical goal of improving teaching practices so as to improve children's learning lies at the heart of any teacher development programme. While aspects of the evaluator's report were important, a concern for this research is that little reference is made to the critical aspect of classroom teaching.

5.7.3 Evaluation of the PSP and its Cluster Project 2001 – 2004

In 2001, the service provider, the Western Cape Primary Science Programme (PSP) commissioned the Centre for Educational Research, Evaluation and Policy (CEREP), University of Durban Westville, to conduct an external evaluation of the organization. Led by Professor Clifford Malcolm and prepared by Malcolm, Knowles, Steers and Gopal, (2004), the overall evaluation of the organization's work included an assessment of the Cluster Project model. The study described impact and effectiveness of the PSP's processes in the context of curriculum change in South Africa.

The research design comprised a longitudinal study to enable evaluation of impact over time, and to explore processes of evolution and development of the organization, participating schools, teachers and learners. The evaluation plan comprised two strands. The first strand gathered "large scale" data on the organization through descriptive data and questionnaires, and included learner assessments from a representative sample of schools. The second strand explored the contexts, inputs, processes, interactions and outcomes within the organization itself, and a small selection of schools and classes. Since the Cluster Project formed only one

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part of this broad study, this section refers to only that component of the research, highlighting significant observations and conclusions pertaining to the Cluster Project.

From the large number of schools PSP worked with at the time, a sample set was identified. Classroom observations and interviews with teachers showed that lessons were generally well designed and presented, learners were deeply engaged, and children and teachers alike felt that considerable learning was taking place, (Malcolm et al, 2004: 8). However, assessments conducted with learners generated results which were not well-matched with the evidence obtained through observations of teachers' work.

Summarizing some important observations of the Cluster Project, Malcolm et al (2004:53) report that teachers generally felt that being part of a cluster had helped them, especially as it allowed them to exchange ideas, materials and resources and to produce better quality lessons; teachers developed closer relationships with their colleagues (in and across schools) and worked as a team within a school instead of working individually; and having principals involved with curriculum planning and cluster meetings allowed them to develop better insights that allowed them to act accordingly.

As to improvements in science knowledge and teaching practice, general observations contained in the report pertain to the population of teachers the PSP worked with at the time across various projects. The evaluation team observed that teachers were almost always well-organized, had clear lesson plans, employed variety in their teaching, were accurate in their science and confident in their relationships with children. However, teachers were less strong in connecting science to children's out-of-school interests and experiences, especially children's social and cultural knowledge, and promoting higher-order thinking skills, problem-solving and deep thinking about science, (Malcolm et al, 2004:55). According to the evaluation team, the latter inferences derived from the following observations: Classes often did the "ground-work" for concept development, but did not adequately draw ideas together towards a better understanding of some of the "big ideas" in science; assessment tasks often emphasized low-level knowledge and skills, recall and application of words, reporting on observations and measurements, presenting narrative accounts of activity and; classes made little use of open activities, such as designing investigations, exploring meanings and knowledge structures, and free writing.

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5.8 Cluster Project Contradictions

In activity theory change and development is associated with contradictions that develop within and between systems. Contradictions include issues of conflict and tension occurring within an activity system, as well as those impacting from outside a system. This section explores links between Engeström's (1987) concepts of Contradictions, Expansive Learning Cycles and Boundary Crossing and the design, implementation and outcomes of the Cluster Project model.

The Cluster Project as an Activity System is situated within the broader system of education. Contradictions, conflict and tensions affecting implementation and outcomes of TPD programmes such as the Cluster Project can arise from many sectors, from within the system itself, the broader educational, political, social and economic spheres, the teaching community, schools and classrooms, and learners. Its situation also means it is subject to rules and regulations developed by the national department of education, as well as those decided upon by the provincial education department, education districts, various teacher unions, schools and teachers.

Referring to instances of profound conflict within the education system Malcolm et al. (2004:52) state that: On the one hand the Education Department's policies promote devolution of authority (in management and curriculum), but on the other hand they tie down the allowable behaviours of teachers and schools through requirements for plans and reports in specific formats, and a plethora of performance indicators. Also, on the one hand is a view of the moral, intellectual, creative, responsible professional working organically, intuitively, democratically, but on the other hand the reductionist specification of performances as the basis of school and teacher assessment. In cases such as these, Malcolm et al. (2004:52) propose that schools and teachers may be dealing with some of the conflicts and challenges they face by offering the trappings of the imposed roles and processes – written school plans and lesson plans, group-work, activity-based learning – often without embracing the spirit of reforms. Schools and teachers clearly face many challenges on a daily basis, for which they seem to have developed "coping strategies" as they attempt to "manage" the challenges they face in the only way they know how. Providing another example to illustrate a conflict situation for teachers and schools at the time, Malcolm et al. (2004:53) quote a teacher as saying *"Sometimes, the PSP (service provider) tells us one thing and the Department another. Who do we listen to?"*

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The quote highlights that conflicting instructions from different entities involved with education are often not very helpful to schools and teachers, exacerbates existing tensions, and increases frustration and discontent.

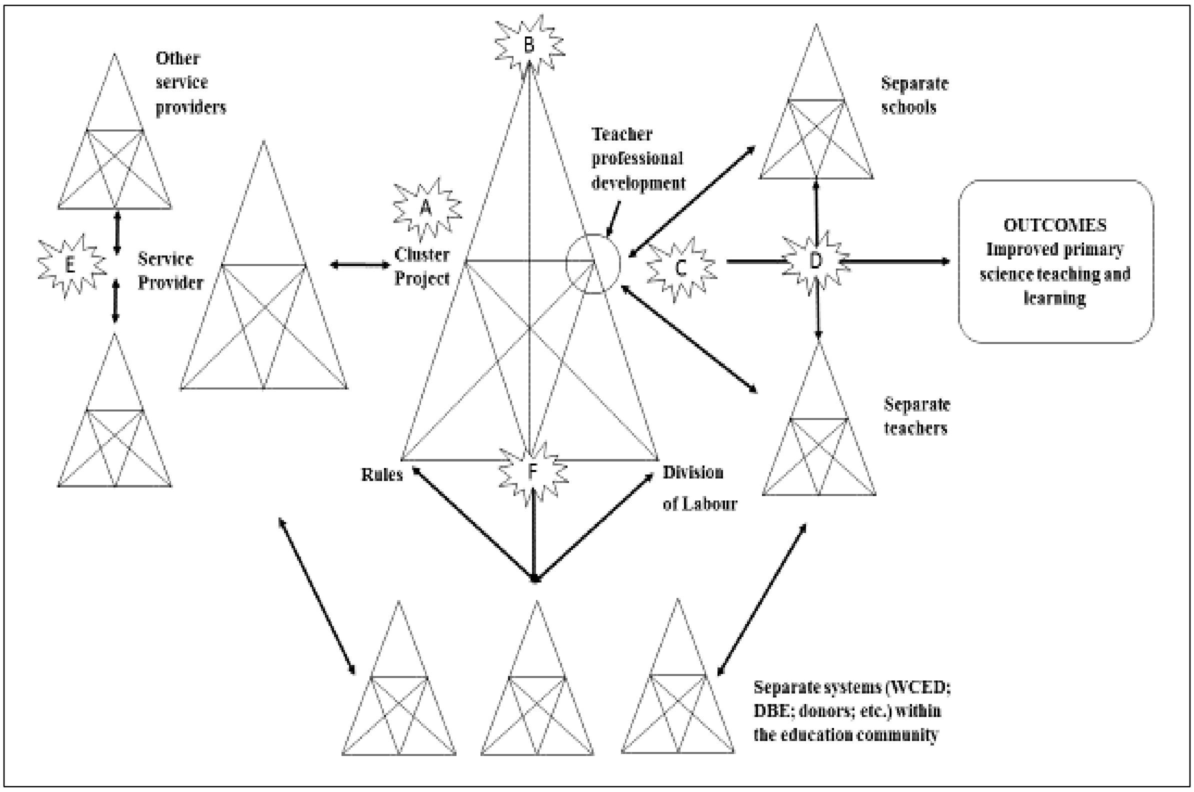

Figure 5.3: Contradictions related to the Cluster Project

Figure 5.3 illustrates the location of some of the contradictions related to the Cluster Project. These are examined in Table 5.6, together with the corresponding actions employed by the service provider.

Table 5.6: Contradictions related to the Cluster Project

Contradictions, conflicts and tensions		Corresponding Actions
A	Is there significant difference in the science knowledge and skills learners take to the high school following a primary school's involvement with the Cluster Project? How is Project impact tracked into the high school? And, how are high school teachers connecting with, sustaining and building on the input made at primary school?	
	The need for improvements in Mathematics and Science education at all levels in South Africa is well-documented, and is	The Cluster Project represents a response to the appeal for improvements in science teaching and learning. By offering teachers training,

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	described in detail in Chapter 2. As mentioned, several strategies have been implemented by government, generating varying degrees of improvement.	support and resources, the objective is to equip them with appropriate knowledge and skills to help children build a sound foundation in the primary school for further study of science at high school and beyond.
B	How does the Cluster Project accommodate teachers who achieved minimal shifts in TPD (science knowledge and teaching practice) after a two or three year period? Is further training and support provided?	
B1	Teachers at primary schools are often required to teach all the subjects. For some teachers their education and training has not sufficiently prepared them to teach science. Knowledge and skills deficiencies affect their teaching of the subject. Teaching strategies used most often in the classroom may be inappropriate for promoting a better understanding of science. Teachers tend towards an over-reliance on an assortment of textbooks as the main source of information for science teaching. In other cases, teachers in underprivileged schools are not always able to access resources to teach science concepts practically.	The *"Tools"* of the Cluster Project respond to the specific education and training needs of primary school teachers for improving their teaching of science by providing: • Training workshops to improve teachers' knowledge of science and science teaching • Practical teaching strategies in workshops. • Classroom mentorship, coaching and support to improve teaching of science. • Strategies to integrate language development for science learning. • Strategies for assessment of learning. • Teaching and learning resources to support teaching of the subject. • Innovative strategies on how to teach important science concepts using / improvising with low-cost or waste materials, without diminishing the focus on the concept being taught. This strategy is especially helpful for schools where there is a shortage of science apparatus for practical investigations.
B2	As a way of supporting and streamlining the implementation of Curriculum 2005, the WCED introduced a series of Work Schedules with Teachers' Guides for each learning area for each grade during the third year of the Cluster Project.	Training programmes were adjusted to accommodate teachers' need for guidance with interpreting and implementing the WCED Natural Sciences Work Schedules. The launch of new national documents – CAPS – followed soon after.

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C	Do all the teachers at the school remain committed to the Cluster Project for the two or three year period, attending training workshops and implementing classroom strategies consistently? How does the withdrawal of some teachers at the school affect further Project implementation and impact?	
C1	The Cluster Project must proceed with the full support of schools and teachers. The successful achievement of Project objectives is dependent on the cooperation of education district offices, schools and teachers towards achieving the learning outcomes as an accepted and integral part of curriculum delivery.	The Cluster Project can be demanding in respect of teachers' time and effort. Teachers would need to spend countless hours in training workshops to acquire new knowledge, and learn to use new instructional strategies and materials, and practice activities in the classroom with children. For this reason, the Cluster Project is first presented to education districts, schools and teachers for their consideration, to ensure they voluntarily agree to and actively engage all aspects of the programme, believe the Cluster Project is worth their time and effort, that it is not an activity disconnected from their daily work, that it is not more work over and above the science they have to do with learners, and that it can provide support with implementation of the national curriculum. Following the presentation, schools and teachers are asked to commit to active participation via a memorandum of understanding.
C2	Implementation of the various components of the Cluster Project, especially visits to teachers' classroom, require sanction from other organizations involved with education as well, for instance the teacher unions.	During the period of Project implementation, the dominant teacher union at the time SADTU (South African Democratic Teachers Union) barred visits by education officials, particularly curriculum advisors, to teachers' classrooms. The researcher recorded an occasion when Project facilitators visiting a school for follow-up support were met at the gate by SADTU delegates who refused them entry to the school. Staff changes since the start of the Cluster Project meant that teachers who had signed on for the Cluster Project were no longer at the school, and the new teachers had not been informed about the Cluster Project by school management. Only after lengthy discussions were facilitators permitted to enter the school and continue supporting teachers.

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D	How does non-participation by teachers at schools affect Project implementation for whole school development? Are sufficient resources available at the school for effective implementation of inquiry-based science?	
	Programmes for TPD should preferably align with school needs, for a shared interest and commitment to improvements in science teaching and learning.	The Cluster Project involves all the teachers in whole school development, and is established as coherent and continuous experiences that provide a consistent message of how science should be taught in the classroom, encouraging all teachers at the school from Grade R to Grade 7 to engage learners in age-appropriate practical, inquiry-based classroom experiences for promoting learning of science.
E	How effective is the alignment of the diverse views and methods of very different organizations involved with education? How are alliance partners able to accommodate issues of conflicts and tensions between them without these affecting teachers and schools?	
	Various service providers involved with education have very different views about how science should be taught in schools, often advocating very different emphases and teaching methods.	The common goal of improved science teaching and learning in schools encourages cooperation amongst different organizations. By working together organizations are able to pool their resources. In doing so, they strengthen science development programmes offered to schools and teachers. To strengthen their work with schools in the Cluster Project, the PSP actively collaborates with other organizations, for instance with the South African Astronomical Observatory (SAAO) for their knowledge and expertise with the science strand Planet Earth & Beyond, the Two Oceans Aquarium for class excursions, and often draws on materials such as the EnviroKids magazine developed by other organizations, such as WESSA.
F	How does minimal / poor support from education districts and their officials impact the Cluster Project?	
	Various government departments determine the rules and regulations for teachers and TPD. Where instructions issued by the education department conflict with suggestions from various organizations involved with teachers, it	The Cluster Project is intended to support government efforts, and takes into consideration rules and regulations determined at national, provincial, district, and school level. Training and support provided through the Cluster Projects is aligned with the national

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	creates uncertainty, instability, and a great deal of frustration for teachers.	curriculum. Regular meetings are arranged with the key WCED and district officials for their sanction of the programme, to discuss issues related to science education, and to report on Project impacts. Curriculum advisors for Natural Sciences in the districts are encouraged to participate in the Cluster Project, and are consulted on issues related to Project delivery. Backing from education officials raises the authority of the Cluster Project with teachers, and reassures them that it the Cluster Project is consistent with departmental / district requirements.

Table 5.6 illustrates some of the contradictions, conflicts and tensions occurring within the Cluster Project as an activity system the service provider has taken into account. And, although the organization developed a corresponding strategy for each, this is not to say that the contradictions described have been fully resolved, or that the system is without any other contradictions and tensions.

5.9 Cluster Project Expansive Learning Cycles and Boundary Crossing

5.9.1 Cluster Projects Expansive Learning Cycles

Contradictions, conflicts and tensions are the catalysts initiating a review of current situations, and initiates the series of changes that follow within systems. Change processes resulting from tensions and conflicts within systems give rise to expansive learning cycles. For Engeström (1987), the expansive learning framework is a collaborative journey. With Vygotsky's "zone of proximal development" as its foundation stone, Engeström's (2008a, 2008b:12-13) expansive learning cycle or spiral comprises seven expansive learning actions of: questioning, analyzing, modelling, examining, and implementing the model, reflecting on processes and consolidating outcomes.

The seven learning actions / activities can be discerned within the Cluster Project's structure and strategy. Though the Cluster Project reflects elements of expansive learning, the cycle does not proceed in exactly the same manner as Engeström describes. The Cluster Project is

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presented to teachers in two or three year cycles, and can also be interpreted as a collaborative journey where facilitators with teachers, schools and education districts work towards a shared objective of enhanced science education within schools. With each training workshop and classroom support visit, teachers with facilitators interrogate their science knowledge, understanding and teaching practice, identify weaknesses, and teachers gradually with the support of the facilitator work on enhancing aspects of their teaching as the Cluster Project unfolds. The experiences, observations and comments of participants such as the teachers, school management teams, facilitators, curriculum advisors are considered for adjustments to the model. Against the backdrop of ongoing change and development within the educational field, with each stage of the Cluster Project cycle the service provider analyses outcomes, reviews relevance of structure and processes, identifies challenges and makes adjustments to the model, for implementation with a new set of schools for the next cycle of the Cluster Project.

5.9.2 Boundary Crossing

In their professional careers teachers traverse numerous boundaries on a regular basis, between home, school, classrooms, community, higher education institutions, training facilities, and many more. As they move from the school environments into workshop situations, they cross school boundaries into different spaces created by the Cluster Project to receive training, reflect on teaching of science, engage in discussion, and collaborate and exchange ideas with colleagues.

Project facilitators representing one of the "*Tools*" of the Cluster Project cross boundaries too as they move into different school, classroom and education district environments. There they interact with various people, the teachers, learners, principals and curriculum advisors, adapting support to the particular professional needs of teachers. Through these movements and interactions and the exchanges that take place, the Cluster Project as a system through its various "*Tools*" affects and is affected by various individuals, organizations and systems it encounters and interacts with, for example:

- Education districts have the authority to support or restrict Project activities. Acknowledging this authority, the service provider regularly meets with various officials

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to discuss and agree on Project design and implementation, and to align support for schools with district improvement objectives.

- Weak relations with other bodies such as teacher unions can hamper Project implementation, such as when facilitator visits to teachers' classrooms were prevented, as mentioned earlier. At the time of the incident mentioned in C2 (Table 5.6), the teacher union, SADTU, had taken a decision to restrict visits by curriculum advisors to schools. Project facilitators negotiated with SADTU members, explained the work of the organization and the nature of the school visit, and only thereafter were facilitators permitted to continue with their work.

- On another occasion, a curriculum advisor requested to accompany Project facilitators on a school visit to observe teachers' science lessons. Although the Cluster Project facilitators expressed their reservations about the arrangement, they acceded to the request of the curriculum advisor. Arriving at the school, the curriculum advisor was turned away, and the Cluster Project facilitators were allowed into the school. A positive outcome was achieved for the Cluster Project, but on the other hand incidences such as these strain relations with curriculum advisors and education districts, and could affect future Project implementation in the district.

- Poor school management and an unproductive school ethos can hinder the achievement of Project outcomes. The Cluster Project cannot be interpreted as a means of remedying or improving functionality within schools. The Cluster Project requires a context characterized by strong, organized school leadership together with a strong collegial spirit for its contribution to science teaching and learning to take root in the school.

I recorded instances where training courses and school visits could not proceed for reasons associated with a poor collegiality, ineffective leadership and uncoordinated management:

- School management failed to communicate dates of training workshops and school visits with teachers, despite receiving several reminder notices and calls. Later, it emerged that there was a breakdown in the relationship between the principal and the teachers.

- Relations between school management and teachers were strained to the point that all visitors to the school were turned away.

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- Teachers who disagreed with the appointment of the principal were deliberately uncooperative towards any development programme at the school.

- On the other hand, where the principal and the school management showed commitment to the Cluster Project, attended training workshops with teachers, and helped organize resources for lessons, science teaching and learning at the school progressed well.

- When a few teachers at a school are uncooperative and unresponsive, this affects Project implementation at the school, and the continuity of particular teaching methods promoted through the Cluster Project for science teaching through the different grades. Non-participation by teachers recorded at several Project school results in inconsistent development of science teaching and learning.

Comments made by teacher participants and the principal exemplify some of the benefits of Engeström's boundary crossing which he terms horizontal learning and development through sharing ideas, and gaining insights through collaborative action and learning. Teacher D stated *"The cluster workshops were so important to us because we could even learn from other schools, also from other teachers….",* in this way, (Teacher F): *"Fresh, new ideas need to come in."*

Principal: *"I really think our kids have grown a lot since your programme started here".* (Teachers observed that children's learning improved through the Cluster Project; for some teachers this showed that children have the potential and are interested in learning science, and by using different teaching strategies children's learning of science can improve); *"They* (learners) *showed much more interest in working with people* (facilitators) *who wanted to be at our school"* (Children and teachers can benefit from the expertise and experience of outsiders, in this case the Cluster Project facilitators); *"…and we always encourage one another…" "one teacher could inspire more teachers to get involved with the Cluster Project"* (Teachers working collaboratively encourage, support and learn from each other).

By bringing teachers together into a common space the Cluster Project encourages communities of practice forming where teachers share knowledge, insights, teaching practice, and resources. Where teachers are able to sustain the communities of practice without additional support, the learning can continue.

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Furthermore, the Cluster Project encouraged and supported teachers to use an integrated approach in their science lessons, to blend the learning of language, mathematics and technology and other subjects with the learning of science, in an authentic and meaningful way. The crossing of subject boundaries in this way helps children make connections across the curriculum, and to relate learning in the classroom to real-life situations.

The Cluster Project also guided teachers with understanding the connection between science and technology, how the two disciplines work together, and their relevance to life beyond the classroom. Not forgetting an important link between science and the arts, for appreciating the beauty of the natural world, for understanding and expressing the world, and for promoting creativity, ingenuity, critical thinking and problem-solving.

Boundary crossing in the Cluster Project does not only involve the movements and interactions of teachers, learners and facilitators and others, teachers' learning, and integrated teaching and learning in the classroom. Professional developers also perform a strategic role as scouts, negotiators and boundary-spanners who bring together previously separate activity systems and domains of expertize, facilitating the formation of expanded objects and novel partnerships, (Engeström, 2006). Through connections with education districts and their officials, schools, universities, prominent academics in education, companies and sponsors, and other teacher development organizations the Cluster Project is a channel for critical contributions of a number of sectors towards deepening teachers' learning, and the sharing of important insights, thoughts and ideas on the subject of education.

5.9.3 Critiquing Activity Theory

Activity theory is widely considered useful for anatomizing activity systems, and identifying and describing the main components/participants and their relationships. Activity theory gives intense attention to one particular aspect of a much larger convoluted landscape, disassembling it for the purpose of analysis, also locating and examining central and peripheral influences as contradictions, conflicts and tensions within and between systems and the context. Its triangular structure supports the possibility of analysing a multitude of activities and their relations.

Revisiting activity theory as a research framework crucial commentary regarding its application in research was reviewed. Critiquing the relevance of activity theory to the field of

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cultural psychology Toomela (in Engeström, 2008b) identifies five aspects he terms fatal flaws, four are briefly mentioned:

- It relies on unidirectional instead of a dialectical view of culture-individual relationships.
- It focuses on analyses of activities without taking into account the individual involved in the activity at the same time.
- It approaches mind fragmentally, without understanding the holistic nature of mind.
- It is fundamentally adevelopmental and therefore cannot be appropriate for understanding emerging phenomena, including the mind.

Similarly Davydov (in Engeström, Miettinen & Punamäk, 1999: 45 - 52) discusses eight 'unresolved problems' he associates with activity theory, of these five are mentioned:

- In the first instance, Davydov (in Engeström, et al, 1999) challenges activity theory's key notion of transformation, arguing that although transformation is most frequently understood as changing the object, not every change can be considered a transformation. Many changes performed by people may only affect the object externally without changing it internally, and can therefore hardly be called a transformation. He interprets transformation as involving both external and internal changes to an object, by making evident its essence and altering it.
- In the second instance, he questions the relation between collective and individual activity and between collective and individual subject. While only briefly mentioning the role of the individual, Davydov (in Engeström, et al, 1999) considers social-to-individual exchanges, and advises distinguishing activity in the two domains.
- In the third instance, he takes issue with the general structure of activity which consists of needs, motives, goals, actions, and operations, and questions the omission of aspects such as the means of solving a problem.
- In the fourth instance, he questions the classification of different kinds of activity. In different languages, various meanings are associated with the term activity. He contends that the common English use of the term activity is too inclusive and broad, since not all expressions of vital activeness can be defined as activity. He considers true

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activity as always being connected to the transformation of reality, and proposes instead the historical-sociological approach to activity as the main basis for classification of different kinds of activity.

- In the fifth instance, Davydov (in Engeström, et al, 1999) expressed concern about the interrelation between the notion of activity and the notion of interaction. Some philosophers and psychologists emphasize interaction and communication, and to a lesser degree the role of activity in people's social life. Since collective and individual activity is realized in the form of material and spiritual social relationships, and communication is key to these relationships and for forming activity, he urges for recognition of the important connection between activity and communication.

Towards creating an interdisciplinary theory of activity, Davydov (in Engeström, et al, 1999) proposes attention be given to some of the problems identified within activity theory, through concrete research in human activity, so that theoretical approaches to practical improvement of human life can emerge. Still further, according to Minnis & John-Steiner (2001) activity theory is most convincing when it is focuses on activity systems in teams and organizations, but is less so at the level of the individual person. In addition to learning, expansion and development, Minnis & John-Steiner (2001) enquires about the relevance and applicability of activity theory to investigating the perils and renovating possibilities of destructive cycles, as well as disintegrating transformations, and their functions and trajectories.

However worthwhile a methodology it may seem to some, activity theory has drawn a fair share of criticism from a number of quarters. Though in-depth reflection on the comments mentioned in this section is beyond the current scope of this research, the critical weaknesses highlighted within the activity theory framework supports the inclusion of complexity theory for expanding analysis of the Cluster Project TPD model.

5.10 The Cluster Project in a Complexity Framework

Complexity theory in this research gives attention to some of the critical concepts for expanding understanding of teacher professional learning in the Cluster Project, with respect to: learning as a nonlinear process; unpredictability; networking and connectedness; change by emergence and self-organization; changing environments; teacher development programmes as open, complex adaptive systems; pedagogy; and holism.

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The above is taken into consideration in the formulation of Cluster Project training workshops for science teachers. Training workshops are developed around the professional training needs of primary school teachers, focussing on the latest Natural Sciences curriculum to familiarize teachers with the content and assessment requirements for the different grades. Training workshops are also practical and interactive, and allow teachers to experience first-hand the practical activities they can use with learners in the classrooms for teaching certain science content. Teachers are encouraged to interrogate practical classroom activities presented to them, and to reflect on and discuss according to a set of instructions.

It was observed that including a framework (Appendix LL) helped teachers process the activities they were introduced to in the training component of the Cluster Project. The process helped teachers make sense of the practical science activities, and helped with connecting the activities in a meaningful way with the science concepts and content, the learners, the Natural Sciences curriculum, and the assessments. The approach corresponds with Marx, Blumenfeld, Krajcik, and Soloway (1998: 33) contention that "what teachers eventually take away from professional development efforts is based on their existing knowledge and belief structures. Rather than having information delivered to them, teachers need opportunities to examine their beliefs and understanding about subject matter, student learning and instruction in the light of innovation." Guidance with making sense of practical teaching activities is strategically integrated into training workshops, assures improved take-up by teachers, and contributes to confident implementation of practical science activities in the classroom.

Complexity emphasises the unpredictability of learning, whether working with children or teachers. For designers of professional development this means that they can set up a framework for conceptual development, but can never predict precisely what those processes might become through interaction, emergence and self-organization. There is no certainty about, or control over what the take-up by teachers ultimately would be. Fullan (1993:257) writes that in order to achieve a desired change, 'professional development must be reconceptualised as continuous learning, highly integrated with the moral task of making a difference in the lives of diverse students under conditions of somewhat chaotic complexity'. Monitoring teacher learning, the Cluster Project employs various strategies for evaluating impact and reflecting on take-up. Pre- and post-tests measure improvements in knowledge, and classroom observations are used to establish how teachers are able to implement practical teaching strategies successfully in the context of their classrooms.

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Facilitator visits to teachers' classrooms are critical for understanding what teacher take-up from the training workshops has been. The practice of following teachers into classrooms in order to observe their teaching practice is in line with Marx et al.'s (1998) recommendation that "teachers, like other learners, construct their knowledge through social interaction with their peers, through the practical application of acquired knowledge, and through reflection and modification of their ideas and practices, and therefore, activities designed to offer support and feedback, in combination with observation of modified practices, essentially helps teachers to teach in new ways". As an essential component of the Cluster Project, classroom visits reveal the most about improvements in understanding about teaching and learning derived from the Cluster Project. With each visit, facilitators with teachers reflect on and discuss the lessons taught for the day. Marx et al. (1998) agree the enactment of new practices is best supported when accompanied by discussion and analysis of the events. It is only through observations of teaching practice in the classroom that fair assessments of teaching can be made, and appropriate support can be provided for improvements in science teaching.

Systems together with their constituents change and co-evolve as they learn, adapt and grow. According to complexity educational systems institutions, programmes and practices such as schools, classrooms and development programmes are "complex adaptive systems, dynamical and emergent; often operating in unpredictable and changing external environments, which shape and adapt to macro- and micro-societal changes, and, through self-organization, respond to, and shape the environments of which they are a part", (Morrison, 2006:3). The Cluster Project as a teacher development programme operates in a context where change, dynamism, and unpredictability can be observed at all levels, from the classroom to the national education body, which together make demands on it for flexibility to adapt to changes in education.

The potential of the Cluster Project to inspire authentic and effective teacher learning is affected by influences emerging from its real-world context. Ongoing change, unpredictability and instability within the context has the effect of increasing uncertainty and insecurity amongst teachers and learners. The challenge for developers of teacher development is to understand the challenges associated with change, and to ensure training programmes are aligned with the changes as these occur. Programmes for teachers should reflect the relevant concepts and content, teaching and assessment strategies suggested for implementation of the latest curriculum. During the third year of the Cluster Project, in 2008, the WCED introduced its version of the national curriculum known as the WCED Work Schedules and Teachers'

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Guides (Appendix MM), urging teachers in the Western Cape to use the documents as a guide as they implemented the NCS. Amending the learning objectives, the Cluster Project revised the content of its training workshops, and aligned to the new professional training needs of teachers.

Changes to the curriculum persisted following the conclusion of the 2007–2009 Cluster Project. Before either formats – the NCS or the WCED's documents - could reasonably take root in schools, the CAPS (Curriculum Assessment Policy Statements) documents were introduced in 2012 in the Foundation Phase and 2013 in the Intermediate Phase, containing revised curricular instructions, and once again, the service provider amended its training programme. Presented as yet another streamlined version of the NCS, the CAPS document set out concepts and content per subject in a week by week format, which included termly assessments for each grade.

About the same time, science learner workbooks developed by a separate organization, Siyavula, sponsored by the Sasol Inzalo Foundation were delivered to schools nationally (Appendix MM), with the support of the national education department. The decision by the national education department to form a highly structured curriculum, while at the same time separately supporting the provision of a new and different teaching and learning resource for science complicated teachers' work. Teachers were instead bombarded with separate documents in a short space of time, and it is not surprising that many experienced these developments as bewildering. With regard to highly structured curricula, Morrison (2006:6) writes "tightly prescribed, programmed and controlled curricula and formats for teaching and learning, and standardised rates of progression are anathema to complexity theory, as they leave little opportunity for emergence and self-organization, and room for development." Together, the various changes frustrated the service provider's efforts to provide appropriate training, support and guidance to teachers for improving science teaching and learning.

Complexity attaches importance to disturbances and disruptions, the disequilibrium that results are significant in systems, however, the intensity of change experienced in education in a short period had leading educational researchers concerned about whether teachers could cope with the quick pace of change. I observed the instability generated by the introduction of different sets of official documents had the general effect of increasing teachers' confusion, uncertainty and insecurity. However, I also noted that those teachers who had participated actively in the

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2007–2009 Cluster Project appeared better equipped to cope with, and manage the changes in the Natural Sciences curriculum confidently and competently, in comparison to those who had not participated actively in the Cluster Project. Although some content was new to them, a few teachers suggested that all they needed was a refresher course to set them on their way again.

5.11 Further Analysis of the Cluster Project

This section expands analysis of TPD within the Cluster Project model: contrasting the structure and outcomes of the model with critical aspects of frameworks, models and processes described elsewhere in this research; describing connections with Engeström's (1987) Learning Cycles, Contradictions and Boundary Crossing mentioned in Chapter 3; and elaborating on influences of the Cluster Project on teacher development within a Complexity framework.

The Cluster Project model is reviewed against the frameworks, models and processes mentioned in Chapter 3 so as to further examine its potential for TPD.

The Cluster Project model effectively accommodates various aspects of teacher development described in Janse Van Rensburg and Le Roux's (1998) set of indicators and Bell and Gilbert's (1994) domains of influence with regard to development of teachers' knowledge and practices, and sharing through networks. Opportunities for formal-informal and planned-incidental learning in accordance with Reid's (2007) quadrants are provided within the Cluster Project model. Formal-planned teacher learning takes place through training workshops and classroom visits, informal-unplanned learning occurs through informal networks and at workshops when teachers share their experiences and ideas.

Kennedy (2005) locates cluster models with elements of coaching and mentoring in the transitional category, where continuing professional development supports either a transmissive agenda or a transformative agenda. With fair opportunities for teacher professional autonomy, and its change objective and function with respect to improving teachers' science knowledge and practice, it would seem the Cluster Project model can situate in Kennedy's transformative category. The Cluster Project model also reflects the five phases distinguished within the North Central Regional Educational Laboratory's (1997-1999) framework, as well as aspects of Clarke and Hollingsworth's Interconnected Model (2002). Training workshops build a science knowledge base; classroom support visits allow for the

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observation of models and examples, reflection on practice, changing practice, and gaining and sharing expertise.

Of the various models reviewed in detail elsewhere in this research, the Cluster Project model is most similar in its design and presentation to Hackling and Prain's (2005) Primary Connections model, a professional learning programme for teachers also consisting of learning workshops, curriculum resources, opportunities for practicing science teaching supported with resources, reflections on practice, and references to principles of teaching and learning. Both models integrate science learning with Language development to develop science-specific and general literacies, Assessment to connect lessons with students' prior knowledge and to monitor learning, and Co-operative learning where learners work in groups towards a common learning goal. Unlike the Cluster Project, the Primary Connections model includes a teaching and learning model, the 5E inquiry model. Whereas, the Cluster Project has classroom support as an essential component for improving teaching practice, less detail is provided in the Primary Connections model regarding this type of support for teachers.

In a Professional Development Design Framework, Loucks-Horsley et al. (1998) offer service providers guidance with TPD. A number of the concepts and strategies suggested within the framework can be distinguished in the organization and implementation of Cluster Project model. The model adheres to the planning sequence of goal setting, planning, doing and reflecting, and takes into consideration challenges and critical issues related to teaching and learning in the context. Regular reflection on Project outcomes, and various internal and external monitoring and evaluation procedures allow the service provider to make adjustments to Project processes as and when shortcomings or weaknesses in the model are identified. For instance, in 2006 the one-year Cluster Project was considered too short a time for significant impact on science TPD, hence the organization extended the Cluster Project to run over a three year period from 2007–2009.

In another instance, following their evaluation of the 2002 – 2004 Cluster Project Malcolm et al. (2004:55) established that "teachers seemed less strong in connecting science to children's out-of-school interests and experiences, especially children's social and cultural knowledge, and promoting higher-order thinking skills, problem-solving and deep thinking about science". They mention that this showed up in three ways: First, classes often did the "groundwork" for concept development, but did not adequately draw ideas together to close in on the learning

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available or the "big ideas" of science. Second, assessment tasks often emphasized low-level knowledge and skills – recall and application of words, reporting on observations and measurements, presenting narrative accounts of activity. Third, classes made little use of open activities, such as designing investigations, exploring meanings and knowledge structures, and free writing. Malcolm et al. (2004:55) traced some of the weaknesses to the modules developed by the service provider that teachers used extensively at the time as the basis for their lessons. Malcolm et al. (2004:55) further critiqued the materials in 2002 and 2003, led workshops on curriculum design with the service provider aimed at building their theoretical knowledge of curriculum, and provided practical examples and models. The service provider further undertook to redevelop some of the modules for teachers, and has since researched and experimented with a variety of new approaches for science teaching.

Notwithstanding some of the weaknesses of the Cluster Project as indicated by Schaffer (2009) and Malcolm (2004), the model compares favourably with the various frameworks, models and processes reviewed, and contains some of the critical aspects related to TPD emphasized in each.

5.12 Conclusion

The constituent elements of the Activity System – *Subject*, *Tools* and *Community* are directed towards affecting the *Object* in such a way so as to achieve the desired *Outcomes*. In the case of this research, the *Object* of the Activity System is the professional development of primary science teachers. Representing the *Outcomes* – the end-product of the motivated action – are improvements in science teaching for improvements in Natural Sciences learning in schools. The two external evaluations referred to in this section employed different methods to give account of various aspects of TPD relating to the Cluster Project, and its influence on teachers' work and children's learning of science.

The activity theory framework supported analysis of data on the Cluster Project model, as well as analysis of six teacher participants' comments and experiences related to their professional development through the Cluster Project. This research focused on the Cluster Project as the *Subject* of an activity system, implementing a *Tools* set consisting of training, classroom support and material and other resources to assist teachers move towards the *Object* (teachers' professional growth and development), and on to the *Outcomes* (enhanced teacher competency

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for science teaching, so that teachers are able to confidently and competently use practical teaching strategies, where appropriate, in their teaching of science, for improving children's learning of science).

Analysis involved monitoring and reflecting on the *Outcomes* of Project activities, as well as locating and describing *Contradictions* relating to Project implementation. The three domains of *Rules*, *Community*, and *Division of labour* exerted definite influences on achievement of the *Object* and the *Outcomes*. As observed, these domains can add coherence or contradiction as the *Subject* works towards the *Object* and *Outcomes*. Promoting collaboration, reducing *Contradictions*, and making adjusts to the professional learning model to accommodate curriculum changes to content can enhance Project *Outcomes*.

Two separate external evaluations of the Cluster Project were consulted. Malcolm et al. (2002:4) make a pertinent observation that teacher development programmes such as the Cluster Project assume that improved classroom practices will lead to improved learning of science for children. They emphasize that the relationship between teaching and learning is not a simple one, and certainly is not causal, further recommending that the assumption needs to be tested, through assessment of children's learning. They state that the way children learn is equally important, that children learn more, less or differently from the lessons presented by the teacher, and learning is affected by many factors impacting from in the classroom as well as beyond the school and its environs, with many more factors also residing within the learners themselves.

Not following up on the influence of the programme on children's learning of science in conjunction with reflecting on teachers' learning and improved science teaching in the classroom is identified as a weakness of this study. However, an instance that shows some growth was achieved deserves a mention. A curriculum advisor reported that she taught a Grade 8 science lesson at a high school in the same neighbourhood where Project schools are located. She noted a difference in the way some students responded which demonstrated sound science knowledge and understanding. Only a few learners in the Grade 8 class could respond to her questions during the lesson, showing some foundational knowledge had been established at the primary school. Later, she enquired about the feeder primary schools, and was informed that the students demonstrating improved science knowledge came from primary schools involved with the Cluster Project. I acknowledge this instance by itself is insufficient evidence to draw

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positive conclusions regarding improvements in children's learning as a product of the Cluster Project, further research is required.

Chapter 6 examines the *Object* of the Activity System: teacher professional development (TPD), achieved through the Cluster Project in the form of empirical interview data. The data analysis is performed according to the researcher-developed qualitative framework.

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CHAPTER SIX: EMPIRICAL DATA ANALYSIS

6.1 Introduction

Teacher professional development (TPD) with respect to the six teacher participants selected for this research is interpreted and analysed within an analytical framework (3.5.3) consisting of the five key focus areas of:

1. Professional autonomy
2. Professional knowledge
3. Professional practice
4. Professional collaboration
5. Continuing professional development.

Methodological triangulation, using a combination of methods such as interviews, questionnaires, and observations, and data triangulation, using data from different sources, supported interpretation and analysis.

6.2 Interpreting Teacher Development in a Cluster Project within a Qualitative Framework

Criteria developed for each of the five indicators in the framework guided the search for corresponding evidence of TPD within the set of data. Each of the six teachers are acknowledged as idiosyncratic, unique beings given their personal differences with respect to their life experiences, socio-economic circumstances, cultural and religious background; and professional differences as regards their initial and ongoing training, teaching contexts and teaching experiences, and it was therefore not expected that they would respond to the Cluster Project in the same way, or to the same degree. Whilst there were differences relating to teachers' experiences, interpretations, perceptions and take-up of the programme, and their individual approaches and pedagogical practices, it was possible to distinguish general patterns regarding each indicator of professional development within the data set, presented below.

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6.2.1 Professional Autonomy

Various opportunities are located within the Cluster Project for teachers to exercise professional autonomy, such as voluntary participation in the Cluster Project, involvement in decisions concerning the Cluster Project, attendance at training workshops, allowing facilitators into the classroom to observe and team-teach lessons, implementing new strategies, incorporating resources supplied into their lessons, reflecting on their practice with the facilitator, and demonstrating a willingness to share their expertize. These occasions were reviewed for any evidence of professional autonomy exercised in choice and action, so as to describe the nature of teachers' participation in the Cluster Project.

Teachers' responses in the interviews were used to establish whether or not they were included in the decision to become involved with the Cluster Project, and whether or not their participation in the Cluster Project proceeded voluntarily. The Head of Department (HOD), Teacher F, recalled attending the initial presentation of the Cluster Project made to school principals and School Management Teams (SMTs) by the service provider.

> *…Yes, yes, we went to … where we met you guys. There was an invite for all the schools … that day I remember that afternoon. And, then we met you guys and you explained everything about Project in a nut shell, and also said it was a three year contract and all of us from the School Management Team to the teachers, the Natural Science teachers or who want to be part of it must sign. And that is how it started. And for about an hour yes. And then we dispersed. And then we went back to our schools, the next day the staff chatted about it and the principal asked us what we thought about it and we said this is help, this is what we need. And that is how we came on board. And then all of us signed…*

Teachers A, B and F were able to explain the discussion held at schools, indicating their involvement in decisions made at schools. Whereas, Teachers C, D and E indicated the HOD's at the schools instructed them to attend the training workshops, indicating less involvement in decisions made at the schools. Probed about their involvement in the training opportunity, the teachers had this to say:

> *…and I also felt that although I was at college I felt that that there was a need (to participate in the programme) because we live in a changing world and every time*

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things are changing and I didn't have sufficient training at college, ... we did a lot of admin but not practical and so I would like to have more information so that I can become more confident about the subject…"; "... uh… I felt there was a need and you can only get stronger when there are people helping you, assisting you, showing you things", and "... of course we live in an area where we actually wanted to upgrade ourselves and the children too ... (Teacher A)

…we as teachers we bought into it very quickly, because the science was not a subject that was high up there… In my opinion I felt that it was busy dying ... honestly ... but …um… as a blessing in disguise ... we as teachers we accepted to be part of this programme, to see how we can rescue….at the end of the day it is all for the learners… (Teacher B)

Teacher C said, "… *I said let me take it* (the Cluster Project), *because since I was in grade twelve, my biology teacher told me that he can see that I love biology, it was biology then now it is Natural Science ..."*

Teacher D mentioned the reason she was sent for training was because "… *It was the first time that I was doing Natural Science. I was doing grade 5 to grade 7 and I learnt a lot… about how to introduce science…. I was scared that the learners would not make it (*would not pass the subject)"

Teacher E made a similar observation, "*Yes, I have chosen as a volunteer because I want to know, I want to learn, I want to develop myself. That's why I volunteered myself to go to the workshop ... the Cluster workshop."*

Thus, while three teachers said that they had been sent for training by the school, further responses indicate an understanding of the need for training to improve their knowledge and teaching of the subject, and their motives for participating in the Cluster Project, such as the desire to improve Natural Sciences knowledge and teaching practice, to improve confidence to teach the subject, and to improve the teaching of the subject at the school.

Attendance records show that the six teachers regularly attended the once a term six-hour training workshops, and Teacher F confirms that: "…*maybe I left early but I basically attended all the workshops …. and ... and meetings and conferences you had ..."*

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Early into the programme, four of the six teachers became Project coordinators at the schools, Teachers A, C, D and F. And, as coordinators they arranged the class visits for the Cluster Project facilitator. This meant that their classes were usually visited with each school visit. Facilitator records of school visits show that the six teachers regularly presented Natural Sciences lessons or team-taught lessons with facilitators, they used the activities modelled in the workshops, and used the resources provided by the Cluster Project.

Additionally, Teacher C and D attended Natural Sciences training courses at CTLI, also presented by the same service provider. Three of the six teachers, Teachers A, B and C, shared practical teaching strategies and ideas at the Cluster Project Conference. Active participation indicates a willingness to engage in further learning opportunities, and a readiness to share professional knowledge, expertise and experience.

The above shows that teachers participated of their own accord, were active members, often serving as coordinators (drivers) of the Cluster Project at schools, implemented "new learning" in the classroom, used resources supplied, and readily shared with colleagues. The willingness to share is also evident in a comment made by Teacher F when she said:

"*… don't keep the information to yourself, share with people, teach people, share, teach, so when you leave there's somebody else to take over…"*

There were challenges to participation in the Cluster Project at schools, especially with respect to teacher attendance at training workshops and with the class visits as indicated by the following comments:

> *"…that the admin and workload. Sometimes we would have loved to encourage other people to attend the workshops, saying you will get more information to assist you with diagrams and things like that, but what happened at our school is so … we're loaded with meetings, sports…" (Teacher A)*

Teacher B recalled that: "*Well in my three years I attended every session, almost every session and spent quite a lot of hours with it, enjoyed every moment of it as well."*

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Teacher F: "*…there's times when you want to duck out, but then you think it's a three year contract you have to be here. Even if you are so tired you know you have to go to the workshop …"*

Where teachers appeared compelled to participate in the Cluster Project, attend training and to allow facilitators to visit their classes, perhaps by their principals or HOD's, they appeared sullen, uncooperative and resentful, and according to a Project facilitator:

"… this is why we work with the willing … it is the only way we can make a difference…"

On the whole, the six teacher participants did not appear coerced into participating in the Cluster Project, voluntary participation was crucial for take-up and implementation of "new" learning. Project processes allowed teachers to take responsibility for their own learning and professional growth. In spite of complaints about a high workload and feelings of tiredness, teachers consistently expressed commitment to the Cluster Project for its duration.

The above shows the six teachers demonstrated aspects of professional autonomy in various ways, in terms of their decisions and actions, they exercised freedom of choice with regard to participation in all aspects of the Cluster Project, and they appeared committed and motivated to engage aspects of the Cluster Project so as to change and improve their Natural Sciences knowledge and teaching practice for the benefit of the children.

6.2.2 Professional Knowledge

The Cluster Project aimed to improve teachers' Natural Sciences concept knowledge, and improve teachers' knowledge of the curriculum. As indicated previously, improvements in teachers' Natural Sciences content and concept knowledge was regularly monitored through written pre- and post-tests / questionnaires. The test scores for the six teachers in this study, though, could not be separated from scores of the total teacher population for various reasons, one of which was that teachers were not required to enter their names onto the tests / questionnaires, they used numbers or pseudonyms instead. Only the scores of teachers selected for the external evaluation were recorded separately, and these were not the same teachers selected for this study. The discussion in this section with regard to professional knowledge development and its subset of criteria refers to data acquired by the external evaluators, Angela

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Schaffer (2009) and Malcolm et al. (2004), the class visit records compiled by facilitators, and the interviews with teachers.

The Cluster Project commenced with a baseline assessment, which was again administered when the Cluster Project concluded, (Appendix N). Teachers were asked to record all the important concepts they thought learners should know within a single subject strand. Marks were allocated for every acceptable topic cited up to a maximum of 32 marks for both Basic Knowledge and Scientific Knowledge. A score of 16 was awarded for "Applications" or ideas about how to elaborate on each phenomenon.

Teacher B recalls writing the baseline test and his perception about the knowledge of the curriculum and science he started off with at the time:

> *… in fact, what caught me off guard was the first session in 2007 where we were given a page that we had to fill in about what is a Learning Outcome 1, Learning Outcome 2, Learning Outcome 3, and what knowledge do you know of each aspect and the assessment standards… and from there actually, it became clear as they worked with us…*

Important differences were noted between sample teacher's pre-test and post-test scores on three key aspects of Natural Sciences knowledge, Basic and Scientific Knowledge and Application Science Knowledge. According to Schaffer's (2009) records, the mean improvement in teachers' Basic Knowledge was 39%, the mean improvement in teachers' Scientific Knowledge was 40% from a low baseline, and the mean improvement on "Applications" was only 2.5% from a low baseline score of 4%.

As regards teachers' knowledge of the curriculum, Schaffer (2009) concluded that all teachers' knowledge of curriculum content improved through involvement with the Cluster Project, with a mean improvement of 38% over the four Natural Sciences strands. She additionally observed that most gains were made on Planet Earth & Beyond and Matter & Materials followed closely by Life & Living and Energy & Change.

Schaffer (2009) further observed that impacts of the Cluster Project on teachers' knowledge for each strand varied, and the range of qualifications and teaching experiences as well as different levels of commitment may account for the varying impacts of the Cluster Project on

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teachers' Natural Sciences knowledge. Her concluding statement is significant, that "while there was a significant mean improvement on all four curriculum strands, the mean post-test scores were lower than one would hope for as the Cluster Project exits", citing "irregular attendance of training workshops and work sessions at schools, and a lack of commitment amongst some teachers,' as factors affecting improvement in science knowledge, (Schaffer, 2009:25).

Following her visits to selected teachers' classes, Schaffer (2009:26) formed the following crucial observations:

- Where the teachers had insufficient knowledge of their topic, the lessons tended to focus entirely on procedure and teacher talk was of a "do this, do that" nature, and basic science terminology and explanations requiring content tended to be absent.

- Where teachers had insufficient content knowledge, they appeared to have "turned off" their learners' questions about why certain phenomena occurred. Learner imagination and curiosity were only apparent in the classes of teachers who were also sufficiently interested in the topic to have mastered much of the necessary content.

- When the teachers, themselves, had insufficient understanding of a topic, the practical lessons tended to be exciting but largely wasted learning opportunities. Lessons on electricity, for example, had excellent learner engagement but after the exciting "hands on" activity most of them floundered on teachers' own ignorance.

The third observation mentioned concurs with the observations made by Malcolm et al. (2004: 55) regarding the 2001 – 2004 Cluster Projects, that "teachers appeared less strong in connecting science to children's out-of-school interests and experiences, especially children's social and cultural knowledge, and promoting higher-order thinking skills, problem-solving and deep thinking about science", which showed up as "classes often did the "ground-work" for concept development, but did not adequately draw ideas together towards a better understanding of some of the "big ideas" in science".

The above interpretations of the evaluators are significant, and highlights the serious implications of a poor science knowledge base for science teaching and learning. Certain comments made by facilitators in Project and school visit reports corroborates some of the

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evaluators' observations regarding teachers' poor science knowledge base, but also showed instances of the contrary. Evidence for both instances are now discussed with respect to the six teacher participants, as well as other teachers in the Cluster Project.

Along with the tests to monitor progress in teachers' science knowledge, facilitators also recorded instances of teachers' low level science knowledge that showed up in training workshops and training work sessions, below are two such instances:

In a Project report (November, 2007) the facilitator noted that*, "Most teachers at ... struggled with making a light bulb light up* (using small light bulbs, cells and connecting wires)*, and to explain what an electrical circuit is. Using guiding questions I got them to understand the concept, focussing teachers' attention on what is flowing, what enables it to flow, and what it means when there is a gap between two components."*

In the same report (November, 2007), the facilitator noted that, *"Although teachers know about magnets, magnetism appears to be an unfamiliar concept. All the teachers at ... could not make an electromagnet. I had to take them back to the concept of electric circuits, and guided them with making the electromagnet, testing it to see if it worked, and how to increase its strength."*

The recordings that follow agree with Schaffer (2009) and Malcolm's (2004) observations, and demonstrate how teachers' low level science knowledge impacted their ability and confidence to either develop the lesson further, or to extend and deepen children's experience and learning of science, this after two years into the programme.

In a March 2009 facilitator school visit report, she recorded that:

> *The Grade 6 teacher first revised the process of photosynthesis with the learners. She explained the purpose of iodine solution and how it can be used to test for the presence of starch in foodstuffs. The teacher then requested input from the facilitator because she did not feel confident about taking the lesson further. At this point the facilitator took over and taught the rest of the lesson.*

In a May, 2009 report a facilitator noted, *"The Grade 5 - 6 teacher* (a multi-grade class) *did the practical on mixtures and solutions using resources familiar to the children such as coffee,*

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tea, sugar, milk and mielie-meal, and then asked me to explain the science concepts relating to mixtures and solutions".

Investigating further, the research noted recordings where teachers appeared more knowledgeable and were therefore more successful in assisting learners to develop their science knowledge in a constructive manner.

In a school visit report (August, 2008) a facilitator recorded a lesson for Grade 6 learners where:

> *Teacher revised prior knowledge. Children had a practical "hands-on" experience making a complete circuit using a cell, connecting wire and a small globe, and they had to explain how electric current flows through the circuit to make a light bulb light up. The teacher noticed that most of the learners connected the components in the same way, he then challenged the learners to connect the components in a different way to make the light bulb light up. A discussion of the results followed. Thereafter the teacher gave each group an additional cell and connecting wires to fit into their circuits. First the learners predicted what would happen to the light bulb when they increased the energy in the circuit by inserting another cell, then they connected the components, and another discussion of their results followed.*

The lesson above demonstrates that the teacher bore a sound knowledge of the content, he understood the learners, and this knowledge allowed him to direct the lesson with appropriate learning experiences to support and extend children's learning of electric circuits.

Similarly, in an August 2008 report, the facilitator observed a lesson at a different school where:

> *… the Grade 5 teacher extended children's knowledge of circuits by challenging them to construct their own torches using waste material. She supplied torches to groups of learners which they took apart. Teacher explained the functions of various components, using questions to guide learners' thinking. Teacher developed a word list, and learners repeated words as teacher sounded them. As the class took the torches apart, teacher and learners reflected on the kinds of waste material they could use to perform a similar function for each component… learners were given the diagram of the torch to label, suggestions for alternate materials were also entered*

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onto the diagram. Thereafter teacher supplied the small globes, cells and connecting wires for the learners to construct their own torches. Learners discussed the task in pairs, decided what they were going to do, and started with the design for the torches in class…

The facilitator reports returning to the school to follow up on this lesson, and to see the torches the children made, (Appendix KK).

Furthermore, in the two lessons mentioned below the teacher participants made sound attempts to link science learnt in the classroom to cultural knowledge and events outside the classroom. Although the ideas used by the teachers were suggested at the training workshops for extending science learning beyond the classroom, these ideas were handled proficiently by the teachers:

For the lesson on testing foods for the presence of starch using iodine solution in a Grade 6 class, the teacher invited learners to bring samples of foods they usually ate at home and which they thought contained starch. She instructed learners to make predictions about which foods contained starch before testing the samples, then to test the food samples, and then to sort the foods into two groups using the information obtained from their tests – the foods containing starch and those without starch. Thereafter, she asked the learners to reflect on the kind of foods they usually ate every day and the amount of starch it contained, and how much starchy foods they ate, followed by a discussion on healthy eating plans (Teacher E)

Linked the topic "circuits" in Energy & Change in Grade 6 to real world experiences. Concluding the lesson, the teacher enquired about problems in the community associated with illegal electrical connections, cable theft and electricity outages, and how these events impacted daily living (Teacher A)

Both lessons also demonstrate teachers' context awareness, as the topics dealt with helped learners relate science learning to real world experiences. Context awareness is further demonstrated in an earlier comment made by Teacher A:

… I felt that that there was a need (to participate in the Cluster Project) because we live in a changing world and every time things are changing, and I didn't have

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sufficient training at college ..." ; and "... of course we live in an area where we actually wanted to upgrade ourselves and the children too...

I observed the six teacher participants generally felt their knowledge of science, curriculum content and science teaching improved through participation in the Cluster Project. Commenting on their knowledge gains, two teachers had this to say:

It was the first time that I was doing Natural Science. I was doing grade 5 to grade 7 and learnt a lot about how to introduce science. The cluster workshops were so important to us because we could even learn from other schools, also from other teachers about how to introduce the subject in the classroom... (Teacher D)

Teacher E: "*I gained more knowledge each and every time I attended the workshops."*

Low levels of science content and concept knowledge observed amongst teachers in the Cluster Project seemed to impact all aspects of primary science teaching and learning at schools, from whole school planning to the delivery and assessment of the curriculum in the classroom. Teachers with insufficient knowledge of important science content and concepts appeared challenged to teach science, develop practical investigations with learners, and assess learning, lacked the confidence to develop children's science knowledge; and lacked the ability and insights to extend and enhance children learning through connections to real world learning experiences. Hampered by science knowledge deficiencies, teachers tended towards over-reliance on the resources supplied and various other textbooks as the main sources of science information, and employed mainly "chalk-and-talk" methodologies for teaching science.

The converse is also true, as demonstrated by the examples presented above, where teachers' science content and concept knowledge improved they demonstrated sound science teaching capabilities, appeared more confident in their teaching ability, were able to engage children in appropriate learning experiences, and could extend and deepen children's learning of science. This observation agrees with Harlen's (in Tytler, 2010:34) contention that what may essentially "be holding back teachers' understanding is not the ability to grasp ideas, but the opportunity to fully explore, discuss and develop them." For this to happen, teachers would need time to develop their science knowledge within a supportive environment. However, given the considerable workload and demands made upon primary school teachers and the constraints on

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their time, it is not surprising that developing science knowledge may not always be a high priority at schools.

6.2.3 Professional Practice

Improving teachers' professional knowledge, though important, is only one aspect of TPD. Improving teaching in the classroom is an equally crucial, if not the more important component of the teacher development process. Abundant research literature shows that classroom teaching more than other factor has a decisive effect on children's learning. Research also shows the shift from traditional rote, fact-based science instruction towards teaching that fosters critical thinking and problem solving has been very slow in taking root in classrooms.

School and classroom visits are an essential component of the Cluster Project for assisting teachers to make the shift towards practical science teaching. Visits to teachers' classrooms provide a means of ascertaining how teachers interpreted and internalized what they received during training, and how teachers were able to implement learning in their particular teaching contexts. These visits present opportunities for science teachers to observe others teaching in real-life teaching situations. And, they also offer teachers an opportunity to trial new and unfamiliar teaching strategies in a supportive environment.

There is some agreement between the observations made by both external evaluators, Schaffer (2009) and Malcolm et al. (2004) with regard to teachers' professional practice in the Cluster Project, mentioned elsewhere. Schaffer (2009: 26) noted the facilitators had shown teachers how to manage their learner activities so that they began with a brief period of contextualisation and ended with some form of consolidation. She further observed that most teachers seemed to have grasped the principle of "hands on, minds on" and the importance of engaging children in practical experiences for developing science knowledge, though sometimes learners were not always given the opportunity to complete the trilogy of "words on", to explain their thinking and understanding of science. Some classes did draw or write a few words about what they had observed but few had the opportunity to "speak" new terms such as "circuit" and "conductor" or "solution" and "molecule". Some lessons tended to focus entirely on procedure and teacher talk was of a "do this, do that" nature, while in others the practical lessons tended to be exciting but largely wasted learning opportunities.

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For a separate review and analysis of teaching practice in the Cluster Project, the research consulted facilitators' quarterly school visit reports that present the teaching practices of some of the teacher participants in this study, as well as other teachers in the programme. Regarding Schaffer's (2009) observations of teachers in their classrooms, mention must be made that these were conducted during the second year of the programme in 2008, whereas the lessons discussed in the table below were purposefully selected from the 2009 records, for the reason that most of the lessons during that year were taught by the teachers themselves, with minimal support from the science facilitators.

Table 6.1: Teacher Lesson Performance

Lesson	**Analysis of teaching practice. Teacher:**
1. Teacher A presented a lesson on "Forms of Energy" to Grade 5 (2009) *On a mind-map teacher revised: What do we know about energy? Teacher reviewed plants, photosynthesis and the importance of energy from the Sun for photosynthesis.* *Guided by questions, learners named different forms of energy, solar energy – light and heat, etc. Teacher supplied a series of pictures and learners were asked to identify the forms of energy illustrated, which they shared and discussed with the class. Thereafter, teacher provided food containers and packets, explained how to read a food label, and discussed the energy contained in foods per 100g serving, developing a word list of new words and symbols as he went along – kilojoules (kJ), calories (cal), kilocalories (kcal), carbohydrates/ sugars, protein, fats, vitamins, fibre, etc. Learners compared high and low energy foods. Learners wrote a paragraph about what they had learnt as part of the consolidation.* The facilitator wrote: *The teacher's lesson was well planned and confidently executed. Learners respond respectfully and enthusiastically which shows that he has a good relationship with them.*	• Connected new learning with prior learning • Used a variety of instructional materials to engage learners in age-appropriate activity • Presented opportunity for learners to share (speak) • Related learning to the real-world experience • Developed understanding of science • Developed science vocabulary • Provided an opportunity for learners to summarize learning • Demonstrated knowledge of content and pedagogy. • Has good rapport with learners
2. Teacher B presented an Astronomy lesson "Space travel and living in space" (2009) *The lesson focussed on helping children understand that astronauts are usually professional space travellers trained to*	

command, pilot, or serve as crew aboard a spacecraft. Astronauts conduct specially designed experiments. An environment with almost no gravity challenges humans living in space. Humans must adjust their diets, sanitation, and sleep patterns, and wear specially designed space suits. *Teacher started the lesson with the word astronaut. He developed a mind-map of words and information provided by learners, and also guided learners using questions such as "What is an astronaut? What does an astronaut do? Who is the first African in space?" Teacher then provided resources on Space Travel (PSP Astronomy cards) which learners read quietly for a while. He then paired the learners for the task to prepare an "An Interview with an Astronaut", and instructed paired learners to develop the questions and answers for an informative interview, with one learner as the journalist interviewer and the other as the guest astronaut. Teacher guided learners to focus on the role of the astronaut, how astronauts live in a weightless environment, and the effects on everyday activities, such as eating, taking a shower, and using the bathroom, how a spacesuit works, etc. Teacher moved around the classroom and provided support. Then pairs of learners were invited to the makeshift stage at the front of the class to present their interviews. A few questions from the "audience" for the "astronaut" were permitted in each case. He concluded the lesson with an "Astro – Quiz", and integrated a writing activity for Language with the topic: "A journey into space".* The facilitator wrote: *The teacher is very innovative and always open to new ideas. His passion for science and children is evident in his teaching.*	• Revised prior learning • Developed science vocabulary • Used a variety of instructional materials to engage learners in age-appropriate activity • Presented opportunity for learners to read, write and speak. • Related learning to the real-world experience • Used questioning and discussion techniques • Demonstrated knowledge of learners • Provides individual support where needed • Developed understanding of science • Has good rapport with learners
3. Teacher C presented a lesson on the "Transfer of heat energy through conduction and convection" to Grade 7 (2009) *The facilitator provided all the equipment (burners, gauze wires, tripods, etc.) the teacher needed for the investigation with his learners. We were on hand to support the teacher, but in this case we are happy to report that our assistance was not needed. The teacher guided the learners through the investigation confidently, as he had experienced it in the training workshop. The lesson went well, and we observed that*	• Required less support from facilitators • Implemented an investigative approach • Confidently conducted an investigation with his learners

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the learners thoroughly enjoyed it. The lesson concluded with learners writing a report about their observations. The facilitator wrote: *The teacher has a great passion for science and science teaching, and his positive attitude and energy towards the learning area has impacted the learners. He is a very capable Natural Sciences teacher. He strives to make science relevant and interesting for the children. The teacher reported he feels good when the previous Grade 7 learners return to the school and tell how well they are coping with Natural Sciences at high school.*	• Integrated language development with science learning • Demonstrated a positive attitude towards teaching science • Demonstrated a willingness to implement new ideas and strategies
4. Teacher D presented a lesson on "How plants make food – Photosynthesis" in Grade 6 (2009) *The teacher revised previous knowledge, developed a word list. Learners explained the process of photosynthesis using a chart. Learners did a drawing and wrote a paragraph about photosynthesis. The teacher outlined what would follow in the lesson:* • *Testing a green leaf for the presence of starch* • *Testing other food such as potato for the presence of starch* • *A study of staple foods of different cultures in South Africa* • *Home-cooked meals versus fast foods, and processed foods.* The facilitator wrote: *The teacher is working well. The evidence of this can be seen in the learners' workbooks, as well as their responses to the teacher's questioning.* The teacher was promoted to Head of Department (HOD) in 2009.	• Revised prior learning • Used a variety of instructional materials to engage learners in age-appropriate activity • Presented opportunity for learners to speak and write • Provided an opportunity for learners to summarize learning Related learning to the real-world experience • Developed understanding of science • Developed science vocabulary
5. Teacher E presented an investigation on "Burning of fuels" to Grade 5 (2009) *The facilitator provided all the equipment (burners, gauze wires, tripods, thermometers, etc.) the teacher needed for the lesson. Using a mind-map, teacher revised prior knowledge regarding fuels as a source of energy. Learners were asked to elaborate on the uses of different fuels. Thereafter the teacher: Explained the purpose of the investigation. Described the different steps for the investigation. Described the apparatus used in the investigation. The teacher made sure the learners knew how to handle the apparatus properly. Learners read the*	• Revised prior learning • Implemented a strategy that was new to her • Implemented an investigative approaches

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steps of the investigation again, and teacher discussed the safety precautions. *Learners conducted the investigation very confidently, recorded temperature increases onto a table, and then shared their findings with the class. Teacher offered support and the facilitator joined in whenever she needed to.* *Teacher explained the temperature recordings would be used in the follow-up lesson. Learners would draw a graph and write a paragraph about their findings and observations. The facilitators suggested an extension whereby the teacher links the investigation (Learning Outcome 1) with Learning Outcome 3 by discussing the impact of the uses of the different fuels (paraffin and methylated spirits) on the environment and people's health, air pollution and its effects, and what can to be done to improve the situation.* The facilitator wrote: *This teacher is always well prepared and appears to enjoy teaching science. She remarked that her confidence increases with each science lesson that she has presented successfully. Her confidence is very evident in the manner in which she presents her lessons. We noticed a great improvement in this teacher's ability to engage learners in science teaching and learning since she started the programme.*	• Sequenced materials in age-appropriate activities to promote learning • Provided opportunities for language development – reading and following instructions, and communicating results • Demonstrated knowledge of children's learning needs • Demonstrated confidence in knowledge and practice throughout
6. A Grade 5 lesson on "Life Cycles" (2009) *In his introduction the teacher referred to ex-President Nelson Mandela. The learners so enjoyed the manner in which the teacher reviewed the history of Mr. Mandela and related the story to the topic "life cycles". The teacher used this as a starting point to introduce the concept of life cycles, and the different stages that can be observed in the life of a human being. The teacher reviewed vocabulary associated with life cycles: teenager, adolescent, toddler, baby, etc. Learners were then given pictures of the human life cycle, they were required to sequence these and write sentences about the human life cycles, then to present and explain their posters to the class.* The facilitator further noted: *The teacher has a pleasant personality, and has developed a good working relationship with the learners who seem to really enjoy the manner in which he teaches. The lesson was knowledgeably and confidently presented.*	• Demonstrated creativity by using strategy not shared in the training workshops • Drew on children's real world experiences • Used a variety of learning support materials • Integrated language development, vocabulary, talking and writing • Has good relationship with learners

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7. A Grade 6 lesson on "Electric Circuits" (2009) *The learners were actively involved in the lesson. They used the components supplied – small light bulbs, cells and connecting wires – to make the light bulb light up, draw and explain the flow of electric current in one way. A few learners drew and explained their circuits on the board. Thereafter the teacher instructed the learners to find another way of connecting their circuit that was different to ones already demonstrated. Five different ways of connecting the electrical components were drawn and discussed. Then the teacher supplied drawings of circuits and instructed learners to: First predict if the circuit would work, Connect the circuit, Draw the working circuit and show the flow of electric current using red arrows, and Explain why a circuit did not / would not work at all.* The facilitator wrote: *The learners appeared to enjoy the hands-on lesson, and were able to draw and explain the connections in the circuit, the flow of electric current, etc.*	• Implemented new and improved ways of doing • Engaged children in active learning to promote the acquisition of key science knowledge and skills. • Implemented an investigative approaches • Employed age-appropriate teaching strategies relevant to primary science content. • Scaffolded instruction and resources to help children achieve their learning goals • Integrated opportunities for language development • Provided opportunities for learners to develop their reasoning, and explain their thinking
8. A Grade 7 lesson on "Animal Social Patterns" (2009) *The first part of the lesson focused on developing an understanding of the concept "social living" using the child's knowledge of family structure as the starting point (single parent, extended family, etc.). The teacher developed a word list (solitary, patriarchal, matriarchal, monogamous, polygamous, etc.). Learners worked in groups to research different animals. The teacher provided a list of guiding questions to facilitate the research process (Where does the animal live? When are these animals most active, day or night? What does it eat? How does it find food? Is it a very large group of animals with many roles, or only a few individuals co-operating? Who is at the head of the family? What kinds of co-operative behaviour are needed for, e.g. feeding, protection, marking territory, and so on? Etc.). Using various resources such as the PSP Animal cards and National Geographic magazines learners prepared a poster on the animal they selected. Thereafter, each group presented their research.*	• Although the lesson idea was presented at the training workshop, drawing on her creativity the teacher adapted it to her style of teaching and context. • Related content to children's life experiences • Provided opportunities for language development – writing, reading and speaking • Encouraged questioning • Has a good relationship with her learners

After a particular group presented, group members fielded questions about the animal. The facilitator wrote: *The teacher sets a fine example and is an inspiration to other teachers at the school. She attends all the workshops and work sessions with a view to empowering herself. She also understands the importance and value of the classroom visits and never fails to have a lesson prepared for us. She does indeed go the extra mile for her learners.*	

Guided by the professional development framework analysis shows a number of teachers demonstrated satisfactory science teaching, employed practical teaching strategies, integrated language development through speaking, reading and writing activities, used a variety of resources in lessons, and related science content to children's life experiences. Teachers generally appeared more confident in their science knowledge and teaching ability during the final year of the Cluster Project, when greater improvements in teaching practice were observed. At this stage teachers seemed more comfortable in their relationships with the facilitators, and amenable to presenting lessons and to reflecting on their teaching. Commenting on this relationship, Teacher D had this to say:

> *… They (facilitators) bring along a lot of equipment. And, they also come. They don't just come to criticize your work because they have told you …. They also help you with your presentation. And that makes you to be ease when you are doing your lesson…*

Reflecting on his teaching of science, Teacher C had this to say about what he learnt most from the Cluster Project: *"… Because teaching a child must also include the practical things. Because they won't forget. If we are going to always teach them the theory, it would be easy for them to forget…"*

And, Teacher B made the following comment about improvements in his teaching practice. Although this did not appear to be a general trend, it is significant observation because it shows involvement with the Cluster Project influenced his teaching of other subjects as well:

> *"I would say it (the Cluster Project) had a major impact in my teaching style … um … I could do … um … more than just the writing on the board. You know what I learned*

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> *through the Cluster Project is that you bring in the practical, you bring in the investigation; and you bring in the research..."* and
>
> *"I don't only teach Natural Science, I also teach Maths and Social Science, and I have used some of these ...er ... styles and some of these approaches in my Maths, and as well as Social Science."*

Recalling what he regarded as the most useful aspect of the Cluster Project, the principal interviewed for this research said *"The classroom visitations were the most beneficial. The way the teachers go about teaching, being more active, and the energy when teaching Natural Science was better because of it."*

The science lessons reviewed for analysis above have incorporated an effective blend of whole-class, group and individual activities; the lessons were age-appropriate, innovative and challenging for the learners; teachers implemented practical teaching strategies and investigations confidently; teachers used appropriate resources to promote engagement and learning; children were actively involved in lessons; classroom instruction was structured and well managed; and the structure and pacing of lessons was reasonable. Where good practice was observed, learners were provided with ample opportunities to express their views and to test and develop their own ideas.

Various school visit reports also show that a number of teachers were less successful in making the shift towards practical and investigative science teaching, although precise figures are not reflected in the records. In some of these cases, where facilitators were permitted to observe teachers, the lessons were mostly teacher-directed, fair to poor in terms of structure and management, with insufficient or poor connections to learners' existing knowledge and ideas, and where learners were afforded little opportunity to actively engage in science learning. In other cases, certain teachers would rather not teach a lesson for facilitators, but preferred to consult with them in the staffroom.

While this research acknowledges the critical observations of the external evaluators, improvements in teaching practice were noted within the Cluster Project, as demonstrated in the lesson instances mentioned. These records show that several teachers were successful in providing a reasonable classroom environment that supported learning of science, as was observed amongst the teacher participants as well as amongst other teachers in the programme.

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6.2.4 Professional Collaboration

Teachers' work is embedded in networks of relationships with a great many people, with their learners, learners' parents and guardians, and colleagues at school, education district officials, members of teacher unions, and community of teachers. Teachers' professional growth and development does not come about in a vacuum, but is inextricably bound to relationships formed in the school context, with members of the community and with the broader professional fraternity.

Programmes for TPD anchored in teachers' reality, sustained over time, and which provide sufficient opportunities for peer collaboration appear more successful, according to Chan and Pang (2006) and Richardson (2003). Taking research regarding the importance of professional collaborations into consideration, the Cluster Project organized opportunities for professional collaboration to encourage a community of practice forming. Schools selected for a cluster in a district are located close to each other in the same area. The proximity of schools allowed teachers from neighbouring schools to connect in a common space – the training workshops, for a common purpose – to improve Natural Sciences at schools. The purposeful arrangement allowed teachers to connect with each other professionally, to share scarce resources, teaching ideas and teaching strategies, and to collaborate on solutions for teaching and learning challenges within communities with similar characteristics.

Teachers generally understood the advantages of working together. For instance, referring to a benefit of collaborating professionally in the Cluster Project Teacher D said *"The cluster workshops were so important to us because we could even learn from other schools, also from other teachers about how to introduce the subject in the classroom."*

Highlighting two important benefits of collaborating and sharing Teacher F advised: "… *don't keep the information to yourself, share with people, teach people, share, teach, so when you leave there's somebody else to take over…"* In doing so teachers can support others in their professional development, and ensure that another teacher is available to sustain learning from the programme within the school.

Also, according to Teacher F: *"Fresh, new ideas need to come in…"* This way, teachers engage and learn different, innovative approaches, teaching ideas and strategies from each other.

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Teachers' preparedness to share and support each other was further demonstrated at the Cluster Project Conference where three of the six teachers, Teachers A, B and C, presented practical strategies they found useful for teaching important science concepts, (Appendix DD). Teacher A co-presented with another teacher from a different district on "How to teach about circuits in Grade 5". After the partner read a story to introduce the lesson, Teacher A did his part of the presentation. He fished out various components for the circuit from different pockets of the jacket he wore at the time, explaining the function of each component as he went along, then connected the components to make the light bulb light up. He concluded the presentation emphasizing the importance of using concrete apparatus in certain science lessons. Teacher B, the youngest male of the group of presenters, did a lesson for Astronomy focusing on integrating language development in Natural Sciences through engaging children in reading, writing and speaking activities. For his presentation, Teacher C focused on conducting an investigation with Grade 7 learners, writing an investigation report, and supporting learners with developing an understanding of how science knowledge is used in the real-world context.

Four teacher participants served as Project coordinators and undertook to lead and guide Natural Sciences education at the schools. By participating in the Cluster Project Conference and serving as leaders of the Cluster Project, teacher participants demonstrated a willingness to share professional knowledge, expertise and experience. While at the start of the Cluster Project Teacher F already held a senior position at the school, as Head of Department (HOD), in the third year of the Cluster Project Teacher D was promoted to HOD for Natural Sciences, and two years later Teacher C was also promoted to HOD for Natural Sciences and Technology, this shows their competency to lead other teachers in Natural Sciences was acknowledged by the school.

Collaboration and support at schools, and the absence thereof had an effect on teachers' engagement of the Cluster Project, their teaching in the classroom, and their professional development. All schools in the Cluster Project were very different, and one distinct difference was the way teachers worked together. For instance, Teacher participants C and E worked very much in isolation, there was minimal interaction amongst colleagues about teaching practice at the school and teachers seldom engaged in professional conversations. The researcher was also made aware of instances of jealousy and infighting that disrupted co-operation amongst teachers at the school. Teacher C endeavoured to find other opportunities for professional collaboration such as attending Natural Sciences and Technology courses at CTLI and he also

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presented at the Cluster Project Conference, and Teacher E moved to another school in the same area. Teacher participants A, B, D and F were in schools where teachers worked collegially towards finding solutions for some of the challenges facing teaching and learning, although the strength of collaborations with respect to Natural Sciences education differed from school to school.

6.2.5 Continuing Professional Development

On the subject of education and training for science teaching, Teachers C, D and F reported they studied science at college, Teachers C and D additionally attended science teacher training courses presented at CTLI, Teacher B stated that much of his science knowledge he acquired through research on the Internet, and all the teachers reported attending various workshops presented by the WCED and various other service providers towards improving their teaching in general, and their teaching of Natural Science. Further, three of the six teachers, Teachers A, B and C, presented practical teaching strategies at the Cluster Project Conference.

Several advantages and disadvantages associate with Teacher B's strategy to use the Internet for his learning of science. An important advantage is that the Internet makes available a large amount of resources to teachers, and offers diverse perspectives on a range of issues. However, the fact that information can be uploaded onto the Internet very easily means it is inevitable that incorrect information can also make its way onto the network. This means that users always have to question the reliability of the available information. If teachers are not aware and conscious of this problem, there is a real risk that they may acquire and use information related to science that is incorrect and/or misleading and that can lead to confusion in later years.

Although there generally was a readiness to engage in further learning opportunities, and to share professional knowledge, expertise and experience, at the time the study was conducted none of the teacher participants mentioned they planned to continue with additional study programmes for science and science teaching. A comment made by Teacher A could provide a reason for teachers not engaging further science study programmes, he said *"I would actually love more workshops, but because of the workload most of the teachers when they come there … and they feel so stressed… I think most don't want to go there* (to attend workshops) *because then it's … soccer, sports, the workload…"*

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The response from Teacher A partly explains teachers' lack of attendance at workshops and lack of enthusiasm for continued learning through workshops, or independent study. Yet, despite a heavy workload, there is recognition that teachers need more training, as Teacher A continued: *"And more people are asking this* (training workshops and classroom support) *for other subjects as well."*

Regular collaborations can offer teachers many opportunities for professional development, and is a way of ensuring teachers keep abreast with important developments within any subject. A critical element though is teachers' willingness to engage in continuous study programmes so that they can regularly update and improve their knowledge and teaching abilities. In order to do so teachers would need to maintain a positive attitude, enthusiasm and a learning disposition. Also of importance for further study are teachers' general perceptions about science and science learning. Through her involvement in the Cluster Project Teacher D became keenly interested in science and science teaching. Reflecting on a new found interest and passion she said:

> *I just regret not doing Physical Science as a subject when I was doing … when I was in the high school, but I did not know that I could do matric science. And, we have that knowledge that science is very difficult. And, that it is only done by people who are brilliant...*
>
> *… I was disadvantaged by the attitude and people putting me off and not believing in myself. If I could have stuck to it, who knows where I could have been. That is why I tell my children that they must learn Natural Sciences up until grade 12 because science is the best…*

As demonstrated by the teacher's quote above, negative perceptions of science as being *"very difficult"* and that it only involves those who are *"brilliant"* persists in a many communities. Reviewing attitudes to science, Osborne, Simon and Collins (2003:1054) writes that an individual's attitude towards science is made up of several components, including: teachers' perception of science, anxiety towards the subject, the value of science, self-esteem at science, motivation towards the science, enjoyment of the subject, attitudes of peers and friends towards science, attitudes of parents towards science, the nature of the classroom environment, achievement in science and fear of failure in science. Teacher D's regard of science as being

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"very difficult" links with "fear of failure in science", *"science is only done by people who are brilliant"* and *"not believing in myself"* links with "low self-esteem at science", and "*people putting me off"* links with the effect of negative perceptions of family and community on children's learning of science. Her involvement with the Cluster Project and new experiences of science as being accessible and doable, enabled the teacher to alter her perceptions of science, so much so that she now encourages her learners to continue to learn science. Thus, her involvement with the Cluster Project helped with a turnaround in her perceptions and understanding of science and science education.

For real change and improvement of science teaching and learning in schools it is important that teachers: believe that science is relevant and important, believe that science is for everybody, encourage all learners equally, develop positive attitudes toward the subject, gain confidence in their knowledge of science through further study, and constantly reflect on and improve their teaching of the subject.

6.3 Conclusion

This section analysed the evidence for indications of TPD achieved through the Cluster Project. The focus was the *Object and Outcomes* of the Activity System, and examined improvements in science teaching for improvements in Natural Sciences learning in schools.

Analysis involved applying the qualitative framework to the evidence to map out and clarify the professional development of six teacher participants with respect to the five key indicators of professional autonomy, professional knowledge, professional practice, professional collaboration, and continuing professional development, taking each criterion separately.

A number of opportunities existed within the Cluster Project for teachers to exert their professional autonomy. The six teachers participated actively in all aspects of the Cluster Project such as training workshops and classroom visits, were leaders of the Cluster Project at schools, implemented suggested lessons and activities, used resources the Cluster Project provided, and readily shared with colleagues. They voluntarily and enthusiastically engaged the Cluster Project towards improving their Natural Sciences knowledge and teaching practice for the benefit of the children.

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The Cluster Project aimed to improve teachers' Natural Sciences concept knowledge, and to improve teachers' knowledge of the curriculum. From a low baseline for knowledge development, Schaffer's (2009:25) statement that "while there was a significant mean improvement on all four curriculum strands, the mean post-test scores were lower than one would hope for as the Cluster Project exits" is relevant. Schaffer (2009:25) further cited "irregular attendance of training workshops and work sessions at schools, and a lack of commitment amongst some teachers," as causes of the poor gains in science knowledge. In addition, schools' assessment plans received a poor score of 4.4 out of 10, only one mark higher than it had been before Project delivery began. And, the shift of only 2.5% from a low baseline score of 4% with regard to "Application of science knowledge" is consistent with Malcom et al.'s (2004: 55) observation that "teachers appeared less strong in connecting science to children's out-of-school interests and experiences, especially children's social and cultural knowledge, and promoting higher-order thinking skills, problem-solving and deep thinking about science". It can be inferred that teachers were unable to make the shift from "knowing science" to "using science knowledge" because they had not sufficiently moved beyond acquiring basic knowledge and understanding of science towards recognizing the connection between science knowledge of the classroom and real-world applications of science knowledge.

Improving teaching in the classroom is a critical focus of the Cluster Project. Notwithstanding the observations of the evaluators which were not very positive about the science teaching they observed in schools, a separate analysis showed that a number of teachers demonstrated satisfactory science teaching ability, employed practical teaching strategies, used a variety of resources in their lessons, integrated language development through speaking, reading and writing activities in their lessons, and made reasonable attempts to relate science content to children's life experiences. However, improvements in teaching practice were really only observed during the third and final year of the Cluster Project, when teachers appeared more confident in their science knowledge and teaching ability.

Professional collaborations, whether formal or informal, provide a supportive environment for teacher development. Strong collegiality permits participants to engage in meaningful learning activities, and to cooperate with colleagues on fine tuning and improving instructional methods and curriculum implementation. Where a spirit of positive and strong collegiality existed in schools, teachers worked well together towards whole school development of Natural Sciences,

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ensuring continuous constructive science teaching and learning through the various grade levels.

Responses from Teacher A partly explained teachers' lack of enthusiasm for continued learning through workshops or independently, mentioning primary teachers' heavy workload as the main reason for some not attending training workshops. Schaffer's (2009:25) reports of "irregular attendance of training workshops and a lack of commitment amongst some teachers," and the fact that none of the six teacher participants were involved in further study programmes does not engender much optimism for further growth and development in science teaching beyond the Cluster Project.

Instability in schools and insecurity amongst teachers resulting from regular curriculum reform, heavy workloads and increased stress are regularly identified as factors affecting teachers' work in primary schools. Primary teachers in general are often exhausted and discouraged by the pace and frequency of transformation. While they may appreciate a centrally provided curriculum and other materials and would like to see more of them, having to make adjustments to their daily planning, teaching routines and assessments requires an enormous effort, especially considering that as class teachers they teach all subjects and have to alter plans and assessments according to new sets of instructions for each.

Analysis of TPD within the framework shows uneven influences of the Cluster Project on teachers and science teaching and learning. Teachers voluntarily and actively participated in the Cluster Project, though they had no plans to further their studies of science and science teaching independently. Even though improvements in teachers' science knowledge were recorded, "application of science knowledge" and assessments reflected poor progress. And, although improvements were observed in science teaching practice, this was not a general trend. Thus, it seems teachers by and large would need more time, and additional training and support to build and strengthen their knowledge of key science concepts, understanding of application of science knowledge, teaching practice and assessment of learning.

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CHAPTER SEVEN: CONCLUSIONS

7.1 Introduction

This research draws attention to the role of professional development programmes in upskilling teachers for improved science teaching and learning at primary schools. Central is an analysis of a teacher development programme known as the Cluster Project. Analysis focused on primary science and teacher professional development (TPD) with respect to three key areas of improved teachers' knowledge, improved teaching practice, and support for teachers during periods of curriculum change.

Data and discussion showed that with respect to the six teacher participants in the study the Cluster Project achieved a measure of professional development and improvements in the teaching of science, though Chapter 6 showed this was not a general trend within the Cluster Project teacher population.

7.2 The Cluster Project in Review

The focus on teachers in this research is driven by the understanding that the pedagogical component plays a critical role in educational change and improvement. The link between teachers' critical role and the achievement of national objectives to improve learning in the key subjects of natural sciences, mathematics and languages is compelling. The decisive role of teachers in education and educational change brings processes for their development strongly into focus, along with the imperative to distinguish effective from ineffective teacher development programmes.

Towards achieving its primary objective of improving science teaching and learning in primary classrooms, the design and delivery of the Cluster Project targets key areas of teachers' professional need; for training to improve teachers' science knowledge, for guidance with understanding and adapting to changes to the Natural Sciences curriculum, and for assistance with managing assessment; and classroom support for improving teaching practice. Additionally, the Cluster Project provides essential resources to teachers to enhance science teaching and learning in the classroom.

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Analysis of the Cluster Project involved mapping the evidence within a framework, describing the professional development of six teacher participants with respect to the five key indicators of professional autonomy, professional knowledge, professional practice, professional collaboration, and continuing professional development.

This research observed the six teachers exercised professional autonomy, participating voluntarily and actively in the Cluster Project towards improving their Natural Sciences knowledge and teaching practice. Aspects such as teachers' commitment and willingness to engage all components of the Cluster Project for their development are acknowledged as crucial factors affecting successful achievement of professional development objectives. This research noted disparate influences of the Cluster Project on teachers and science teaching and learning, which correlated strongly with teachers' level of commitment and participation. Even though improvements in teachers' science knowledge and teaching practice were observed, crucial areas such as the application of science knowledge to real-world contexts, and the topic of assessments reflected poor progress.

Moving off a very low base, a significant mean improvement on all four Natural Sciences knowledge strands, as defined by the curriculum, was achieved through the Cluster Project, although the mean post-test scores were lower than anticipated at Project exit. This research agrees with observations made in the external evaluations that teachers were less strong in helping children make connections between science learning in the classroom and out-of-school interests and experiences.

Providing support in the classroom is a crucial component of the Cluster Project. Analysis showed that with constructive support teachers could improve classroom teaching for improved learning of science, which amongst others, involves employing a range of practical teaching strategies and resources, and integrating activities for language and mathematics development into science lessons.

Professional collaborations provide formal and informal environments for promoting TPD. Analysis highlighted that effective leadership and efficient school organization affects the way teachers are able to cooperate and support each other for whole school development of Natural Sciences. Strengthening science teaching and learning at schools beyond the Cluster Project

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will be determined by teachers' willingness to cooperate with each other, and by their participation in continuous professional development programmes.

Several challenges experienced with Project implementation affected overall outcomes. Firstly, although the WCED recommended schools participate in the programme, the fact that the Cluster Project was presented by an independent agency seemed to reduce its authority with some teachers. This meant that implementation depended in part on official support from the districts and strong school leadership to bolster its authority with teachers, and encourage teachers' cooperation and preparedness to participate fully in the programme. To reduce conflicting messages for teachers with regard to science and science teaching, the service provider worked closely with various Natural Sciences curriculum advisors attached to the different districts.

Secondly, where ineffective school leadership and poor collegial spirit resulted in a poor school ethos, the Cluster Project was sorely challenged to make any kind of impact. Although a few teachers at a school might have been committed to involvement with the Cluster Project, sparse participation by teachers affected whole school development of science.

Thirdly, essential science equipment at some schools was in short supply. This meant that the service provider had to draw on its own resources to supply equipment teachers needed for science lessons. Facilitators repeatedly motivated for schools to acquire science kits of their own, but this did not always happen, which inspired an additional concern about further development of science teaching and learning when the Cluster Project exited.

Fourthly, changes in the language policies for some schools with first language isiXhosa mandated as the LOLT across all subjects and all grades (R-6) except grade 7 generated its own set of problems for science teachers. The switch from teaching science in English to teaching science in isiXhosa, unsupported with appropriate text for guidance, and an inadequate knowledge of isiXhosa equivalents for important science words, was experienced as particularly challenging by some teachers. On the one hand, the argument is that where science is taught in English for learners with home language isiXhosa, the practice denies the child's right to be taught in his/her mother tongue, and this practice may also affect the child's conceptual development of science. On the other hand where science is taught in isiXhosa,

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appropriate material resources and other forms of support are not always available to teachers to help them make the language transition.

Project facilitators regularly observed that teachers used both languages, English and isiXhosa in their science lessons. Malcom et al. (2003:10) also observed teachers and children had difficulty deciding when and how much to use mother tongue and language switching within the classroom. The HRDC (2014) found that where terminology for mathematics and science in the African language was not fully developed teachers resorted to using English during lessons, and where African languages were homogenous, dialects varied, and the standard varieties of language differed from those learners used. The language issue for science teaching and learning, whether science should be taught to learners with home language isiXhosa in English or isiXhosa, is a highly contested one with definite challenges for both teachers and learners.

Fifthly, teachers' baseline knowledge of science varied considerably. In many cases teachers' initial education and training did not always include science and science teaching. These teachers therefore entered the Cluster Project with a very low baseline, and only a few had a moderate knowledge of science. The six-hour training time per term for each Natural Sciences strand therefore proved inadequate for accommodating the different levels of baseline knowledge to allow for personalized learning. Science knowledge deficits also had the effect of minimalizing impacts of the Cluster Project in some cases.

Sixthly, stated repeatedly, major changes to the Natural Sciences curriculum exacerbates many of the challenges in schools already complicating the work of science teachers and the efforts of TPD programmes for upskilling teachers.

Overall, analysis of TPD within the Cluster Project showed differing influences on teachers and science teaching and learning. This research agrees with the concluding observation made by the external evaluator, Angela Schaffer (2009) that for a number of teachers progress was only slight at Project exit, which means they would need additional training and support to further enhance their science knowledge and teaching practice, supported with appropriate texts and other resources, within the context of a stabilized curriculum, towards teachers gaining increased professional competency and confidence for general improvements in science learning in primary schools from Grade R – 7, as a reasonable starting point for further

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growth and development of science. Of concern is the fact that for many teachers the Cluster Project appeared to be the only source of science education and training, over and above departmental orientation workshops, few communicated intentions to further their studies of science and science teaching independently through alternate teacher development programmes.

7.3 Concluding Commentary

Learner underperformance in the critical subjects of science and mathematics in South African schools strongly links with the quality of teachers' knowledge and the quality of their teaching. In a research of South African education from 1994 to 2011 Spaull (2013:8) found that the country had some of the least-knowledgeable primary school (mathematic) teachers in sub-Saharan Africa. He argues that the crises of poor quality of education may be because many teachers have below-basic levels of content knowledge, especially those that serve poor rural communities, since in many instances they cannot answer questions their learners are required to answer according to the curriculum. Inadequate teacher and learner knowledge and understanding of science is well-documented, supported by regular insubstantial matric results (Simkins in CDE, 2010), ample statistical information derived from valid and reliable international studies such as the TIMSS tests (Reddy, 2006), declining numbers of children taking senior Science subjects, and a dwindling interest in science over the years 7-10. Sharing Ramphela's (2008) concern in Chapter 2 about the poor quality of education and its implication for black learners, Mwamwenda (1995:497) writes the chances of African children succeeding are slim, the number of African children completing their education at any given level remains very small compared to the number who are successful, which means education has tended towards being elitist in the sense that it benefits only a few. A turn-around strategy involves directing attention to the teacher, the second most important person in the teaching and learning situation besides the child, and re-conceptualizing processes for growing and improving their Science knowledge and teaching competencies.

Strengthening the argument for a focus on teachers and teaching practice, Wright, Horn and Sanders (1997) (in Sanders and Rivers, 1996:5) in the late 1990s produced compelling research which established that within grade levels, the single most dominant factor affecting student academic gains is teacher effect. They found that groups of students with comparable abilities and initial achievement levels showed vastly different academic outcomes as a result of the

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sequence of teachers they were assigned to. Their analysis determined teacher effects are both additive and cumulative, with little evidence of compensatory effects of more effective teachers in later grades, the residual effects of both very effective and ineffective teachers were also measurable two years later. Wright, Horn and Sanders's (1996) research is significant, and more than ten years later Mourshed and Barber (2007:12) refer to the findings they formed to support the argument that what distinguishes good schools from nonperforming or poorly performing schools is that good schools employ high quality competent teachers in each grade to ensure children receive consistent, high quality teaching and learning at every grade level. In a more recent economic study Chetty, Fiedman and Rockoff (2011) established that good teachers have large impacts in all grades from 4 to 8, and some of these impacts are: that students assigned to high quality teachers are more likely to attend college, attend higher-ranked colleges, earn higher salaries, are better able to contribute positively to the economy, and are also less likely to have children as teenagers. These authors concluded that good teachers create substantial economic value and that test score impacts are helpful in identifying such teachers.

The reasons for poor learner performances are complex and have to be understood in context. Criticizing an over-reliance on purely technocratic approaches to understanding reasons for poor learner achievements, Hargreaves and Shirley (2009: 31-32) argue that while analyses of this nature may protect teachers from being blamed for the learning deficits that students bring with them to a classroom at the beginning of the year, these approaches can be misleading as they narrow the curriculum, prioritize tested basics, and turn a blind eye to teaching to the test. In addition, such tests tend to disregard human dilemmas associated with real life in real schools, that teachers like learners can have good years and bad years, especially when a new curriculum with unfamiliar content is introduced, family members get sick, change in school leadership affects school dynamics, or when a learner with challenging behaviour disrupts classroom activities.

That may be, but more recent reports produced by Mourshed and Barber (2007) and Mourshed, Chijioke and Barber (2010) corroborate Wright, Horn and Sanders' findings that:

- The quality of an education system cannot exceed the quality of its teachers. Teacher improvement and professionalism in South Africa has a long way to go before it shifts from ideology to reality (Gamble, 2010: 32).

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- The only way to improve outcomes is to improve instruction,
- Achieving universally high outcomes is only possible by putting in place the mechanisms to ensure that schools deliver high-quality instruction to every child.

High-quality teaching can only be provided by motivated and well-trained teachers using appropriate methods, who are teaching to reach children in ways that help them learn. Teachers' long service does not equate with quality teaching practice. DeMonte (2013:3) agrees "experience does not lead directly to better instruction", and goes on to emphasize that "enhancing skills, knowing strategies, and understanding content and how to unpack that content in ways that students can understand – these are aspects of teaching that can be learned and improved upon." The role of the teacher and professional development programmes for generating positive educational change and improvement is undeniably significant, and is as consequential as the negative impacts produced by poor teaching.

The Cluster Project represents a strategy for addressing poor science teaching and learning in primary schools. Harlen (1993) mentioned in Chapter 2 supports Lewin (1992) motivation for a focus on the primary school phase since "there is little point in trying to implement policies aimed at strengthening scientific training in higher education if students at the lower levels are ill-prepared; and the better the initial education provision, especially in science, the easier it will be to organize retraining or provide specific training later". The strategy of the Cluster Project is premised on the understanding that science knowledge like mathematics knowledge is cumulative, built up by children additively and incrementally. A sound foundation established at the level of the primary school will assure that more children would be are able to take up and succeed at the high school level, and beyond.

Science teaching in primary schools may be disadvantaged by the fact that teachers at this level are usually generalists, and are expected to teach all school subjects equally well. This is a regrettable tradition, which often has specialist subjects such as science and mathematics being taught by primary school teachers who may not have received adequate education and training for these subjects.

The Cluster Project model presented learning opportunities for both generalists and the few specialists within the group. For specialists teachers the training workshops were mainly refresher courses, whereas for generalist teachers it offered comprehensive support to improve

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their teaching of science. In consideration for their professional development needs its multifaceted form provided: education and training to build and update their science content knowledge, classroom guidance to improve their science teaching in the context where they work, additionally supported with material and other teaching and learning resources. In so doing the Cluster Project worked to strengthen both the generalist teachers' capacity and confidence for practical science teaching.

Inadequate initial and in-service teacher education has debilitating effects on learning in schools and classrooms, often with unfortunate consequences for the development of science and mathematics, since teachers may have a poor background knowledge of the subject, may not have enough "expert" level knowledge to expand learning, may not have appropriate experiences of learning science themselves, may rely on inappropriate teaching strategies in their practice, may lack confidence in their own knowledge and teaching ability, and therefore may lack enthusiasm for teaching the subject, with learners ultimately bearing the brunt of their poor teaching.

In some schools where the learning of science and mathematics are affected by unhelpful teaching practices, teachers' inadequate science and mathematics knowledge and practices can be traced to pre-democracy education strategies. Reform measures for science suffer when teachers have knowledge deficits, poor conceptual understanding of science, have misconceptions of crucial content, or their science knowledge base is sparse. Progress will be insubstantial and ineffective, as Janse van Rensburg (1998: 69) points out "reform initiatives may carry with them the seeds of change, but these are mixed with the soils of the past." Strategies introduced by post-apartheid education to remedy the situation for education have not delivered the kind of improvements policy makers were hoping for, accounting in part for the slow pace of change and development in science education. Janse van Rensburg (1998: 70) advises teacher development work should not take place in a void, as if all teachers and their contexts are the same, instead she urges for South Africa's teachers to be supported as responsibly as possible. Unless more attention is given to diagnosing on-the-ground challenges for teachers and science teaching more completely before innovations are implemented, little will change, and the cycle of poor teaching and learning in science and mathematics will perpetuate, and will affect generations of learners to come.

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Poor quality of education in South Africa is a serious constraint on improved rates of inclusive economic growth vital for combatting poverty (CDE, 2009:4). An education system with limited impact perpetuates social and economic inequalities and limits national development, whereas it is important for growth to narrow the gap between the few who receive a good education and the many who do not. The problem is not one of a lack of funding, South Africa spends substantially on education. Nor is the problem one of access, school enrolment levels in South Africa have made significant progress (CDE, 2009). There have been some improvements in education, but the public schooling system is failing too many young South Africans (CDE, 2011), and the serious problem is one of educational performance and efficiency in schools.

Some may argue that TPD has received intense attention, through the investment of countless hours, huge financial resources and various initiatives such as instituting regulations pertaining to more time on task, increasing accountability in schools, and introducing national assessments, new curricula and materials, new computers and other technologies, and state-of-the-art laboratory equipment. The logical question to follow would be, “so why has there been little overall improvement in learner achievements?” The main reason for the failure, according to Harwell (2003:1-2), is that little attention has been paid to what actually goes on in the classroom, noting two important aspects have changed little over the years and that is, formal teacher education and classroom teaching. He states further that we cannot expect students to change what they do if we are content for teachers to continue doing what they have always done. According to Harwell (2003: 2), the solution is consistent high-quality TPD where teachers are given the opportunity to learn new strategies for teaching and to practice what they learned.

Workshop-based, one-size-fits-all approaches to TPD, almost always neglects the classroom observation and support dimension of TPD. Preference for the cascade approach in teacher development is dominant, as Janse van Rensburg (1998: 70) noted “departmental officials thought project teachers could easily “transfer” what they learned to other teachers”. TPD must be understood as involving much more than a simple transfer of knowledge, and Janse van Rensburg (1998: 70) agrees an understanding of deeper contextual issues affecting education is important and necessary. Although approaches used in training workshops may be based on sound educational theories, they do not always speak to particular issues some teachers struggle with on a daily basis. Removed from the classroom situation, these forms of teacher

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development usually do not include ongoing individualized feedback and support to strengthen teaching practice. A general observation is that what teachers need to learn and be aware of in their practice cannot be learned solely through theory.

Teaching in the classroom is a complex activity, demanding multiple activities of knowing, doing and learning. In preparation for "doing", teachers have to learn about the children and how they respond in lessons, they might have to learn new content, and they might have to learn how to integrate new technologies. Knowing theories of teaching and learning, the curriculum, the content, teaching strategies, and knowing the children represents only one aspect of a teacher's task. Teaching further requires that teachers translate the knowledge they have acquired in a context as they respond to learners with diverse knowledge, abilities and interests, which may be very different to the context in which they themselves experienced learning. A critical factor is how efficiently the teacher is able to connect knowledge, theory, curriculum, assessment, and the learning needs of different children in their teaching practice, while at the same time managing a host of complex competing contextual factors. Making those connections in a way that helps children learn comes easier for some teachers than others, and there might be those teachers who may need support with how this can be achieved.

Classroom engagements through demonstrations, observations and team-teaching offer teachers an important means of learning how to teach. Some teachers may feel vulnerable or uncomfortable about being observed by colleagues, seniors or education officials, while others respond territorially and guardedly when visitors enter their classrooms. However, the Cluster Project shows that where classroom observation and support is done in a considerate, respectful and inclusive manner, it is seen as support, can be beneficial for teachers, and can present opportunities for the teachers to re-evaluate their classroom teaching from a different perspective, while at the same time it allows teachers to benefit from input (suggestions, ideas, teaching strategies, and resources) received from a knowledgeable and experienced colleague. Teacher development programmes that include classroom support for teachers can strengthen their professional capacity where it counts the most, in the classroom.

Science TPD should rather steer away from approaches promoting the perception that a teacher's main task is to "transmit" knowledge, skills, and attitudes, towards seeking approaches which offer teachers guidance with organizing and influencing every day classroom

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conditions that help children relate what they learn to their own lives, so that it means something to them.

7.4 Recommendations for Teacher Development Programmes

Schools today face enormous challenges, some historically generated and others associate with recent changes in education. The challenge of educating a diverse group of learners in science through teachers with weak, insubstantial knowledge of science is unfeasible, and is one that ought not to be dealt with only through costly “teacher-proofed” curriculum and resource packages. In accord, Maurice (in Hunter, Ashley and Millar, 1983:102) writes the “best and wisest and the most progressive curriculum (or resources) in the hands of poorly qualified teachers, lacking competency and confidence, without facilities and equipment, in unsatisfactory buildings and accommodation, with unmotivated pupils frustrated by their social conditions, has little real meaning and little chance of success”. Adding, that in fact it can be just as “ineffective and as disastrous as any ill-conceived or reactionary curriculum, operating in the most favourable of circumstances and conditions”. This means that however progressive national plans and policies may be, the effort will be fruitless without the proper functioning structures, mechanisms and competent personnel to implement these effectively.

Top-down, unidirectional, “one-size-fits-all” reform initiatives that disregard specific teaching realities in schools, or that make the mistake of overlooking the teacher in the design phase inevitably fall flat. The considerable investment of time and effort in teacher development shows that it is considered a significant endeavour, and for that reason greater effort must be devoted to determining which approaches to TPD are more successful than others. Lewin (1992: vi) suggests seeking more effective methods of training for improving the quality and flexibility of the teaching force, that would support teachers to adapt to changing conditions. Researchers regularly contemplate the conditions that promote effective teacher development, amongst these works is a nationwide survey of American science and mathematics teachers conducted by Garet et al. (2001) which indicates that effective professional development as rated by teachers:

- Was sustained and intensive rather than short-term,
- Was focused on academic subject matter with links to standards of learning,

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- Provided teachers with opportunities for active learning,
- Afforded opportunities for teachers to engage in leadership roles,
- Involved the collective participation of groups of teachers from the same school, and
- Was meaningfully integrated into the daily life of the school.

Similarly, some lessons for professional developers of programmes for primary science teachers emerged from this review of the Cluster Project. These are that programmes for professional development of teachers should:

- Focus on teachers and their particular professional training needs. A good starting point for any programme of development would be to consider and analyse teachers' existing knowledge base and classroom teaching. Making assumptions about what teachers know or do not know does not serve the essential purpose of professional development.
- Formulate clear goals and strategy in terms of the analysis. This means involving participants in discussion about the focus and format of the programme. In this way a shared commitment to high quality teaching can be developed. Programmes should ideally be flexible enough allowing for adjustments, should these be necessary, building in time for teachers to reflect on their learning.
- Maintain a high standard in all aspects of the TPD. This involves including continuous evaluation processes and reflections with teachers to monitor progress, for identifying topics for discussion, and for providing constructive feedback.
- Be responsive to teachers' particular professional training needs within the dynamic school context. Understanding the context in which teachers are working, as well as the challenges for science teaching and learning. This includes an awareness of changes in the context, such as changes to the curriculum or the introduction of new resource packages. Strategies to accommodate new or newly assigned teachers into the programme should be included, especially in areas where teacher turn -over is high, helping them feel included and supported to participate fully, and also benefit from the programme.

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- Link theory with practice in a practical way. This entails using training and classroom situations to model good teaching practice, providing teachers with opportunities to reflect on pedagogy, and allowing teachers to demonstrate their own teaching ability in a supportive environment.

- Engage teachers in active, meaningful and hands-on learning experiences, allowing teachers to share their experiences, to raise questions, to offer suggestions, to reflect on their own beliefs and practices, and to reflect on practical science activities they can do with learners. At the same time, activities should demonstrate how integrated learning across the curriculum can be achieved, and how this can help make classroom instruction more engaging and meaningful to children.

  According to research by Masats and Dooly (2011:1159) student teachers tend to replicate their own experiences as learners, as well as falling back on more traditional methods during their own teaching, especially in moments of tension and uncertainty. This could be true of practicing / in-service teachers as well, making the experience of practical, integrated, active teaching and learning in teacher education and training programmes all the more important for changing and improving teaching practice.

- Embed learning in the context where teachers work. It is important to meet teachers where they are, at a time that works for them, to use the tools that are accessible to them, and to acknowledge their knowledge and experience before designing and delivering the kind of personalized professional development experiences they need.

- Individual teacher education and training should further be embedded within whole school development of a subject, this way teachers do not see their contribution in isolation, but as a constituent part of the overall development of children's knowledge, understanding and skills.

Mwamwenda (1995:505) reminds us that there is no greater reason for teachers' presence in school than to see that their pupils master and understand what they are being taught so that they are in a position to transfer such knowledge to real life experience. Further recommending a focus on key aspects of quality knowledge, quality teaching and the productive use of time at school (Mwamwenda, 1995:497) for improving the quality of education.

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Perhaps it is time that attention is given to sound, grounded alternative approaches to TPD instead of the current strategies which appear insubstantial for ameliorating science and mathematics education. It is time that we conceded that the "cheaper" options, the quick-fix schemes and short, spasmodic orientation programmes are wholly ineffectual for the intense challenges for teaching and learning every day in schools.

And, instead of focusing solely on external models of TPD for inspiration, perhaps we need to direct our attention inwardly, to locating those pockets of excellence in South Africa where sound, and contextually-relevant TPD is achieving change in the classroom and improving children's learning. Perhaps it is time that we abandon the innovation bandwagon and focus on what is real, that we face up to the harsh teaching realities in some schools and invest the kind of effort, support, resources and caring that can make the difference we want to see in education.

7.5 Recommendations for Further Research

The quality of teaching is increasingly recognized as critical to children's learning of science. Research is essential for expanding and deepening our understanding of the critical relationship between the quality of teachers' knowledge and effort and children's learning of science, as well as understanding processes for enabling teacher learning, and the impacts of current professional development programmes.

This small-scale short-term interpretive case study research was designed to play its role, by making available worthwhile insights with regard to primary science education, teacher professional development (TPD), curriculum change and its implications for science teaching and learning. Moreover, this research acknowledges that important emerging issues require further study extended over a longer term across different contexts and involving different sets of teachers. The focus for further research should be investigating particular classroom challenges for science teaching and learning, and what kinds of teacher professional learning experiences can be most effective within particular school contexts for raising the quality of science teaching and learning.

As advised by a number of researchers, a logical starting point for TPD involves evaluating teachers' existing science knowledge base. This would require teachers to submit to testing of some sorts so that a comprehensive data-base with regard to their knowledge and teaching

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competency can be compiled, to effectively guide professional developers as they design more appropriate and personalized learning programmes for teachers. A challenge, though, would be to convince all relevant stakeholders involved with education, especially the teachers and teacher unions, that this is an important and necessary undertaking.

This research acknowledges neglecting the learner component of the pedagogical situation. Its scope limited to the Cluster Project, teacher professional learning, and science teaching in the primary school did not include an evaluation of children's learning of science. Follow up research is necessary to further examine the influence of the Cluster Project on children's learning of science at the primary school level, and to track this influence into the high school to establish whether long-term benefits for children's learning of science are evident.

The issue of which language to use in science lessons for learners with first language isiXhosa requires greater clarification. Arguments for mother-tongue instruction (isiXhosa) instead of English as the medium of instruction have been considered and extensively motivated. For instance, research by Brock-Utne, Desai, Qorro and Pitman (2010) confirms the language of instruction, particularly in post-colonial countries with numerous indigenous languages, is a strongly contested issue. This research observed much confusion still exists in schools with regard to which language is more effective for promoting science learning. It is also clear that teachers' language competency, whether English or isiXhosa, and quality of language used in the classroom by teachers and learners, whether English or isiXhosa, may be a problem hampering science learning. The dilemma with regard to language of instruction for science for isiXhosa first language learners requires further investigation.

For learning of any kind to thrive within the school setting, it is important that the school is functioning optimally. This requires strong leadership and a positive, collaborative school ethos. It is understandable that professional development would be hard pressed to make significant impact in a situation where relationships between school personnel are unsupportive, strained and even hostile. Neglecting this issue comes at a price, usually at the expense of children attending schools in poor communities, as observed by the researcher. Although this cannot be stated as a general observation for all schools located in disadvantaged environments, it was identified as a challenge in the Cluster Project, and therefore deserves consideration. Further study in this regard may be necessary.

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Sharing research findings with the general public is essential. I was fortunate to participate in the 2013 New Voices colloquium, a Stellenbosch University initiative which encourages PhD science students each year to present their research findings to a lay audience in 10 minutes, (Appendix NN). The New Voices in Science event is an opportunity to celebrate the contribution of science to society and to keep the public informed about the latest scientific research. Students are encouraged to reflect on the relevance of their research to society, and to share their findings with a wider audience in an accessible, easier to understand manner. Commenting in the foreword of the magazine Prof Eugene Cloete, Vice-Rector: Research and Innovation at SU, writes, “The general public are often not aware of the role of science and how science affects them on a daily basis. Science communication has therefore become very important and this is exactly what the New Voices programme does.” Communicating science with the general public contributes to greater awareness and the creation of an enlightened, scientifically literate society, which is crucial for assisting society respond effectively to the challenges and opportunities it encounters. It also serves as an important reminder to researchers and society that science is always employed in the service of society.

Most South Africans participated in the first democratic election of 1994 with hopes raised, confident the processes of reformation and transformation at all levels of government and society that would follow could provide the opportunities they deserved and needed towards building a better life for themselves. The promise of change and improvement was to be fulfilled through reformed government structures, in which the role of education for achieving these goals was acknowledged as significant.

To its credit government made some serious attempts through various initiatives to improve its system of education, however, the promise of improvement in the education and the socio-economic sectors is yet to be realized. Poor overall improvements are often linked to poor learner achievements in the subjects of natural sciences, mathematics and languages, which remain critically low, limiting youth educational opportunity and development, and at the same time frustrating substantive growth and improvement in all others sectors. Further research is needed to establish the full extent of these impacts, as well as to propose how positive change can be achieved from policy to implementation level. An improved strategy for addressing the situation can only be developed based upon a comprehensive understanding of the entire system of education in its embedded state, taking into account on-the-ground realities for science, mathematics and language education.

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APPENDICES

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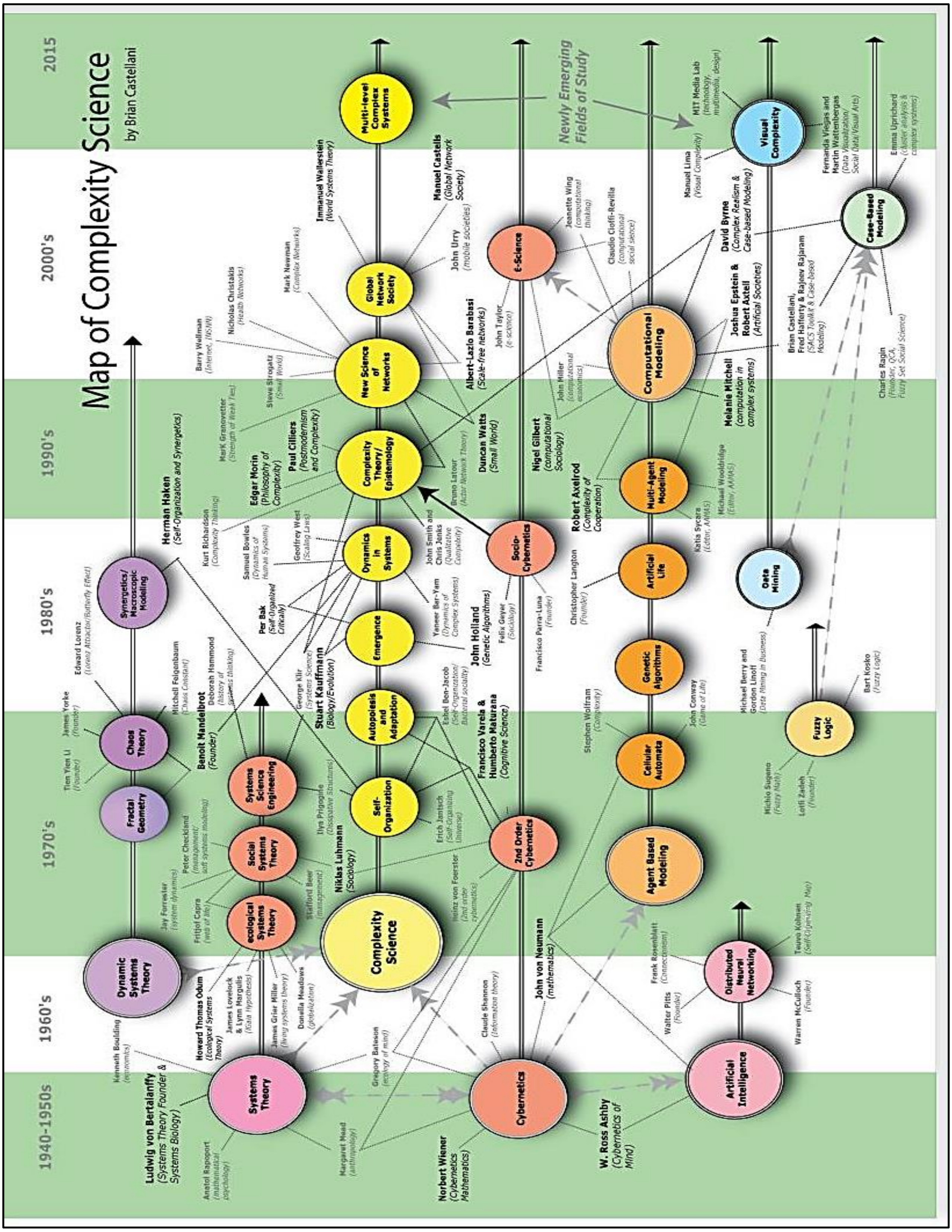
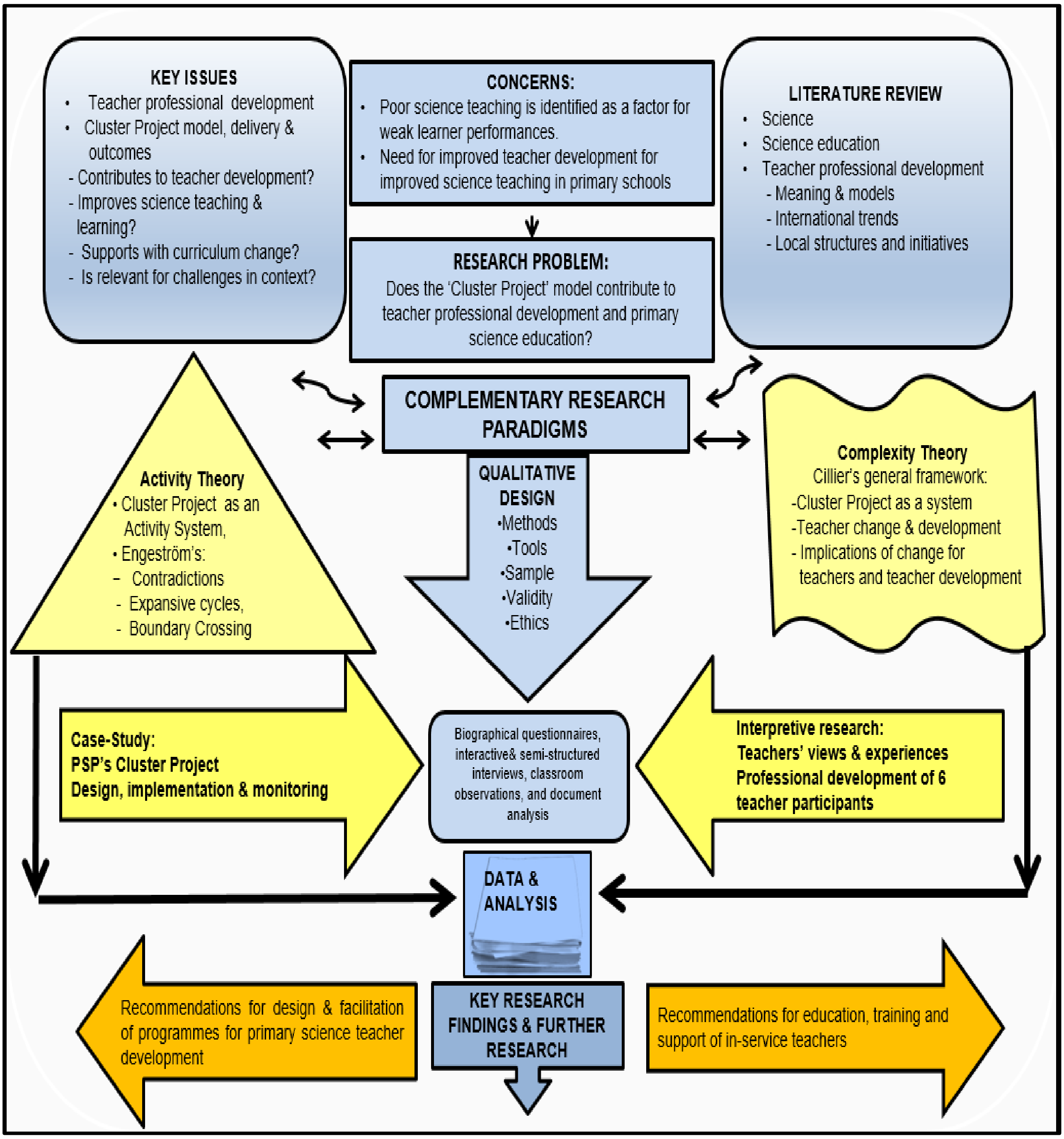
APPENDIX A: MAP OF COMPLEXITY SCIENCE



Source: Castellani (2009)

APPENDIX B: OVERVIEW OF THE RESEARCH DESIGN



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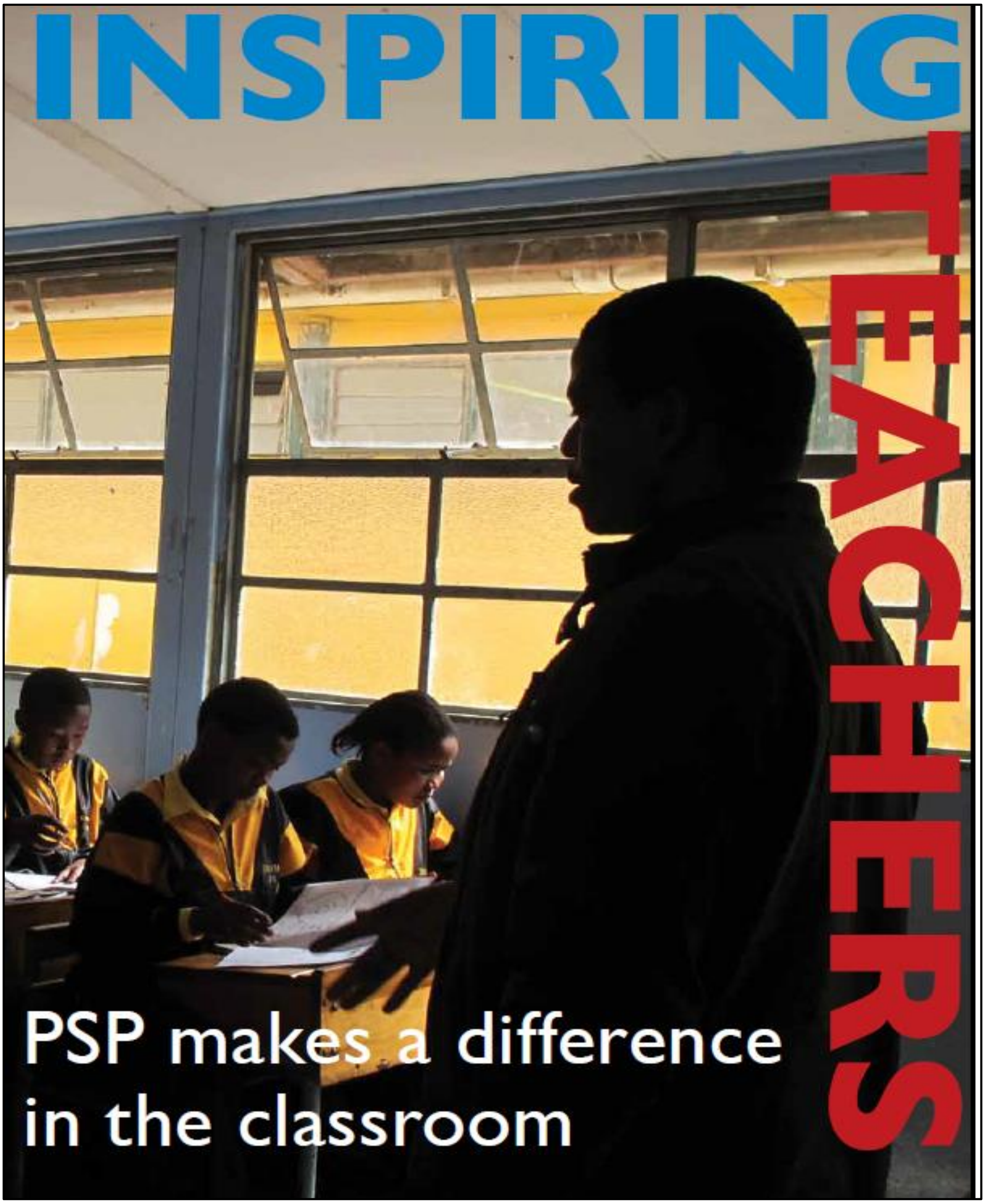
APPENDIX C: TEACHER CASE STUDY



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ALEX WILLIAMS

Hands-on approach 'creates excitement'

Alex Williams is a Grade 5 and Grade 6 Natural Sciences teacher in an under-resourced area in Cape Town. He has a teaching diploma, yet it wasn't until he started attending PSP courses in 2007, he says, that he knew he could make a difference in the classroom.

Manenberg in the Cape Flats is an area Alex knows well. Not only has he been teaching there for 22 years, he has lived there for most of his life and has been a close witness to the drug and alcohol abuse that taints many people's lives.

"I myself was brought up in a good home, but sometimes the circumstances surrounding us weren't good."

He decided that he could make a difference if he pursued a career in teaching and applied for a bursary to attend the Wesley College of Education in Cape Town.

"I knew that the future could be a better place and I wanted to make it bigger and brighter for myself and for future generations."

Alex graduated in 1991. However, soon after he started teaching, he realised that what he was taught at college didn't translate easily into the classroom.

"In college the emphasis is mostly academic. They only teach you a part of the profession, so when you enter the real world, you experience problems you were not prepared for."

These problems included a lack of resources to teach science, changes to the curriculum, feeling incompetent to teach subjects he was not trained in, big classes, language barriers and a heavy workload.

"There was also poor discipline and having to deal with kids on *tik* and other drugs."

Alex's job was difficult, but he did not give up and decided to seek help by getting involved with the PSP.

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" I realised that Natural Sciences didn't have to be taught using the theoretical model; there are also practical models and a hands-on approach. "

"There is a lot of practical work that has to be done in the subject of science. I wanted to acquire the necessary skills and the know-how so that I could carry that knowledge and skill over to the children so that they could understand science better, but in order for that to happen I had to put myself through more training."

The first opportunity to make a change in his teaching came in 2007 when he became involved in the PSP Cluster Project at his school.

Later he also attended the PSP's Innovation Project, which runs short courses during term time. These courses aim at developing primary school teachers' knowledge and skills and provides materials to support learning. Both projects provided Alex with many innovative strategies to enhance his teaching.

"I started realising that Natural Sciences didn't have to be taught using the theoretical model; there are also practical models and a hands-on approach. There's actually a lot of excitement surrounding the subject."

In the past learners in his class were fascinated by science experiments, but it was a struggle to find the right equipment. PSP came to the rescue and provided teachers who participated in the Cluster Project not only with new teaching strategies, but with teaching aids and apparatus.

"The Old Mutual 'Out-of-the-Box' science kits were extremely useful for practical activities. The PSP showed us how to use beakers, measuring cylinders, funnels, thermometers, electrical circuits and the lesson plans provided in the kits."

Alex is confident in his knowledge of Natural Sciences and says the PSP helped "straighten him out", but he finds the curriculum changes disruptive.

"I can understand that they want to implement a new learning model, however, teachers need to have access to workshops when this happens. Teachers should never be in a position where they don't understand all the material."

Although Alex's participation in the Cluster Project ended in 2009, he still uses the resources and materials that he obtained from the PSP.

"I can go to my colour-coded booklets, which have all the different strands of Natural Sciences, and easily plan my lesson for the next day. All the copies and task cards are there, in both languages, and all the materials are coordinated with my science box and the curriculum. It makes teaching easy!"

3

(Western Cape Primary Science Programme (PSP) Inspiring Teachers, 2011.)

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APPENDIX D: WCED CONSENT FORM

Navrae Enquiries IMibuzo	Dr RS Cornelissen
Telefoon Telephone IFoni	(021) 467-2286
Faks Fax IFeksi	(021) 425-7445
Verwysing Reference ISalathiso	20090428-0015

Wes-Kaap Onderwysdepartement

Western Cape Education Department

ISebe leMfundo leNtshona Koloni

Ms Zorina Dharsey
191 Eleventh Avenue
RETREAT
7945

Dear Ms Zorina Dharsey

RESEARCH PROPOSAL: PRIMARY SCIENCE PROGRAMME SUPPORT OF SCIENCE EDUCATION THROUGH TEACHER DEVELOPMENT: A CASE STUDY.

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **30th April 2009 to 30th September 2011**.
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr R. Cornelissen at the contact numbers above quoting the reference number.
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:
    The Director: Research Services
    Western Cape Education Department
    Private Bag X9114
    CAPE TOWN
    8000

We wish you success in your research.

Kind regards.

Signed: Ronald S. Cornelissen
for: **HEAD: EDUCATION**
DATE: 29th April 2009

MELD ASSEBLIEF VERWYSINGSNOMMERS IN ALLE KORRESPONDENSIE / PLEASE QUOTE REFERENCE NUMBERS IN ALL CORRESPONDENCE / NCEDA UBHALE IINOMBOLO ZESALATHISO KUYO YONKE IMBALELWANO

GRAND CENTRAL TOWERS, LAER-PARLEMENTSTRAAT, PRIVAATSAK X9114, KAAPSTAD 8000
GRAND CENTRAL TOWERS, LOWER PARLIAMENT STREET, PRIVATE BAG X9114, CAPE TOWN 8000

WEB: http://wced.wcape.gov.za

INBELSENTRUM /CALL CENTRE
INDIENSNEMING- EN SALARISNAVRAE/EMPLOYMENT AND SALARY QUERIES ☎0861 92 33 22
VEILIGE SKOLE/SAFE SCHOOLS ☎ 0800 45 46 47

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APPENDIX E: CONSENT FORM FOR TEACHER PARTICIPANTS (ENGLISH & AFRIKAANS)

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

STELLENBOSCH UNIVERSITY

CONSENT TO PARTICIPATE IN RESEARCH

Teacher development in a Cluster Project model to support primary science: A case study

You are asked to participate in a research study conducted by Zorina Dharsey (M.Ed.), from the Department of Curriculum Studies at Stellenbosch University. The results of this study will contribute to full thesis that is a requirement for the completion of a doctoral degree. You were selected as a possible participant in this study because of your participation in the Western Cape Primary Science Programme (PSP) Cluster Project.

1. PURPOSE OF THE STUDY

The purpose of this study is to acquire a deeper understanding of the form of teacher development in the South African context, with its unique set of challenges for teachers, and teaching and learning.

2. PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:

1. Complete a teacher questionnaire that serves to describe your academic and professional qualifications and teaching experience.
2. Participate in one recorded semi-structured interview of approximately 1½ hours with the researcher, describing your views and experiences of the PSP's Cluster Project as accurately as possible.
3. Permit the researcher to observe your teaching practice in your classroom during one of your sessions with the learners, and reflect on the recommendations of the observation with the researcher.
4. Provide the following documents that may provide specific insights to the researcher in respect of your teaching practice; the Natural Science Learning Programme for the grades you are teaching, Work Schedule, Lesson Plans and Learner books. These will not be removed from the school premises, and the researcher is committed to returning these before the end of the school day. The researcher is obligated to discuss the specific criteria that will be observed in respect of the requested documents.

3. POTENTIAL RISKS AND DISCOMFORTS

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Your co-operation, open and honest reflections, as well as the sacrifice of time to engage with the researcher are significant to this study.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The subject may not derive direct benefit from this study, financial or otherwise.

However, research of this nature may serve to guide and inform the design and delivery procedures of more sustainable and effective future teacher development programmes relevant to the South African context, ultimately for the benefit of all teaching and learning.

5. PAYMENT FOR PARTICIPATION

The subject of the study will not receive any payment for participation in this study.

Participation without compulsion and is strictly voluntary.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of an assigned pseudonym that would serve to protect your identity. All forms of data concerning your involvement will be kept in a locked cabinet at my residence located at 191, Eleventh Avenue, Retreat, 7945, to which only I have access.

However, the accumulated information / data may be requested by the internal and external examiners in the event that verification of interpretation and analysis is deemed necessary.

Audio recordings of the interviews may be conducted, but these will be subject to the consent of participant. Recording the interview is particularly helpful to the researcher as far accuracy of the responses of the subject is concerned. The recordings would be duly transcribed by me and made available to the subject for verification. Following the verification of the transcript by the subject, all recordings of the interview will be duly erased from the recording instrument.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

8. IDENTIFICATION OF INVESTIGATORS

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If you have any questions or concerns about the research, please feel free to contact the researcher's supervisor, Professor Chris Reddy using the following contact details:

1. Cell Number – XX,
2. Home number- (021) XX
3. Office Number -
4. Address- XX

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to [*me/the subject/the participant]* by Zorina Dharsey (M.Ed.), in [*Afrikaans/English/Xhosa/other]* and [*I am/the subject is/the participant is]* in command of this language or it was satisfactorily translated to [*me/him/her*]. [*I/the participant/the subject]* was given the opportunity to ask questions and these questions were answered to *[my/his/her]* satisfaction.

[I hereby consent voluntarily to participate in this study/I hereby consent that the subject/participant may participate in this study.] I have been given a copy of this form.

____

Name of Subject/Participant

____

Name of Legal Representative (if applicable)

____________________________________ ____________

Signature of Subject/Participant or Legal Representative Date

SIGNATURE OF RESEARCHER

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I declare that I explained the information given in this document to ____ [*name of the subject/participant]* and/or [his/her] representative ____________________________________ [*name of the representative]. [He*/she] was encouraged and given ample time to ask me any questions. This conversation was conducted in [*Afrikaans/*English/*Xhosa/*Other*] and [*no translator was used/this conversation was translated into* ____________ by _________________________].

____ _______________

Signature of Researcher Date

CONSENT FORM

I hereby agree to participate in a research project as regards the Western Cape Primary Science Programme (PSP) 2007-2009 Cluster Project. I understand that I am participating freely and without compulsion.

I also understand that I can stop this interview at any point, should I choose not to continue. The decision to discontinue my participation will not in any way affect me negatively.

The purpose of the study has been explained to me, and I understand what is expected of me. I also understand that this is a research project, and that the purpose of the research may not benefit me personally.

I have received the telephone number of the person to consult, should I need to speak about any issues that may develop from the interview.

I understand that this consent form will not be linked to the questionnaire, and that my answers will remain confidential.

I understand that, if at all possible, feedback will be given on the results of the completed research.

Signature of participant:…………………………………………

Date: ……………………………………………………………….

In addition to the above, I hereby agree to the audio recording of this interview for the purpose of data capture. I understand that no personally identifying information or recording concerning

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me will be released in any form. I understand that these recordings will be kept in a secure environment, and will be destroyed or erased once data capture and analysis has been completed.

Signature of participant:…………………………………………

Date: …………………………………………………………….

TOESTEMMINGS VORM

Hiermee gee ek toestemming om deel te neem aan die navorsing van Western Cape Primary Science Programme (PSP) 2007-2009 Kluster Projek. Ek verstaan dat ek uit eie wil deelneem sonder enige dwang. Ek verstaan ook dat ek die onderhoud ter enige tyd kan stop, indien ek nie sou wou voortgaan nie. Die besluit om te stop sal my nie op enige manier negatief affekteer nie.

Die doel van die studie is verduidelik aan my, en ek verstaan my aandeel daaraan. Ek verstaan dat dit 'n navoringsprojek is, en dat die doel van die navorsing nie vir my persoonlike voordele inhou nie.

Ek het die telefoon nommer ontvang van die konsultasie persoon, indien ek dit sou nodig ag om enige sake wat voortspruit uit die onderhoud te bespreek.

Ek verstaan dat die toestemmings vorm nie gekoppel word aan die vraelys nie, en dat my antwoorde konfidensieel sal bly.

Ek verstaan dat, indien enigsins moontlik, terugvoer gegee sal word oor die resultate van die voltooide navorsing.

Handtekening van die deelnemer:…………………………………………

Datum: ……………………………………………………………………

As toevoeging tot bogenoemde, verleen ek toestemming tot die ouditiewe opname van hierdie onderhoud vir die doel van data kolleksie. Ek verstaan dat geen persoonlike identifiserings informasie of opname rakende my vrygestel sal word in enige vorm nie. Ek verstaan dat hierdie

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opnames in ‘n sekuriteitbewuste omgewing gehou sal word, en vernietig sal word nadat die data verwerk en die analise voltooi is.

Handtekening van deelnemer:……………………………………………

Datum: ……………………………………………………………………...

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APPENDIX F: TEACHER QUESTIONNAIRE

BACKGROUND INFORMATION OF PARTICIPANT

Name:………………………………………………… Date: ………………………………

School: ……………………………………….... Education district: ……………………

For each of the following questions, please indicate your response in the corresponding block by circling the appropriate number. Thank you for your participation.

1	What is your gender?	**1**
	1=Male 2=Female	**2**
2	How old are you?	
3	What is your home (dominant) language?	**1**
	1=English 2=Afrikaans 3=isiXhosa	**2**
	4=Other; State what: …………………………………………………	**3**
		4
4	Which other language(s) are you qualified/proficient in?	**1**
	1=English 2=Afrikaans 3=isiXhosa	**2**
	4=Other; State what: ………………………………………………	**3**
		4
5	What is your highest academic qualification?	**1**
	1= Grade 8 OR 9 (Standard 6 or 7)	**2**
	2= Grade 10 OR 11 (Standard 8 OR 9)	**3**
	3= Matric (Standard 10)	**4**
	4= BA. Degree	**5**
	5=Further studies; State what: ……………………………………	**6**
	6=Other; State what: ……………………………………………	

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6	What is your professional (teacher) training? 1= No formal training 2= 1 or 2 year training 3= 3 year training 4= 4 year training 5= 5 year training 6= 6 year training 7= Mainly workshops 8= Other; State what: ……………………………………..	**1** **2** **3** **4** **5** **6** **7** **8**
7	Through which institution (s) did you receive most of your professional (teacher) training? 1= Workshops only (DoE, CTLI, NGOs, etc.) 2= College 3= University (Please specify) …………………………………	**1** **2** **3**
8	Have you attended any CTLI (Cape Teaching and Leadership Institute) courses in the **THREE** years of the Cluster Project? In which learning areas have you received training at CTLI? 1= Language & Literacy 1 2= Language & Literacy 2 3= Language & Literacy 3 4= Mathematics 5= Natural Sciences 6= Social Sciences 7= Technology 8= Arts & Culture	**(Circle)** **YES/NO** **1** **2** **3** **4** **5** **6** **7** **8** **9**

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	9= Life Orientation 10= Economics & Management Sciences	**10**
9	Which learning area(s) have you taught in the **THREE** year period?	**1**
	1= Language & Literacy 1	**2**
	2= Language & Literacy 2	**3**
	3= Language & Literacy 3	**4**
	4= Mathematics	**5**
	5= Natural Sciences	**6**
	6= Social Sciences	**7**
	7= Technology	**8**
	8= Arts & Culture	**9**
	9= Life Orientation 10= Economics & Management Sciences	**10**
10	Which three learning areas do you feel are your strongest?	**1**
	1= Language & Literacy 1	**2**
	2= Language & Literacy 2	**3**
	3= Language & Literacy 3	**4**
	4= Mathematics	**5**
	5= Natural Sciences	**6**
	6= Social Sciences	**7**
	7= Technology	**8**
	8= Arts & Culture	**9**
	9= Life Orientation 10= Economics & Management Sciences	**10**
11	How long have you been teaching?	**1**

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	1= Less than 1 year 2= 1-5 years 3= 6-10 years 4= More than 10 years 5= More than 20 years 6= More than 30 years	**2** **3** **4** **5** **6**
12	How long have you been teaching Natural Sciences? 1= less than 1 year 2= 1-5 years 3= 6-10 years 4= More than 10 years 5= More than 20 years 6= Before the Cluster Project 7= Since the Cluster Project	**1** **2** **3** **4** **5** **6** **7**
13	What kind of training have you received in Natural Sciences teaching? 1= Workshops only (DoE, CTLI, NGOs, etc.) 2= College 3= University (Please specify) ……………………………………………	**1** **2** **3**
14	In which phases have you taught? 1= Foundation phase 2= Intermediate phase 3= Senior phase (Primary school) 4= Senior phase (Secondary school) 5= A tertiary institution	**1** **2** **3** **4** **5**
15	In which phases have you taught Natural Sciences?	**1**

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	1= Foundation phase 2= Intermediate phase 3= Senior phase (Primary school) 4= Senior phase (Secondary school) 5= A tertiary institution	**2** **3** **4** **5**
16	In which phase(s) are you currently teaching Natural Sciences? 1= Foundation phase 2= Intermediate phase 3= Senior phase (Primary school) 4= Senior phase (Secondary school) 5= A tertiary institution	**1** **2** **3** **4** **5**
17	What has been the extent of your participation with the PSP Cluster Project and other programmes the organization offered? 1= PSP Cluster Project for less than 1 year 2= PSP Cluster Project for 1 year 3= PSP Cluster Project for 2 years 4= PSP Cluster Project for the 3 year period 5= PSP wide-net courses 6= CTLI courses presented by the PSP	**1** **2** **3** **4** **5** **6**

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APPENDIX G: CHECKLIST: CLASSROOM MATERIALS

(Comments are written in the grey areas)

No.	QUESTION	NO	YES
1.	Is a desk/ table and chair available for each learner?		
2.	Are the necessary apparatus such as chalkboard, chalk and duster available to the teacher?		
3.	Is there a table and chair for the teacher?		
4.	Is there sufficient room for each learner to work comfortably?		
5.	Is there enough room for both learners and teacher to move about freely?		
6.	Does each of the learners have the necessary equipment such as books and pencils for the lessons?		
7.	Are there any other additional learning/ teaching aids (visible) in the classroom?		
8.	Does the teacher have access to the safe use of electricity?		
9.	Is there enough light in the classroom throughout the lesson?		

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10.	Are there any interferences such as loud noises outside the classroom impacting on the lesson flow?		
	Specify:		
11.	How are the learners arranged? □ Groups □ Rows (individual) □ Rows (pairs)		
12.	Does the arrangement of learners change for certain lessons?		
13.	Are there computers with Internet facility available at the school, and is this made available to the teacher and learners?		
14.	Is there a library at the school?		
15.	Is there a display of learners' work in the classroom?		
16.	Is the teacher supported with additional resources for science teaching and learning, e.g. additional textbooks and equipment for practical lessons?		

Adapted from Checklist Classroom Materials: Adler, J. & Reed, Y. 2002:154.

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APPENDIX H: RESEARCH INTERVIEW SCHEDULE

Teacher development in a Cluster Project model to support primary science: A case study

INTERVIEW: SEMI-STRUCTURED (RECORDED)

1. Briefly describe your involvement with the 2007-2009 Cluster Project and the other teacher development programmes (Wide-Net courses, CTLI courses, etc.) the PSP offered? How did you come to be involved with the Cluster Project? What was your involvement with the 2007-2009 Cluster Project?

   ……………………………………………………………………………………………

   ……………………………………………………………………………………………

2. Has participation in the PSP Cluster Project contributed in any way to your knowledge and understanding of the Natural Sciences curriculum for your grade (i.e. with developing Learning Programmes, Work Schedules, Lesson Plans, interpreting the 2009 WCED Intermediate Phase Work Schedules and Teachers' Guides; as well as improving your knowledge of the 4 strands of the Natural Sciences, and the Learning Outcomes with its associated Assessment Standards)? If so, how? If not, can you suggest a reason for this?

   ……………………………………………………………………………………………

   ……………………………………………………………………………………………

3. Have you worked collaboratively with the School Management Teams (SMTs) and science teachers to develop teaching and assessment plans for the school during this period? If so, could you elaborate on the process used, and your role in the process? If not, what problems did you encounter?

   ……………………………………………………………………………………………

   ……………………………………………………………………………………………

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4. Do you feel that your participation in the PSP Cluster Project has improved your knowledge and understanding of basic and scientific concepts, as well as the application of science knowledge? If so, how? If not, why not?

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

5. Have you acquired knowledge and understanding of new strategies for teaching Natural Sciences during your involvement with the PSP Cluster Project that you could incorporate in your teaching? If so, what? If not, why not?

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

6. Do you feel that your teaching practice has benefitted in any way from your participation in the PSP Cluster Project? If so, how? If not, what problems did you experience?

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

7. What was the most useful aspect of the PSP Cluster Project?

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

8. What was the least beneficial aspect of the PSP Cluster Project?

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

9. Would you recommend that other schools become involved in a PSP Cluster Project? If so, why? If not, why not?

   ………………………………………………………………………………………………

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…………………………………………………………………………………………………

10. What is the ONE thing that you take away from your involvement in the PSP Cluster Project?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

11. What could you recommend that the PSP adds to/ or adjusts of its Cluster Project to make it more effective as a programme intended to develop teachers professionally?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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APPENDIX I: CLASSROOM OBSERVATION SCHEDULE (ENGLISH & AFRIKAANS)

WESTERN CAPE PRIMARY SCIENCE PROGRAMME (PSP)

SCHOOL SUPPORT VISITS: OBSERVATION

School: ………………………………… Facilitator: ……………………………………….

EMDC: ………………………………… Term: …………………………………………….

Telephone number: …………………… Date: ……………………………………………..

Presenter: ……………………………… Time: …………………………………………….

Grade: ………………………………… Number of learners: ……………………………

1. **Introduction**

Lesson introduction:

- There is no definite start to the lesson.
- A continuation lesson.
- The lesson begins with revision or homework.
- The lesson begins with an activity that stimulates attention and opens issues for the lesson.
- Other: …………………………………………………………………………………

2. Resources

2.1. Organization of work:

- No group work. Whole class only.
- Learners are seated in groups, but work individually.
- Learners are seated in rows, but work in pairs.

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- Learners are seated in groups and work together.
- Other: ……………………………………………………………………………..

2.2. Teaching resources:

- No material available for teachers to use.
- Only the teacher uses the materials in front, while the learners are observing.
- Teacher and a few learners use the materials.
- Teacher and learners share and use the material.
- Other: …………………………………………………………………………….

2.3. Learning resources:

- No material available for learners to use.
- Only the teacher uses the materials in front, while the learners are observing.
- Teacher and a few learners use the materials.
- Teacher and learners share and use the material.
- Other: ……………………………………………………………………………

2.4. Learner tasks:

- Appropriate for the grade, interest / level of learning.
- Relevant to lesson topic.
- Extends the learner's thinking and reasoning.
- Relevant to the achievement of LO's and AS's.
- Differentiation (Learning Barriers / Enrichment) is accommodated.
- Learners are encouraged / motivated to formulate explanations / observations / conclusions in their own words, either verbally or in writing.
- Other: ……………………………………………………………………………

3. Content and concepts

3.1. Clarity of explanation on concepts by teacher:

- Basic
- Simple
- Comprehensive
- Logical
- Fully elaborated explanation
- Teacher does not notice misconceptions.
- Teacher notices misconceptions and offers explanation.
- Teacher facilitates conceptual clarity.
- Other: ……………………………………………………………………………..

3.2.Teacher's content knowledge and confidence:

- Incorrect knowledge of content.

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- Everyday knowledge.
- Specific science knowledge.
- Application of knowledge.
- Makes links with everyday knowledge.
- Integration of knowledge, with other strands / learning areas.
- Teacher makes links to other contexts, including learner context.
- Other: ………………………………………………………………………………….

4. Establishing a democratic ethos in the classroom.

4.1. Whole class: class teacher – learner interaction:

- Teacher exercises total control.
- Control predominantly rests with the teacher.
- Control of interaction shifts between the learners and the teacher.
- Other: …………………………………………………………………………………

4.2. Learner – learner interaction, without the teacher:

- Learners do not question each other or probe for details.
- Learners do not have discussions with each other.
- Learners question each other / discuss very quietly and privately.
- Learners only question or help other learners when prompted to do so by the teacher.
- Learners freely enter into discussions with each other.
- Other: …………………………………………………………………………………

4.3. Learner communication:

- Learners only give one word answers to the teacher.
- Learners give explanations of what they did procedurally to teacher.
- Learners explain their thinking to the teacher.
- Learners explain and engage in debate with each other and the teacher.
- Other: …………………………………………………………………………………

4.4. Teacher's use of questioning as a tool for teaching:

- Teacher does not ask questions at all.
- Teacher asks questions that only require recall, repetition or simple factual answers.
- Teacher asks questions requiring elaboration, justification or explanation.
- Teacher uses questioning that makes extended intellectual demands on learners.
- Other: …………………………………………………………………………………

4.5. Teachers' responses to learners:

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- Teacher ignores incorrect answers by calling on other volunteers until the correct answer is supplied.
- Teacher responds to incorrect answers in a manner that encourages further effort.
- Teacher responds to both correct and incorrect answers in a manner that encourages further effort.
- Other: …………………………………………………………………………………

5. Conclusion:

- Lesson ends without proper discussion.
- Lesson ends with a task, but without appropriate consolidation or conclusion.
- Appropriate summary of lesson provided.
- Setting of tasks for the next lesson.
- Lesson task is relevant / appropriate for topic / grade / interest / encourages independent work.
- Other: …………………………………………………………………………………

WESTERN CAPE PRIMARY SCIENCE PROGRAMME (PSP)

SKOOL ONDERSTEUNINGS BESOEKE: WAARNEMING

Skool: ……………………………………. Fasiliteerder: ……………………………………

Distrik: ………………………………….. Kwartaal: ……………………………………….

Telefoon nommer: ……………………… Datum: …………………………………………..

Aanbieder: ……………………………… Tyd: ……………………………………………..

Graad: …………………………………… Aantal leerders: ……………………..................

2. Inleiding

Les inleiding:

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- Geen definitiewe inleiding tot die les.
- 'n Opvolg les.
- Die les begin met hersiening of huiswerk.
- Die les begin met 'n aktiwiteit wat aandag stimuleer en kwessies aanspreek.
- Ander: ……………………………………………………………………

2. Hulpmiddels

2.1. Organisasie van werk:

- Geen groepwerk. Slegs hele klas.
- Leerders sit in groepe, maar werk individueel.
- Leerders sit in rye, maar werk in pare.
- Leerders sit in groepe en werk saam.
- Ander: ……………………………………………………………………

2.2. Onderrig hulpmiddels:

- Geen materiaal beskikbaar vir opvoeder se gebruik.
- Slegs opvoeder gebruik materiaal voor in die klas, terwyl leerders waarneem.
- Opvoeder en 'n paar leerders gebruik die materiaal.
- Opvoeder en leerders deel en gebruik die materiaal.
- Ander: ……………………………………………………………………

2.3. Leerder hulpmiddels:

- Geen materiaal beskikbaar vir leerders se gebruik.
- Slegs opvoeder gebruik materiaal voor in die klas terwyl leerders waarneem
- Opvoeder en 'n paar leerders gebruik die materiaal.
- Opvoeder en leerders deel en gebruik die materiaal.
- Ander: ……………………………………………………………………

2.4. Leerder take:

- Gepas vir graad, interessantheid/ vlak van leer.
- Relevant tot les inhoud.
- Brei die leerders se denk- en redenasie vermoe uit.
- Relevant tot die bereiking van die Lu's en AS'e.
- Differensiasie (Leer gestremdheid /Verryking) is in ag geneem.
- Leerders is aangemoedig /gemotiveer om verduidelikings/waarnemings te formuleer in hul eie woorde, skriftelik of mondelings.
- Ander: ……………………………………………………………………

3. Inhoud en konsepte

3.1. Duidelikheid van verduideliking van konsepte deur die opvoeder:

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- Basies
- Eenvoudig
- Verstaanbaar
- Logies
- Ten volle uitgebreide verduideliking
- Opvoeder kom nie wanbegrippe agter nie.
- Opvoeder kon wanbegrippe agter en bied ‘n verduideliking aan.
- Opvoeder fasiliteer duidelike konsepte.
- Ander: ………………………………………………………………………….

3.2. Opvoeder inhoudskennis en selfvertroue:

- Foutiewe kennis van inhoud.
- Alledaagse kennis.
- Spesifieke wetenskap kennis.
- Toepassing van kennis.
- Maak verbindinge met alledaagse kennis.
- Integrasie van kennis, met ander inhoudsvelde/leerareas.
- Opvoeder maak verbindinge met ander kontekste, asook die leerder se konteks.
- Ander: ……………………………………………………………………………

4. Vastelling van ‘n demokratiese ethos in die klaskamer.

4.1. Hele klas: klas opvoeder – leerder interaksie:

- Opvoeder is ten volle in beheer.
- Beheer berus meestal by die opvoeder.
- Beheer van interaksies verskuif tussen die leerders en die opvoeder.
- Ander: ……………………………………………………………………………

4.2. Leerder – leerder interaksie, sonder die opvoeder:

- Leerders vra nie mekaar of soek vir besonderhede nie.
- Leerders het nie besprekings met mekaar nie.
- Leerders vra vrae vir mekaar / bespreek stilweg en privaat.
- Leerders vra slegs vrae of help mekaar wanneer opvoeder hulle daarvoor vra.
- Leerders neem vrylik deel aan besprekings met mekaar.
- Ander: ……………………………………………………………………………

4.3. Leerder kommunikasie:

- Leerders gee slegs een woord antwoorde vir die opvoeder.
- Leerders gee verduidelikings van die prosedure gevolg vir die opvoeder.
- Leerders verduidelik hul denkwyse vir die opvoeder.
- Leerders verduidelik, neem deel en bespreek met ander leerders en die opvoeder.
- Ander: …………………………………………………………………………….

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4.4. Opvoeder gebruik van vrae as onderrig middel:

- Opvoeder vra geen vrae nie.
- Opvoeder vra vrae wat slegs memorisering, herhalings en feitelike antwoorde verg.
- Opvoeder vra vrae wat uitbreiding, regverdiging of verduideliking verg.
- Opvoeder gebruik vrae wat uitgebreide intellektuele vereistes op die leerders plaas.
- Ander: ……………………………………………………………………………

4.5. Opvoeder reaksie tot leerders:

- Opvoeder ignoreer foutiewe antwoorde deur ander te vra totdat die korrekte antwoord gegee word.
- Opvoeder reageer op foutiewe antwoorde op 'n wyse wat verdere pogings aanmoedig.
- Opvoeder reageer op beide foutiewe en korrekte antwoorde op 'n wyse wat verdere pogings aanmoedig.
- Ander: …………………………………………………………………………...

5. Slotsom:

- Lesse eindig met 'n volledige gesprek.
- Lesse eindig met 'n taak, maar sonder gepaste samevatting of gevolgtrekking.
- Gepaste opsomming van les is voorsien.
- Uitset van take vir die volgende les.
- Lestaak is relevant / gepas vir die onderwerp / graad / interessantheid/ moedig individuele werk aan.
- Ander: ……………………………………………………………………………

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APPENDIX J: CRITERIA FOR DOCUMENT ANALYSIS

1. Type of document: ……………………………………………………………………….
2. Date: ………………..…………………………………………………………………….
3. Author: ………………………………………………………..............................
4. Authenticity: Is it genuine, complete, reliable and of indisputable authorship? ……
5. Who was the intended audience? …………………………………………………...
6. What is the purpose of the document? ……………………………………………….
7. What are the main topics of the document? …………………………………………
8. Credibility: Is the document free of errors or distortions? …………………………
9. Representativeness: Is the document representative of the organization and its work with teachers? ………………………………………………………………….....
10. Meaning: What is the surface meaning? What can be derived from the document?

    ……………………………………………………………………………………..

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APPENDIX K: CRITERIA FOR PHOTOGRAPH SELECTION

1. Brief description of context: ……………………………………………………………….
2. Date: ………………..…………………… Time: ……..……………………………………..
3. Representativeness: Is the photograph representative of the organization and its work with teachers? ………………………………………………………………………......................
4. Image source: Where did the photograph come from? What information does the source provide about the origins of the image? Is the source reliable and trustworthy? …………………………..
5. Is the image original and genuine? Has the image been adjusted in any way that affects the information displayed? ………………………………………………………………
6. Content Analysis: What is it about? What is happening? Are there people in the image? What are they doing? How are they presented? Can the image be looked at different ways? How effective is the image as a visual message? ..………………………………
7. Technical quality: Is the image large enough to suit the purposes of the research? Are the colours, light, and balance true? Is the image a quality digital image, without pixilation or distortion? ……………………………………………………………………...................

(Adapted from: Hattwig, D. *Image Analysis*. USA: University of Washington).

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APPENDIX L: CONSENT FORM COMPLETED BY SCHOOLS IN THE CLUSTER PROJECT

Western Cape Primary Science Programme (PSP)

Application to participate in the PSP / EMDC 2007-2009 Cluster Project for planning, assessing and managing the Natural Sciences curriculum.

When your school has decided to become part of the PSP Cluster Project please complete and return this application form by no later than:

14th November 2006

Fax to PSP at 021 691 6350. Tel 021 691 9039

All our Natural Sciences teachers, Foundation Phase grade representatives, Assessment Co-ordinators and representatives of the School Management Teams (SMTs) are aware of the commitment the programme requires

Name of school: …………………………………………..

Full name & surname	Grade	Principal/ Deputy/ HOD/ Teacher	Signature

Full name & surname of the school principal: …………………………………………………

Full name & surname of contact person at the school: ………………………………………...

School Tel No.: …………………………………… & Fax: …………………………………..

Date: ……………………………………………….

School stamp:

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APPENDIX M: MEMORANDUM OF UNDERSTANDING

WESTERN CAPE PRIMARY SCIENCE PROGRAMME TRUST
Edith Stephens Wetland Park, Lansdowne Road, Philippi, 7785, South Africa.
PO Box 24158, Lansdowne, 7779, South Africa
Tel +27 (0) 21 691 9039 Fax +27 (0) 21 691 6350
EMAIL info@psp.org.za WEBSITE www.psp.org.za
Registration IT2806/99 NPO 015-822-NPO PBO 18/11/13/1351

A memorandum of understanding for participating in the

PSP 2007 – 2009 Cluster Project

The PSP invites all NS teachers, assessment co-coordinators, and representatives of school management teams, including the foundation phase HOD and grade R-3 representatives to participate in a programme of strengthening natural sciences concept and content knowledge, as well as how to teach and assess it in the classroom, together with other schools in the district.

The PSP Cluster Project offers:

- A 6-hour once a term course for SMT representatives, intermediate phase and grade 7 NS teachers on the following:
  - Understanding of the curriculum / NCS and Work Schedules
  - Strengthening NS concept and content knowledge
  - Development of innovative teaching methodologies and assessment strategies
  - Integration of numeracy and literacy in the Natural Sciences
  - Strengthening of classroom management skills.
- A 2-hour once a term course for foundation phase teachers
- A once a term school support visit consisting of:
  - Individual teacher classroom support (grade 7 and intermediate phase teachers only)
  - a work session to do additional NS conceptual & content development and addressing individual school needs with some management focus e.g. assessment, moderation etc.
- A Teachers' Conference at the end of the two year cycle.

The South, North, Central and the Overberg Education Districts have welcomed this Cluster Project, and will also be supporting the process.

Please consider the following criteria for selection to become part of the cluster of schools:

Trustees: D C Campbell, L Matthews, M L Mnconywa, W M F Ainslie, J C Coombe

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Schools are expected to:

1. Ensure that the entire NS team (grades 4 -7), SMT representatives, the assessment co-coordinator, the foundation phase HOD and grade representatives (grades R-3) commit to attending the sessions and participating in this process, with teachers from neighbouring schools.
2. Keep records of teaching and assessment plans in a file.
3. Participate in all school support visits.
4. Implement suggested practical teaching strategies at schools

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APPENDIX N: QUESTIONNAIRES FOR SCHOOLS, PRINCIPALS AND TEACHERS

Natural Sciences Course for Intermediate Phase Educators:

Curriculum Coverage: Matter & Materials

Thank you for completing this questionnaire. The information will help us understand what science is being taught in primary schools so that we can prepare our courses accordingly.

Please let us know how much experience you have in teaching Natural Sciences.

Make a cross in the appropriate box below.

Never	1-2years	3-5 years	more

What phase are you teaching currently? ....

B. Please **tick in the yes or no boxes** to show if you have taught these topics before.

		YES	NO
	Foundation Phase		
1.	Sorting materials according to their different properties		
2.	Mixing different substances		
	Intermediate Phase	YES	NO
1.	Boiling and melting points		
2.	Materials their properties, and classifying them		
3.	Metals, ceramics, polymers and composite materials		
4.	Temporary and permanent changes to metals		
5.	Changes brought about by heating		
6.	Dissolving-factors that affect the speed of dissolving		

	Senior Phase	YES	NO
1.	Different states of matter and their properties		
2.	Absorption and radiation by different substances		

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3.	Magnetism and electrical charging		
4.	Conductors and resistors		
5.	Separating and purifying mixtures		
6.	Oxygen, carbon dioxide and hydrogen-properties and reactions and commercial uses		
7.	Extraction of raw materials		
8.	Processing and producing of raw materials--effect on environment		
9.	Particle model of matter		
10.	Acids and bases, reaction of acids		
11.	Energy in chemical reactions		
12.	Atoms, elements and compounds		

Concept knowledge: Matter & Materials **35 marks**

1. Phases of matter

Explain what you know about the particles of matter in their three phases. Explain 'phase change' and how it affects life on Earth. You can use labelled drawings and examples to strengthen your explanation. 15 marks

2. Mixtures and solutions

a. Explain the differences between a mixture and a solution.

b. Give 2 everyday examples of mixtures.

c. Give two everyday examples of solutions. 8 marks

3. Materials and their properties

Describe four properties for each material below:

A. Clear plastic 2 marks

B. Aluminium foil 2 marks

C. Cardboard 2 marks

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4. Describe one use of each of the above materials in our everyday lives, based on their properties:

Clear plastic; Aluminium foil; and Cardboard 3 marks

5. Boiling points

Explain how you know for certain when a liquid has reached its boiling point (use a diagram to help you) 3 marks

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Project Outcome Two: Teachers improve their concept knowledge

Name of teacher: .... Class: ....
Name of school: .... EMDC: ....

Circle: Pre-test/ Post-test
CTI Teacher Number

1.2 Concept knowledge: Planet Earth and Beyond

Task: Explain what you know about the Solar System, the movement and light of its heavenly bodies, and how it affects life on Earth. Use labelled drawings and examples to strengthen your explanation.

	Phenomenon	Phenomenon is mentioned	Phenomenon is elaborated (described, egs given, links made)	TOTAL (Types of knowledge)
Basic knowledge	The sun			
	The moon(s)			
	Planets			
	Asteroids & Comets			
	TOTAL	(4)	(4)	(8)
Scientific knowledge	Revolution & rotation			
	Gravity			
	Light/ Heat is emitted by the sun (star)			
	Light reflects from moons and planets			
	TOTAL	(4)	(4)	(8)
Application *(any two acceptable applications)*	Day and night			
	Phases of the moon			
	Seasons			
	Tides			
	TOTAL	(2)	(2)	(4)
TOTAL (Level of knowledge)		(10)	(10)	(20)

2.2 Concept knowledge: Matter and Materials

Task: Explain what you know about phase change and how it affects life on Earth. Use labelled drawings and examples to strengthen your explanation.

	Phenomenon	Phenomenon is mentioned	Phenomenon is elaborated (described, egs given, links made)	TOTAL (Types of knowledge)
Basic knowledge	Substances can change phase			
	Solids, liquids & gasses *(all three)*			
	Everything consists of matter			
	Matter is made of particles or atoms/molecules			
	TOTAL	(4)	(4)	(8)
Scientific knowledge	Comparison of spaces between particles in three phases			
	Comparison of movement of particles in three phases			
	Comparison of forces between particles in three phases			
	Energy and phase change			
	TOTAL	(4)	(4)	(8)
Application	The water cycle			
	Appropriate technology application			
	TOTAL	(2)	(2)	(4)
TOTAL (Level of knowledge)		(10)	(10)	(20)

PSP Cluster Project Outcome 2 (concept knowledge)
Analysis of teacher pre and post tests

1

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3.2 Concept knowledge: Life and Living

Task: Explain what you know about photosynthesis and its importance for the survival of all life on Earth. Use labelled drawings and examples to strengthen your explanation.

	Phenomenon	Phenomenon is mentioned	Phenomenon is elaborated (described, egs given, links made)	TOTAL (Types of knowledge)
Basic knowledge	Occurs in plants/ green/ leaves/ chlorophyll			
	Water and mineral salts in			
	CO_2 in, O_2 out			
	Starch/ food / glucose produced			
	TOTAL	(4)	(4)	(8)
Scientific knowledge	Sunlight is energy source			
	Plants are basis of all food chains			
	Plants are basis of all O_2 – essential for breathing			
	Plants are essential for removal of CO_2			
	TOTAL	(4)	(4)	(8)
Application	Link global warming to excess of CO_2			
	Any solutions			
	TOTAL	(2)	(2)	(4)
TOTAL (Level of knowledge)		(10)	(10)	(20)

4.2 Concept knowledge: Energy and Change

Task: Explain what you know about energy, forms of energy and how the sustainability of our energy sources affects life on Earth. Use labelled drawings and examples to strengthen your explanation.

	Phenomenon	Phenomenon is mentioned	Phenomenon is elaborated (described, egs given, links made)	TOTAL (Types of knowledge)
Basic knowledge	Sun is original source of energy			
	Different sources of energy			
	Different forms of energy			
	Energy makes things happen			
	TOTAL	(4)	(4)	(8)
Scientific knowledge	Energy can be transformed			
	Energy can be transferred			
	Energy can change a substance chemically or by phase			
	Renewable/ non renewable			
	TOTAL	(4)	(4)	(8)
Application	Energy crisis e.g.: fossil fuels; food shortage			
	Solutions			
	TOTAL	(2)	(2)	(4)
TOTAL (Level of knowledge)		(10)	(10)	(20)

SUMMARY: Profile of Teacher's Concept Knowledge: Pre-test/ Post-test

	Phenomenon is mentioned	Phenomenon is elaborated (described, egs given, links made)	TOTAL (Types of knowledge)
Basic Knowledge	(16)	(16)	(32)
Scientific knowledge	(16)	(16)	(32)
Application	(8)	(8)	(16)
TOTAL (Level of knowledge)	(40)	(40)	(80)

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APPENDIX O: ASSESSMENT OF CURRICULUM COVERAGE

<u>Project Outcome Four</u>**: Natural Sciences is taught as required by the NCS: curriculum coverage is appropriate, learners are involved in investigations, concept development is evident and appropriate assessment strategies are in place.**

To evaluate progress in terms of Learning Outcome Four, an **analysis of learner workbooks and portfolios** from a sample of Grade 6 learners will be done to assess teaching practice in terms of:

- Curriculum coverage
- Concept development
- Appropriate assessment

This analysis will use the following set of tools:

A. Evidence of curriculum coverage
B. Evidence of investigations (LO1)
C. Evidence that there has been effective teaching for Natural Science concept development
D. Evidence that there has been appropriate assessment of learners' work in terms of LO's.

Name of teacher: ……………………………………………………………..

Class: ………………………………………………………………………….

Name of School: ……………………………………………………………..

A. EVIDENCE OF CURRICULUM COVERAGE

Tick the box opposite the topic name when you find evidence in the learner's book that the topic was taught. Each tick is worth a score of one. However, a maximum of five may be scored for each strand.

Life & Living: Intermediate Phase

	Topics	**Tick**
	Photosynthesis	
	Energy, diet and digestion	
	Sense organs	
	Movement, muscles and skeleton	
	Plants and food	

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	Ecosystems	
	Habitats and social patterns	
	Soil in ecosystems	
	Water in ecosystems	
	Vegetative reproduction	
	Sexual reproduction	
	Fossils in South Africa	
Total	**Maximum score of five**	

Matter & Materials: Intermediate Phase

	Topics	**Tick**
	Boiling and melting points of different substances	
	Materials, their properties and classification	
	Metals, ceramics, polymers and composite materials	
	Temporary and permanent changes to materials	
	Changes brought about by heating	
	Dissolving – factors that affect the rate of dissolving	
Total	**Maximum score of five**	

Planet Earth & Beyond: Intermediate Phase

	Topics	**Tick**
	Earth’s rotation – day and night	
	Phases of the moon and cultural traditions	
	Star patterns and cultural traditions	
	Measuring changes in weather	
	Annual and seasonal changes in weather	
	The water cycle	
	Continents, oceans and polar ice caps	
	Rocks, soils, water and air	
	Erosion and deposition, and landforms	
	Igneous, sedimentary and metamorphic rocks	
	Soils and their properties	

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	Fossils	
	Water resources	
Total	**Maximum score of five**	

Energy & Change: Intermediate Phase

	Topics	**Tick**
	Sources of energy	
	Energy transfer systems	
	Systems for storing energy	
	Electrical circuits	
	Energy brings about changes to substances	
	Sound energy	
	Humans and animals get energy from plants	
	Electricity and safety	
Total	**Maximum score of five**	

A. **Curriculum coverage: Total score out of 20: ……………..**

B. EVIDENCE OF INVESTIGATIONS (LO1)

Life & Living: Intermediate Phase

	Tick
An investigation has been done in class	
The question being investigated is evident	
The content being explored is appropriate for the grade	
Learners have recorded their observations / measurements	
There has been some reflection on the results*	
Maximum score of 5	

For example: a summary, conclusion, further questions, etc.

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Matter & Materials: Intermediate Phase

	Tick
An investigation has been done in class	
The question being investigated is evident	
The content being explored is appropriate for the grade	
Learners have recorded their observations / measurements	
There has been some reflection on the results*	
Maximum score of 5	

Planet Earth & Beyond: Intermediate Phase

	Tick
An investigation has been done in class	
The question being investigated is evident	
The content being explored is appropriate for the grade	
Learners have recorded their observations / measurements	
There has been some reflection on the results*	
Maximum score of 5	

Energy & Change: Intermediate Phase

	Tick
An investigation has been done in class	
The question being investigated is evident	
The content being explored is appropriate for the grade	
Learners have recorded their observations / measurements	
There has been some reflection on the results*	
Maximum score of 5	

B. <u>Investigations (LO1): Total score out of 20</u>

C. EVIDENCE THAT THERE HAS BEEN EFFECTIVE TEACHING FOR NATURAL SCIENCES CONCEPT DEVELOPMENT

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Tick the box opposite the comment when you find evidence in the learner's book of this feature of the teaching. Each tick is worth a score of one. However, a maximum of five may be scored for each strand.

Life & Living: Intermediate Phase

	Tick
The scientific content is accurate	
The same scientific concept is taught / represented in a number of ways	
A logical sequence of tasks is evident	
Children are answering why questions	
Children are writing in their own words	
The child's context is utilized	
Indigenous knowledge is represented	
Maximum score of 5	

Matter & Materials: Intermediate Phase

	Tick
The scientific content is accurate	
The same scientific concept is taught / represented in a number of ways	
A logical sequence of tasks is evident	
Children are answering why questions	
Children are writing in their own words	
The child's context is utilised	
Indigenous knowledge is represented	
Maximum score of 5	

Planet Earth & Beyond: Intermediate Phase

	Tick
The scientific content is accurate	
The same scientific concept is taught / represented in a number of ways	
A logical sequence of tasks is evident	
Children are answering why questions	
Children are writing in their own words	

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The child's context is utilised	
Indigenous knowledge is represented	
Maximum score of 5	

Energy & Change: Intermediate Phase

	Tick
The scientific content is accurate	
The same scientific concept is taught / represented in a number of ways	
A logical sequence of tasks is evident	
Children are answering why questions	
Children are writing in their own words	
The child's context is utilised	
Indigenous knowledge is represented	
Maximum score of 5	

C. <u>Effective teaching for concept development: Total score out of 20:</u>

D. EVIDENCE THAT THERE HAS BEEN APPROPRIATE ASSESSMENT OF LEARNERS' WORK IN TERMS OF LO'S:

Life & Living: Intermediate Phase

	Tick
There is evidence that books have been checked in some way	
AC's have been specified to learners for an assessment task	
The AC's are appropriate to the content and skills of the NS outcomes	
The AC's are differentiated for ability	
There is developmental feedback to learners	
Total of possible 5	

Matter & Materials: Intermediate Phase

	Tick
There is evidence that books have been checked in some way	

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AC's have been specified to learners for an assessment task	
The AC's are appropriate to the content and skills of the NS outcomes	
The AC's are differentiated for ability	
There is developmental feedback to learners	
Total of possible 5	

Planet Earth & Beyond: Intermediate Phase

	Tick
There is evidence that books have been checked in some way	
AC's have been specified to learners for an assessment task	
The AC's are appropriate to the content and skills of the NS outcomes	
The AC's are differentiated for ability	
There is developmental feedback to learners	
Total of possible 5	

Energy & Change: Intermediate Phase

	Tick
There is evidence that books have been checked in some way	
AC's have been specified to learners for an assessment task	
The AC's are appropriate to the content and skills of the NS outcomes	
The AC's are differentiated for ability	
There is developmental feedback to learners	
Total of possible 5	

D. Appropriate assessment of learners' work: Total score out of 20: …………..

PROFILE OF TEACHING IN TERMS OF THE NCS REQUIREMENTS:

Evidence of curriculum coverage:	**Possible Score**	**Actual Score**
Life & Living: Intermediate Phase	5	
Matter & Materials: Intermediate Phase	5	
Planet Earth & Beyond: Intermediate Phase	5	
Energy & Change: Intermediate Phase	5	

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Total Score	**20**	

Evidence of investigations (LO1):	**Possible Score**	**Actual Score**
Life & Living: Intermediate Phase	5	
Matter & Materials: Intermediate Phase	5	
Planet Earth & Beyond: Intermediate Phase	5	
Energy & Change: Intermediate Phase	5	
Total Score	**20**	

Evidence of effective teaching for concept development:	**Possible Score**	**Actual Score**
Life & Living: Intermediate Phase	5	
Matter & Materials: Intermediate Phase	5	
Planet Earth & Beyond: Intermediate Phase	5	
Energy & Change: Intermediate Phase	5	
Total Score	**20**	

A. Evidence of appropriate assessment of learners:	**Possible Score**	**Actual Score**
Life & Living: Intermediate Phase	5	
Matter & Materials: Intermediate Phase	5	
Planet Earth & Beyond: Intermediate Phase	5	
Energy & Change: Intermediate Phase	5	
Total Score	**20**	

Grand Total: 80: ………………

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APPENDIX P: NATURAL SCIENCES TEACHER TRAINING COURSE CONTENT

Developing teachers' Natural Sciences pedagogical content knowledge with respect to the NCS, lesson planning, assessment and classroom management. Courses include the following:

1. Interpreting the curriculum (NCS).
2. Understanding the Natural Sciences concepts and content.
3. Writing out a variety of high quality lesson plans, assessment tasks and criteria for formal assessment.
4. Setting question papers with a variety of questions of different orders including baseline and summative assessments.
5. Equipping teachers with good classroom and time management strategies.
6. Integrating language and literacy through activities such as shared writing and reading.
7. Assisting teachers with developing the necessary skills to adapt learning support materials and textbooks to the needs of the learners.
8. Encouraging teachers to reflect on practices (keeping a journal) with a view to promote professional growth and development.
9. Encouraging teachers to compile a portfolio of lesson plans, learner activities and assessments they developed, as well as samples of learners' good quality work.
10. Encouraging teachers to network with peers from other schools within the cluster.
11. Strengthening Learning Outcome 1 (Scientific Investigations) and Learning Outcome 3 (Science, Society and the Environment).

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APPENDIX Q: TRAINING WORKSHOPS - COURSE OUTLINES

PSP/North Cluster **Course Outline** **19 April 2007: 08:30 – 14:30**	**PSP/South Cluster** **Course Outline** **10 May 2008**
REGISTRATION • Revisit Cluster Project Outcomes • Planning term 2 - Focus strand Earth and Beyond • View the DVD on Planning • Revisit NCS Natural Sciences learning outcomes • Concept mapping per phase • Environmental diaries – to help with 30 % Integrate 30% own context – Environmental Education • Learning programmes and adjust work schedules according to WCED Work Schedules	**REGISTRATION** • Revisit Cluster Project Outcomes • Planning term 2 - Focus strand Energy and Change • Revisit learning outcomes • Concept mapping per phase • Environmental diaries – to help with 30 % • Integrate 30% own context – Environmental Education • Learning programmes and adjust work schedules according to WCED Work Schedules
Activities • Where are we in the big picture? Use the Astronomy Cards (All grades) • Making model of Earth (All grades) • Layers of the Earth. • Making soil • Soil erosion • View DVD- Lesson on Classification of rocks and landforms • OOTB equipment and lessons from the file • Excursions	**Activities** • Energy Transfer Systems (1) Ecosystem • Energy Transfer Systems (2) Windmills, Grinding stones, etc. • Energy Transfer Systems (3) Electrical Circuit. • OOTB equipment and lessons from the file • Excursions • School Visit Reminders • Course Evaluation

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• School Visit Reminders • Course Evaluation	

OOTB refers to the 'Out of the Box' resource supplied by 'Old Mutual Foundation' consisting of equipment such as thermometers, gyroscopes, etc. and files with lesson plans for Environmental Education.

Planet Earth & Beyond course outline 2009

Day and time	**Activities**	**Materials**	**Outcomes**
15 min pre-test	Identify the planets.	Worksheet- solar system pic	Name the planets, name other heavenly bodies
Activity 1 **15 min**	Looking at the curriculum. Requirements for grade 7. Requirements for grade 6.	Copy of NCS requirements.	Find the paragraphs relevant for grade 6 and those for grade 7
Activity 2 **30 min**	The Solar System. Dealing with broad concepts. Whole class discussion Draw solar system on the paper plate Use playdough to model the sun, planets, moon, asteroids	Card 1 2-D model of solar system Paper plate	Planets, fixed orbits, rotation and revolution, gravity, dwarf planet , flat plane

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Activity 3 **45 min**	Use cards assigned to the two grades. Compile a fact file – 5 facts. Present information to the group. With your partner formulate 2 questions w.r.t. to the card you have / something that is not clear that you would like to put to the expert coming tomorrow.	Astronomy Cards. Grade 6 1. Earth 2. Moon 3. Stories about the stars 4. Birth, life and death of stars 5. Mars 6. Mercury and Venus Grade 7 • Our place in space • The faraway planets • The gas giants • Comets, meteors and asteroids • The sun • Discovering new planets	Physical properties of planets, search for life, large distances , extremes of temperature, photographic evidence, many things are still unknown, precious Earth, following the water, Goldilocks position of Earth in the Solar System, atmosphere, position in Solar System

Course outline: Energy & Change **Grade 6 & 7**

Time	Activity	Key concepts	Materials needed	Notebook entries
08:30-09:15	Welcome, registration, reviews and questionnaire			
9:15-9:30	1. Energy. Forms of energy. Main sources of energy. Renewable and non-	What is energy? Energy sources and forms.	(PSP E & C Grade 4-7 Booklets)	Develop a summary. Mind map of forms and sources.

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	renewable sources of energy.			
9:30-10:00	2. Components of an electric circuit. • Connecting the simple electric circuit. • Drawing and labelling the diagram. • Connect the circuit in 6 different ways. • Make a switch	Electric circuit Components: source (dry cell, battery, dynamo, power station, generator) -Light bulb (different types) -Conducting wire -Switch	(PSP E & C Grade 4 & 5 Booklets) Word List Components - support material	Drawings and labelling of circuits
10:15-10:30	3. Effects of electricity (heat, light, movement)	Effects of electricity	(PSP E & C Grade 5 Booklets)	Drawings and labelling circuits Compile summary
10:30 – 10:45	4. Conductors and Insulators	Electricity will only flow in a circuit made of materials that conduct electricity.	(PSP E & C Grade 5 Booklet)	Compile and complete table. Write sentences.
10:45 – 11:00	5. Safety in the home	Do's and don'ts when using electricity	(DVD) (PSP E & C Grade 5 book)	Draw and write
11:00 – 11:15	6. The Fire Triangle	Fire safety	Chart	Role – play Draw and write
11:15-12:30	7. The Coal Story. - Getting the stored energy out of energy sources. (PSP E & C Grade 6 Booklets)	Stored energy and the most efficient and cost effective, environmentally friendly ways of extracting and using this energy.	(PSP E & C Grade 6 Booklets)	Draw, label, write, sequence, present, etc.

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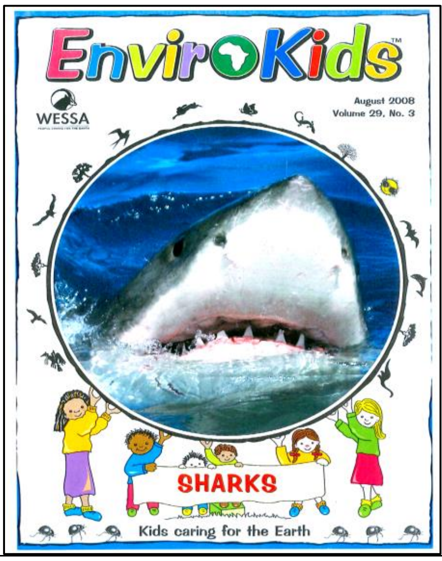
	- Tracing the energy to its source. - Renewable and non-renewable energy (p.13) (PSP E & C Grade 7 Booklets) - Fuels for the future (PSP E & C Grade 7 Booklets)			
13:00-13:30	8. Footprint on Earth (Workshop booklet) Wrap-up	Reducing your carbon footprint		Research, draw and write, sequence.
13:30-14:00	30% and Integration			
14:00 – 14:30	Post Questionnaire Evaluation of course School visit dates			

Cluster workshop: Matter & Materials

Term 4: Course programme **Date: ……………………………….**

TIME	ACTIVITY	EQUIPMENT
9h00 – 9h30	Concept Mapping: 30 %; Environmental Education; Integration – Strands & Learning Areas; OOTB-Box Equipment, File & Diary; Excursions	Flip Chart, Koki Pens, Prestik OOTB Box, Files & Diaries
9h30 – 11h00	Practical Work 1: Boiling Point (**LO 1 at grade 5 level).** KWL; An investigative question (AS 1) Conducting an investigation and collecting data. (Record on a table) (As 2)	Per group: 1 tripod, 1 gauze wire, 1 burner, matches, 3 thermometers, 1 glass container with 60ml water, 2 glass containers (6oml each with either

	Evaluating Data and Communicating findings (AS 3) Translation Task: Using the data to complete a graph. Write a paragraph to interpret data. Assessment: Given to teachers. Different aspects that can be assessed.	Coke, orange juice or apple juice), stopwatch, observation sheet.
11h05– 1h35	Practical Work 2: Corrosion & Rusting Activity 135 in **OOTB Waste Management File**. What is corrosion? What is rusting? Setting up the investigation. What makes this an investigation? Shared writing.	5 containers with lids and labels; four iron nails (not galvanized and not stainless steel); tap water; boiled water; oil; salt water; observation sheets.
11h35 - 12h15	1. Classification of Materials & Mind map. 2. Properties of Materials. 3. Classes of Materials.	Envelopes with outline and materials. Materials (cotton and nylon), burners, matches, spiked pens, observation sheet.
12h45-14h00	**SHARKS** **1.** Examining the **ENVIROKIDS MAGAZINE** 2. Position of the shark in a food pyramid. 	Envirokids, wordsearch Animal pictures, handouts, tins. Chart paper, crayons, koki pens, prestik.

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	3. Group activities and report back: What about Sharks?	
14h00- 1430	1. Questionnaire 2. School visit calendars 3. Course evaluation	Questionnaire, calendars, evaluation sheets.

Foundation Phase course outlines:

Natural Sciences Investigations in the Foundation Phase	**Natural Sciences Foundation Phase Investigating Weather**
<u>Activity 1</u> Curriculum Requirements. Core Knowledge and Concepts of Energy and Change. <u>Activity 2</u> Reading the story, 'The Great Big Enormous Turnip' by Alexi Tolstoy to introduce the concepts. This is followed by 'Word Burrs'. <u>Activity 3</u> Looking for examples of pushes and pulls in magazines, newspapers, etc. and compile a collage for pictures showing pushes, pulls or twists. <u>Activity 4</u> From the 'Feely Box' select an item and answer the following: 1. What needs a push? 2. What needs a pull? 3. What needs a twist? 4. Report back / or describe the action to the class.	<u>Activity 1</u> Write all the vocabulary related to weather on your flash cards. These words can be pasted onto the chalkboard as the learners call them out, and as they answer the following questions: 1. What is the weather like today? 2. Has it been like this for the past few days / weeks? 3. What did the Weatherman say the weather will be today? 4. How do the scientists predict weather? 5. How can we know how hot or cold it is today? (LO1 AS1 Learners plan a scientific investigation) 6. What other things do people look at when they talk about weather? 7. What measuring instruments are used to measuring conditions of weather? <u>Activity 2</u>: Integration with language (a) Give your learners the following measuring instruments: a rain gauge and a thermometer

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5. Complete the table. <u>Activity 5</u> Investigating how to move a marble: forward, backward or sideways by blowing through a straw. <u>Activity 6</u> Investigate what makes a toy car go faster? PART 1- Car races (from a starting line). Note that you could repeat this activity with the same cars, but using different surface materials and then comparing the distances the cars travelled. Surface materials that you could use: sandpaper, carpets, etc. PART 2 – Racing cars from a ramp. PART 3 – Using different materials on the ramp and noting the effects on the speed of the cars. (Sandpaper; carpet; cloth, etc.) <u>Activity 7</u> Using the information obtained in PART 1 to draw a bar graph. <u>Activity 8</u> Investigating: What do magnets pull towards them? Compile a list of items that the magnet 'pulls' towards it. <u>Activity 9</u> Games we can play: 1. Let's make a twister. 2. Let's go Bowling / let's play Skittles (Collect 9 two-litre bottles. Place one number from 1 – 9 on the 9 bottles. Stand a	(b) In groups learners must draw and talk about what each measuring instruments is made of, what shape is it, how is it used etc. (c) Each group tells the rest of the class about each instrument. (d) Teach learners the following: (1) how to use the measuring instruments (2) weather symbols (3) how to record onto the weather chart <u>Activity 3:</u> (LO1 AS2 Learners conduct and collect data about weather) (a) Get your learners outside the classroom where there is an open space and where they can feel a breeze / wind. Let them observe measure and record weather. (b) Hang the weather chart on the chalkboard and record in the appropriate columns the answers your learners give you to the following questions: 1. Which weather symbol can we record for today's weather? 2. What is today's temperature? 3. What is the wind speed? 4. What could you see this? 5. Which way did the wind go? 6. Do you think it is going to rain this afternoon / tonight? **The ongoing weather investigations:** (a) Hang this chart on the wall and tell learners that they are going to take turns to go outside and do the weather investigations (Indicate the time for different pairs of learners to check the weather conditions)

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distance from the bottles, use a ball and see how many bottles you can knock down. Add the scores of the bottles you knocked down. Take turns with a friend).

3. Throw the discus! Gooi die diskus! (Refer to your booklet for information about this game. Note that the different circles can also be numbered and the learners could be adding these towards a score. The learner who throws his/her cardboard circle close to the middle circle is the winner.)
4. Life Orientation – Exercises using pulling actions, e.g. 'Tug of War'

(b) On the Class Weather Chart record the results of the investigation that each pair of learners communicates to the whole class

Activity 4: The Moon Watch

1. For homework the learners must observe and draw everything they see in the night sky
2. In class they show and tell about what they observed
3. The moon might be amongst the things the learners see. Ask learners what they know about the moon

Record the learner's answers onto a table:

What do we know?	What do we want to know?	How can we find out?	What have we learnt?

Planning an investigation / Helping learners to find a testable question Choose one testable question that learners will investigate e.g. Does the moon appear at the same time every day? Is the shape of the moon you see the same every day? How long does it take the moon to be the same shape again?

Preparing learners for the investigation:

Let the learners suggest what can be done to find out? **(LO1 AS 1 Planning the investigation)**

LO1 AS 2 Conducting the investigation and collecting data

(a) Look for the moon

(b) When you find the moon draw the shape you see on your moon watch chart

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	(c) When it is cloudy draw clouds (d) If you did not do your moon watch on a particular night, give a reason why (e) After a few days compare your moon watch drawings with those of your peers in your group (f) Complete this chart for 29 / 30 days The phases of the moon **Insert the Moon Watch Chart on page 8 grade 6 Planet Earth & Beyond booklet** Activity 6: Integration with language With your learners share stories and poems you know about the moon Activity 7: LO1 AS 3 Evaluating data, drawing conclusions and communicating findings Get the learners to answer the testable question(s) by asking what have they learnt about the moon Write their answers in the appropriate column on the **Planning an investigation / Helping learners to find a testable question table** Activity 8: Integration with language. **How much light?** Draw and colour in the shape of the moon to match each sentence

When the moon looks like this it is only showing a little light to me on Earth	When the moon looks like this it is showing all the light to me on Earth	When the moon looks like this it is only showing half the light to me on Earth

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APPENDIX R: CORE KNOWLEDGE INTEGRATED WITH 30% ENRICHMENT

Core knowledge to be taught in *Planet Earth and Beyond* – Senior Phase

Kernkennis vir onderrig in Aarde en Ruimte - Seniorfase

30% and Integration / 30% en Intergrasie.

Our place in space / ***Ons plek in die ruimte.***	***Atmosphere and weather/ Atmosfeer en weer***	***The changing Earth /*** ***Die veranderende aarde***
1. The Earth and Solar System / Die Aarde en die Sonnestelsel. • A visit to the Planetarium, MTN Science centre, or the SAAO (South African Astronomical Observatory). • Videos / Movies / etc. These are available from EDULIS. • Learners can make models / mobile of the planets. • Learners can make zigzag booklets or dossiers of a planet or other celestial body. • Learners can prepare a presentation of a planet they studied for the rest of the class. • Learners can prepare quiz questions on a planet or the planets. They can use these to test each other. • Invite a knowledgeable person / astronomer to speak to the learners.	6. Atmosphere, hydrosphere, lithosphere and biosphere. / Atmosfeer, hidrosfeer, litosfeer en biosfeer. • Researching the importance of each of the above. • Different forms of pollution impacting soil, air and water. • Different ways in which each of the above can be protected and conserved. • Making a model of the Earth. • Looking at, and describing other planets in terms of the above or differences regarding the above.	11. Layers of the Earth / Lae van die Aarde. • Making a model of the Earth to show the different layers. • Researching the manner in which scientists have determined and described the layers of the Earth. • Invite a geologist to present a talk to the learners.

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Integration with other strands: Life & Living	**Integration with other strands:** Life & Living	**Integration with other strands:** Life & Living Energy & Change
4. Movement of the Earth and Moon / Beweging van die Aarde en die Maan. • Orbits of the Earth and the Moon, as well as other celestial bodies such as planets, comets, etc. Looking at extraordinary orbits. • Researching an eclipse, lunar and solar. • Researching the impact of Earth and Moon on each other. • Researching the impact of the movements of the Earth and the Moon on human life and living, as well as on animals.	7. Climatic regions / Klimaatstreke. • Researching the climates of different cities. • How the above determines the kind of plants and animals that occur / survive / are adapted to life in these regions. • Weather patterns of different regions. • How animals and plants have developed unique survival strategies or adaptations to survive.	12. Continental drift and geological events / Kontinentskuiwing en geologiese gebeurtenisse. • Devastation / catastrophic impact on human life caused by earthquakes / volcanic activity, etc. The cost (EMS), emotion, loss (Life Orientation), etc. • Researching the movements of the Earth's Mantle that give rise to the continental drift, etc. • Researching evidences continents have drifted apart, and looking at the fact that there are similarities between some animals and plants that are found on different continents. • Volcanic activity, making a volcano using vinegar and bicarbonate of soda. • Videos/ DVD's on earthquakes, volcanoes, etc.
Integration with other strands: Life & Living	**Integration with other strands:** Life & Living	**Integration with other strands:** Life & Living
Our place in space/Ons plek in die ruimte.	***Atmosphere and weather/ Atmosfeer en weer***	***The changing earth/ Die veranderende aarde***
3. Gravity / Swaartekrag	8. Composition of the atmosphere / Samestelling van die atmosfeer.	13. Formation of the crust and landforms / Vorming van die kors en landforms.

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• Researching Sir Isaac Newton and his contribution. • Practical activities that demonstrate gravity. • Looking at the gravity of the moon. • Looking at space travel and the life of the astronaut. • How would the lack of gravity affect us and life on Earth? • How do spacecraft manage to overcome the force / the power of Earth's gravitational pull, and fly into space?	• How have scientists determined and described the composition of the atmosphere? • Greenhouse Effect • Global Warming • Air pollution, causes, effects, possible solutions. • Climate change	• Making models of different landforms using waste material. • Researching different landforms on the Internet. • Compiling a collection of pictures that show different landforms. • Invite a geologist to present a talk.
Integration with other strands: Matter & Materials. Life & Living Energy & Change	**Integration with other strands:** Matter & Materials. Life & Living Energy & Change	**Integration with other strands:** Matter & Materials. Life & Living Energy & Change
4. The sun as a source of energy. / Die son as n bron van energie. • Importance of the sun for life on Earth. • The composition of the sun, Hydrogen, Helium. • Solar power and its various uses. • Research on the Internet. • The birth, development and death of a star, Red Giant and White Dwarf.	9. Role of the atmosphere in regulating Earth's temperature. / Die rol van die atmosfeer in die Aarde se temperatuur. • Global Warming • Greenhouse effect • Countries that are responsible for greater carbon emissions. • What can and should be done to reduce carbon emissions? • Research on the Internet.	SA's fossil record / SA se fossielrekord. • Visit to the West Coast Fossil Park. • Visit to the Museum. • Creating a fun 'fossil dig' at school. Inviting palaeontologists to do a talk. • Using video/ DVD/ computer visuals to demonstrate more about how palaeontologists work with fossils. • Examine the importance of the study of fossils and its contribution to science, as evidences of the past and possibilities for the future.

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Integration with other strands: Matter & Materials. Life & Living Energy & Change	**Integration with other strands:** Matter & Materials. Life & Living Energy & Change	**Integration with other strands:** Matter & Materials. Life & Living Energy & Change
Our place in space / ***Ons plek in die ruimte.***	**Atmosphere and weather/ *Atmosfeer en weer***	**The changing earth/ *Die veranderende aarde***
5. Space Exploration and telescopes / Ruimteverkenning en teleskope. • The work being done at the SAAO and SALT. • A visit to the museum. • A visit to the planetarium / museum/ SAAO in Observatory. • Quite a few Internet sites provide information that is relevant to this section. • Design & make model telescopes/ spacecraft, space station, etc. • Researching spacecraft, space stations, the work of the astronauts such as the first South African in space, Mark Shuttleworth, the space race, etc.	10. Effects of human activities on the atmosphere / Uitwerking van menslike bedrywighede op die atmosfeer. • Different forms and causes of pollution, especially air pollution and its contributors. • What can be done to reduce the contributors of pollutants? • Global Warming / Greenhouse Effect • Impact on life and living, human, plants and animals.	15. Formation of Fossil Fuels / Vorming van fossielbrandstowwe. • Researching the recovery of the materials used to make fuels. • Researching the processes involved to acquire this material. • Visiting a refinery and studying the different processes performed. • Inviting a Chemical Engineer to explain these processes to learners. • Researching the processes involved to convert the material to various products that we use.
Integration with other strands: Matter & Materials. Life & Living Energy & Change	**Integration with other strands:** **Integration with other strands:** Matter & Materials. Life & Living Energy & Change	**Integration with other strands:** **Integration with other strands:** Matter & Materials. Life & Living Energy & Change

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		16. Mining / Mynbou • Researching mining activities in South Africa. • Researching mining techniques used to extract different products from the Earth. • Looking at videos, movies, DVDs, Internet websites that show different mining activities. • Researching the before and after, looking at what kind of metals, minerals are mined, what it looks like, how it is changed, the processes involved, and the final products developed. • Researching the importance of mining to South Africa (EMS). • Inviting a guest speaker to do a presentation, geologist to explain how they know where to mine, etc. • Looking at the impact of mining for the economy of South Africa, resources, employment, etc. • Looking at the impact of mining activities on human life, diseases (asbestos mining), loss of life due to cave-ins, etc.
	Integration with other strands:	**Integration with other strands:** Matter & Materials. Life & Living Energy & Change

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Core knowledge to be taught in *Life and Living* – Intermediate Phase

Suggestions for the 30% own context:

Life processes and healthy living **1. Photosynthesis**	***Life processes and healthy living*** **2. Energy, diet and digestion**	***Life processes and healthy living*** **3. Sense Organs**
• The impact of Global Warming • Climate change, droughts and floods • Growing a vegetable garden • Encouraging learners to take the knowledge home and grow their own gardens/ community development. • Bio fuel , biomass , the implications for food prices, food shortages, etc.	• Illnesses associated with food, namely malnutrition, etc. • Healthy and unhealthy eating habits, junk food. • Reading and analyzing food labels. • Food allergies • Genetically modified foodstuffs. • A presentation by visiting Nutritionist • Technology, making healthy sandwiches, fruit salad, having a picnic with healthy foods. • Planning a healthy eating plan • Linking eating with other healthy habits such as exercise. • Maintaining healthy practices such as washing your hands before meals. • Worms that infect the digestive system and deworming.	• Inclusivity • Technology, Looking at devices that are designed to make life easier for people with disabilities • Inviting speakers of different organizations working with people coping with various disabilities • Eye care • Noise pollution • Visiting centres catering for people living with disabilities. • Discussing ways we can be helpful to other people, e.g. reading to someone who is blind.
Integration with other strands: • Energy and Change, pg. 7	**Integration with other strands:** • Energy and Change, pg. 1,7	**Integration with other strands:** • Energy and change, pg. 6
Life processes and healthy living **4. Movement, muscles & Skeleton**	***Life processes and healthy living*** **5. Plants and food**	***Life processes and healthy living*** **6. Ecosystems**
• Correct posture • Importance of exercise • Preventing accidents	• Alien vegetation. • Food survey • Food packaging	• Looking at different ecosystems, rock pool, sea-shore, etc.

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• Looking at various physical disabilities and how these are accommodated, building ramps, toilets, etc. • Looking at X-rays	• Traditional foods • Cooking methods • Preserving food • Genetically Modified Food (GMF) • Food contamination • Impact of soil and water pollution • Use of fertilizers and insecticides • Growing food, school and home gardens – linking with EMS and the selling of the harvests or community development and the establishment of soup kitchens.	• Alien vegetation • Growing a water-wise garden • Visiting Kirstenbosch Gardens • Visiting different habitat, wetlands and the plants and animals that are unique to that environment, EE calendar, • Arbor Day • Oyster Farm- Knysna • The influence of insects such as the bee, a visiting bee-keeper can shed more light • Biodiversity • Ecosystems unravel with the loss of crucial members, the balance is hindered, plants and animals are unable to survive through the loss of members they are dependent upon.
Integration with other strands: • Energy and Change pg. 1, 7	**Integration with other strands:** • Energy and Change, pg. 7	**Integration with other strands:** • Energy and Change, pg. 7
Life processes and healthy living **7. Habitats and social patterns**	***Life processes and healthy living*** **8. Soil in Ecosystems**	***Life processes and healthy living*** **9. Water in Ecosystems**
• Stories and beliefs about animals • Keeping small animals in the classroom • Caring for animals • Invite the SPCA • Inviting specialist such as the beekeeper • DVD on animals and animal behaviour • Loss of habitat • Encroachment of man • Adaptation and survival practices of animals	• The impact of different poisons such as insecticides • Making a wormery • Compost making • Inviting a soil specialist • Studying the organisms that live in soil	• Global warming, climate change and changing atmospheric conditions. • The impact of global warming on plant and animal life • Droughts and floods • Desalination of water • Visit sewage plant • Visit the local dam and water purification system

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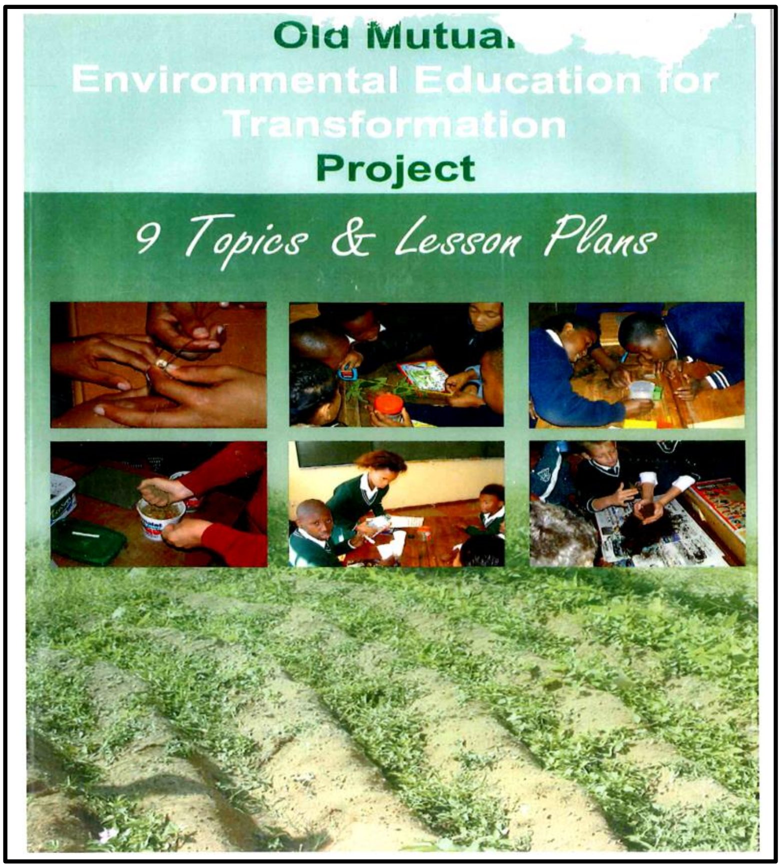
• Evolution of animals • Loss of biodiversity / Loss of habitat		
Integration with other strands:	**Integration with other strands:** • Earth and Beyond pg. 9, 11	**Integration with other strands:** • Earth and Beyond pg. 6, 7, 13
Life processes and healthy living **10. Vegetative Reproduction**	***Life processes and healthy living*** **11. Sexual Reproduction**	***Life processes and healthy living*** **12. Fossils in South Africa**
• Growing different plants using vegetative sections of the plants. • How this process is used in farming activities • Invite horticulturist to do a presentation. •	• Sexuality • Cultivating culture of mutual respect and tolerance • Invite clinic sister, cleanliness • Sexually transmitted diseases , HIV & Aids •	• Make your own fossil • Visit local museum • Visit Fossil Park in Langebaan •
Integration with other strands:	**Integration with other strands:**	**Integration with other strands:** • Earth and Beyond pg. 12,

APPENDIX S: 'OUT OF THE BOX' KITS



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Environmental education survey

'Out of the Box' Project: School Information

Name of the School: ………………………………………………….

Cluster: ……………………………………………………………

Date Completed: ………………………………………………….

1. Please complete the following table:

Grade	Teacher's Name	Number of Learners
4		
5		
6		
7		

2. Number of learners at the school: ……………………………………………………

3. Number of teachers at the school: ……………………………………………………

4. Number of teachers teaching Natural Science: ……………………………………

5. Which teacher is responsible for the School Environmental Projects at the school?

   ……………………………………………………………

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6. What environmental projects have been established at the school? …………………..

7. What environmental projects are you still planning to do at the school? ....

8. Name the OOTB apparatus that you use most often? …………………………………..…

9. Which OOTB apparatus do you hardly use? Why? …………………………………..

10. Have you already used any of the lessons from the OOTB file? Have you collected and/ or filed evidence of this? Please give some indication of this: …………………………

11. Name those projects at your school which involve any member of the public/ parent/ other organizations: ……………………………………………………………………….

12. Which Environmental Education Calendar events have you celebrated this year? Briefly indicate what was done: …………………………….

13. Which EnviroKids Magazines has your school received? How have these been used? ….

14. Did you attempt any Waste Management activities in your class? Explain: ………………

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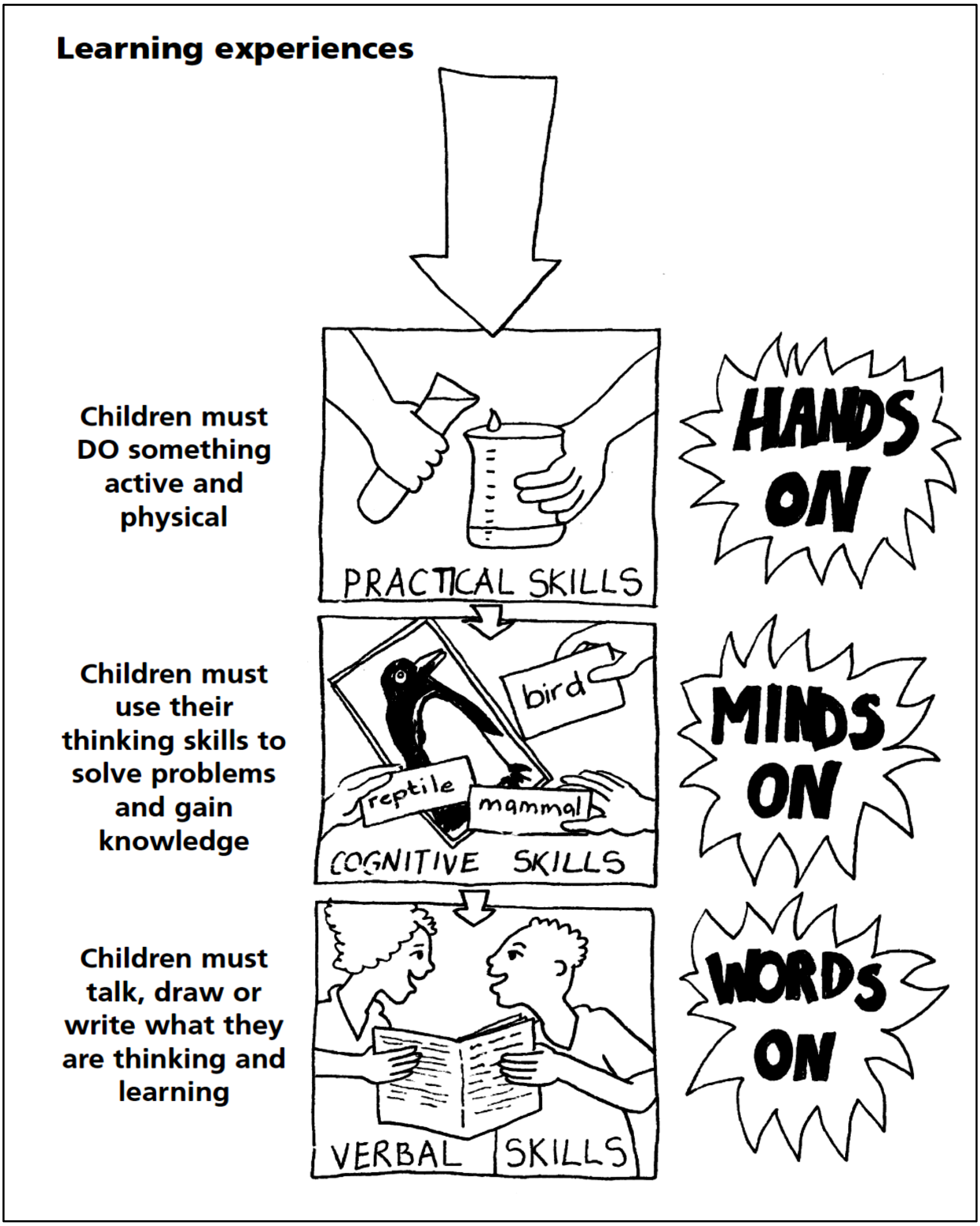
APPENDIX T: LEARNERS' 'HANDS-ON, MIND-ON AND WORDS-ON' EXPERIENCES OF SCIENCE



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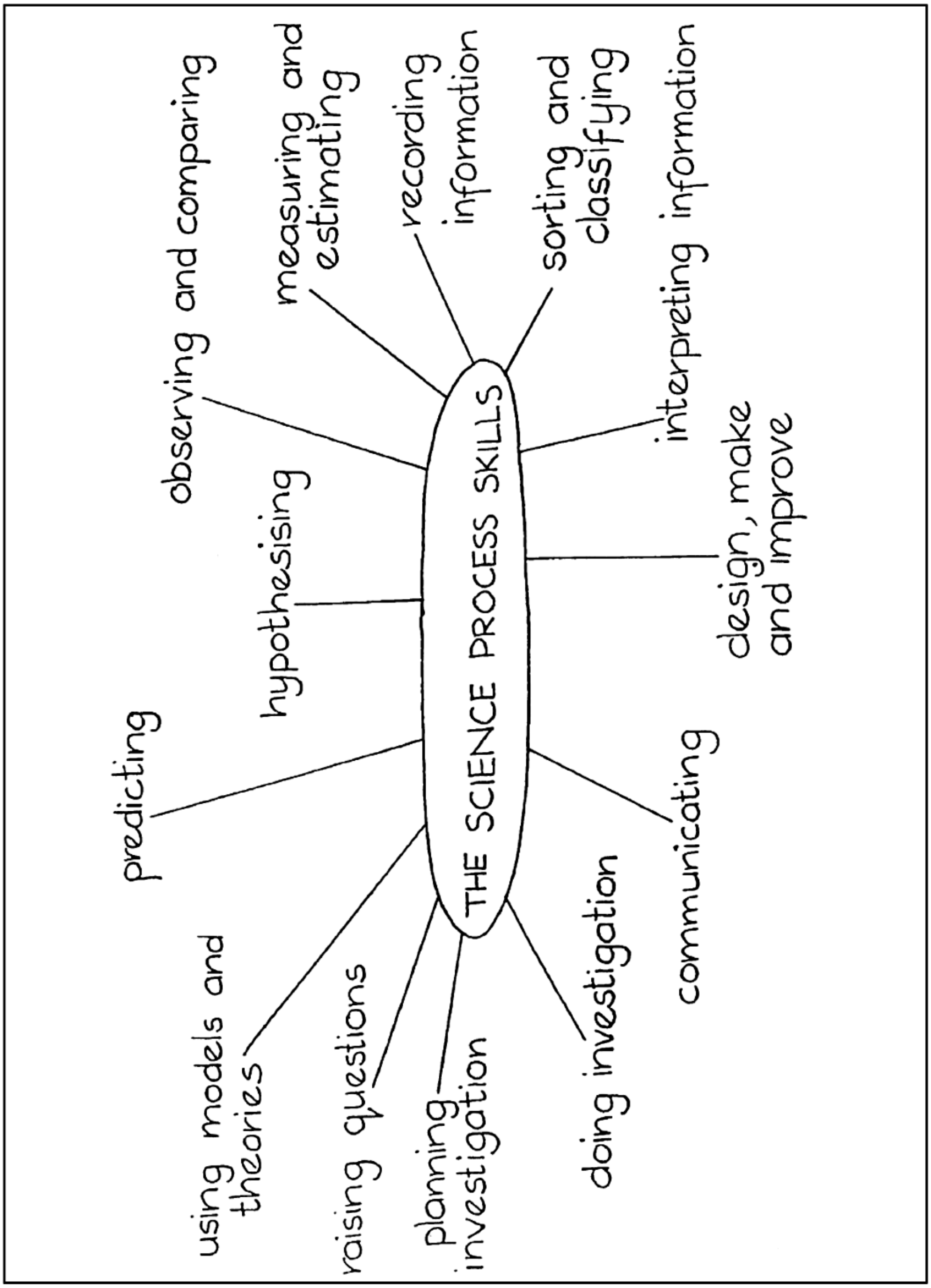
Introducing the Science Process Skills











MARS

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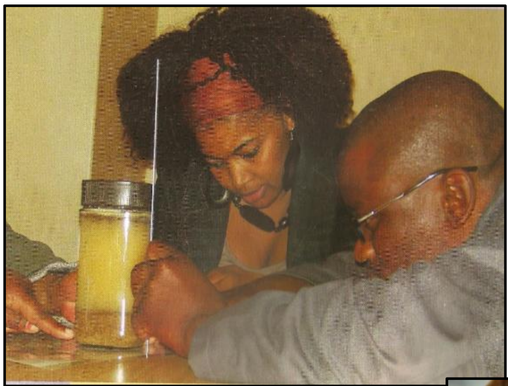
APPENDIX U: PRACTICAL TEACHER TRAINING WORKSHOPS

Photographs taken during Natural Sciences training workshops in the PSP Innovation & Cluster Projects.

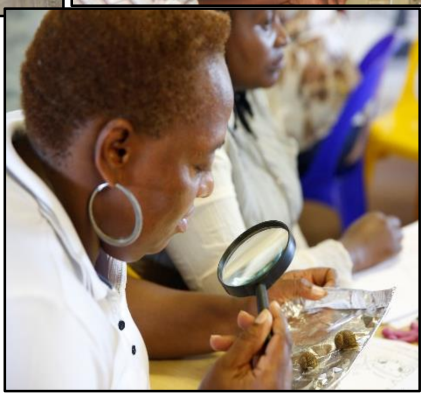













APPENDIX V: SCIENCE TEACHING IN THE CLASSROOM



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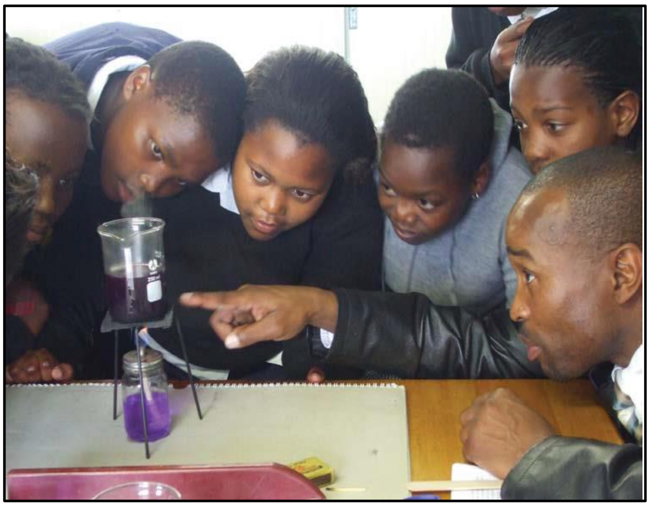

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APPENDIX W: TEACHER EVALUATION OF TRAINING WORKSHOP

WESTERN CAPE PRIMARY SCIENCE PROGRAMME

Evaluation of Workshop

We value the comments and opinions of the educators participating in our workshops. Please take a little time to reflect carefully on the way this workshop turned out for you.

Did it meet your needs?

What did you gain from the activities?

What did the workshop mean to you personally and professionally?

Rating Scale **1** – Poor

2 - Fair

3 – Good

4 – Very Good

5 - Outstanding

Session	Rating	Comment
Planning Term 3 Focus Strand: **Energy and Change**		

General Reflection on the Workshop:

……………………………………………………………………………………………………
……………………………………………………………………………………………………

Name: ____ Grade (s) __________________

School: ____ Date: _____________________

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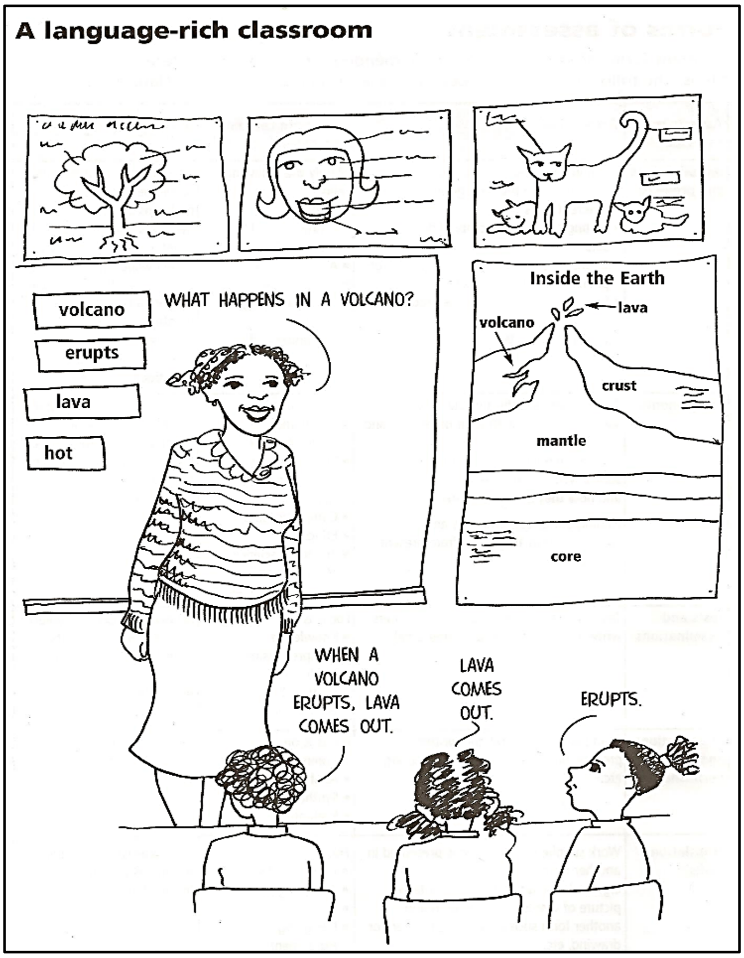
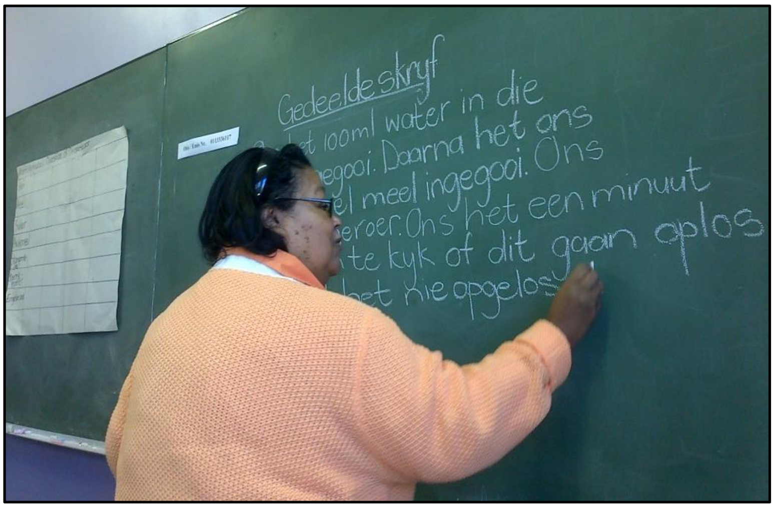
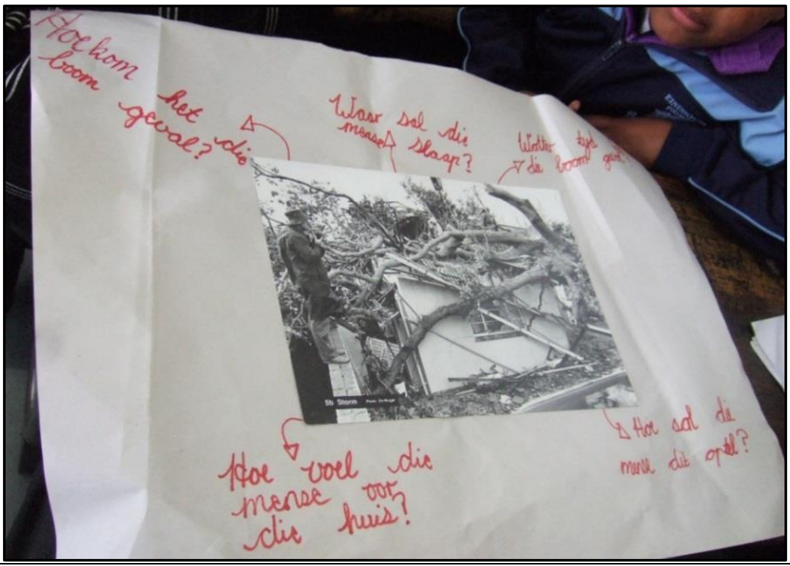
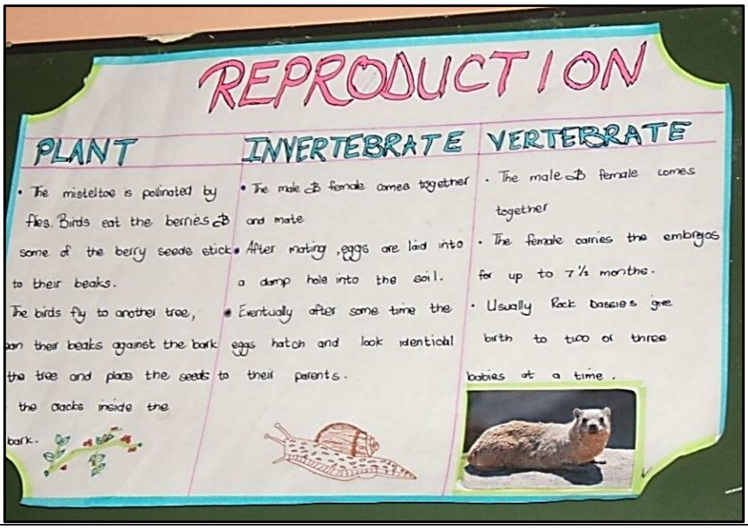
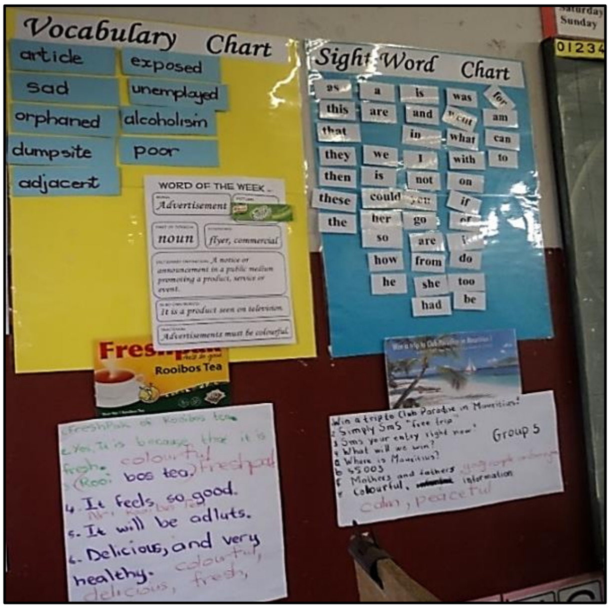
APPENDIX X: INTEGRATING SCIENCE WITH LANGUAGE & MATHEMATICS DEVELOPMENT

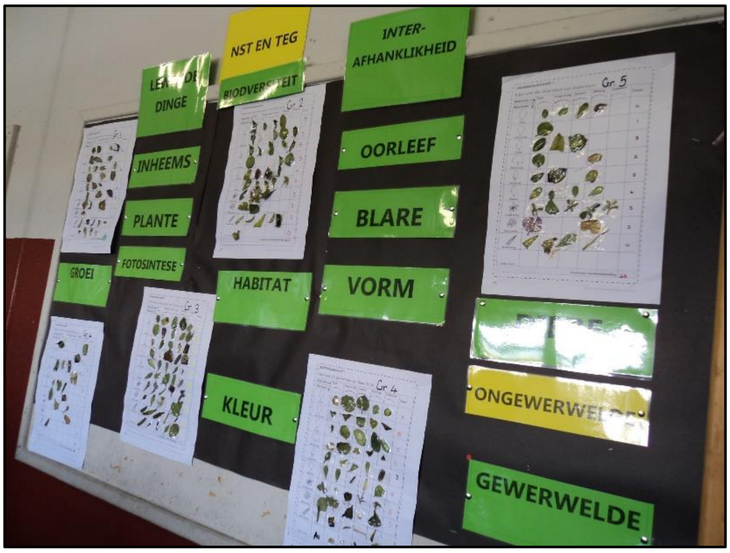


Language integration	
Compiling summaries / Teacher provides questions to guide learners' summaries:	

Shared writing:	 
Teachers write up instructions, and learners read and follow:	

Compiling a flow diagram/ Sequencing (Drawing and writing):	
Developing questions:	
Making posters:	

<table>
<tr>
<td>Consulting the dictionary for the meaning of science words:</td>
<td></td>
</tr>
<tr>
<td>Word Lists:</td>
<td>


</td>
</tr>
</table>

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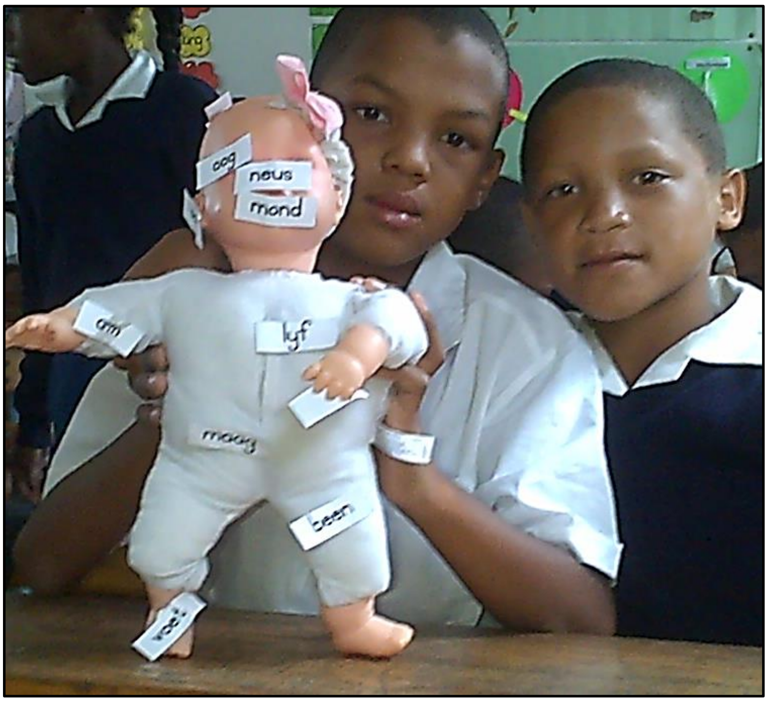
Nature Table with labels.

Matching or writing labels for pictures, real objects and/or drawings:



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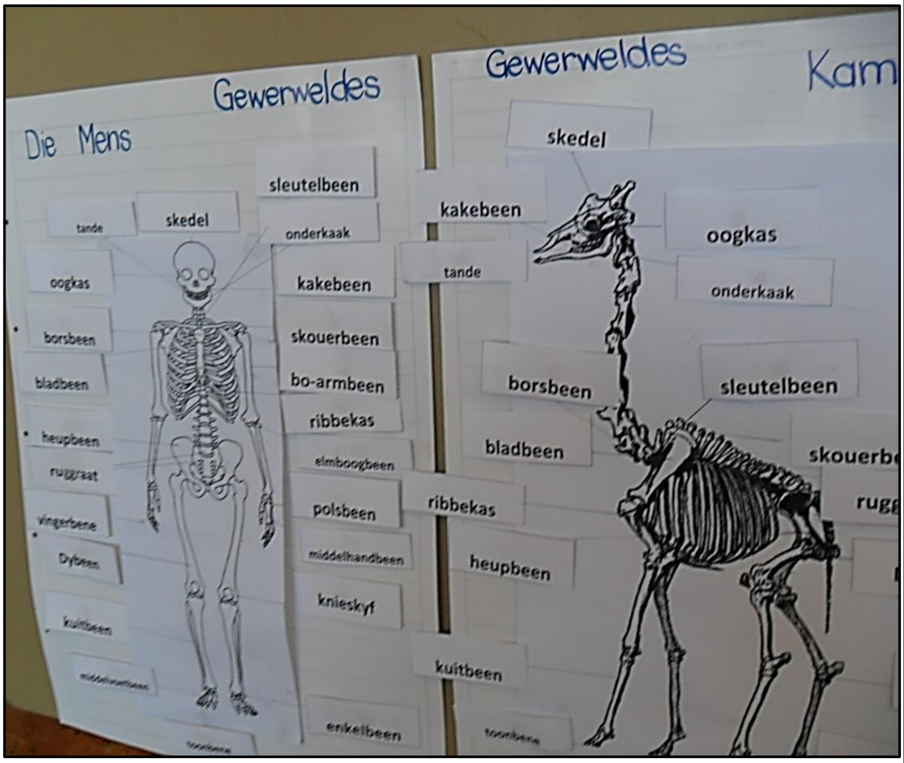

Mathematics integration:

Organizing data on a table:

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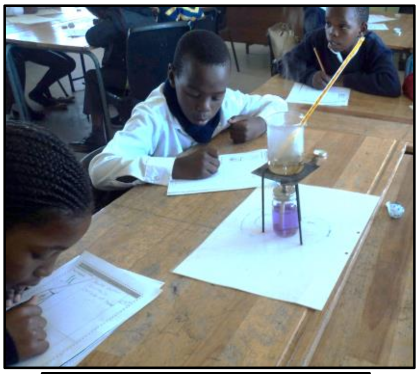
Drawing graphs to represent data:	
Using measuring instruments (such as rulers and thermometers) to measure length, weight, capacity, time and temperature:	  

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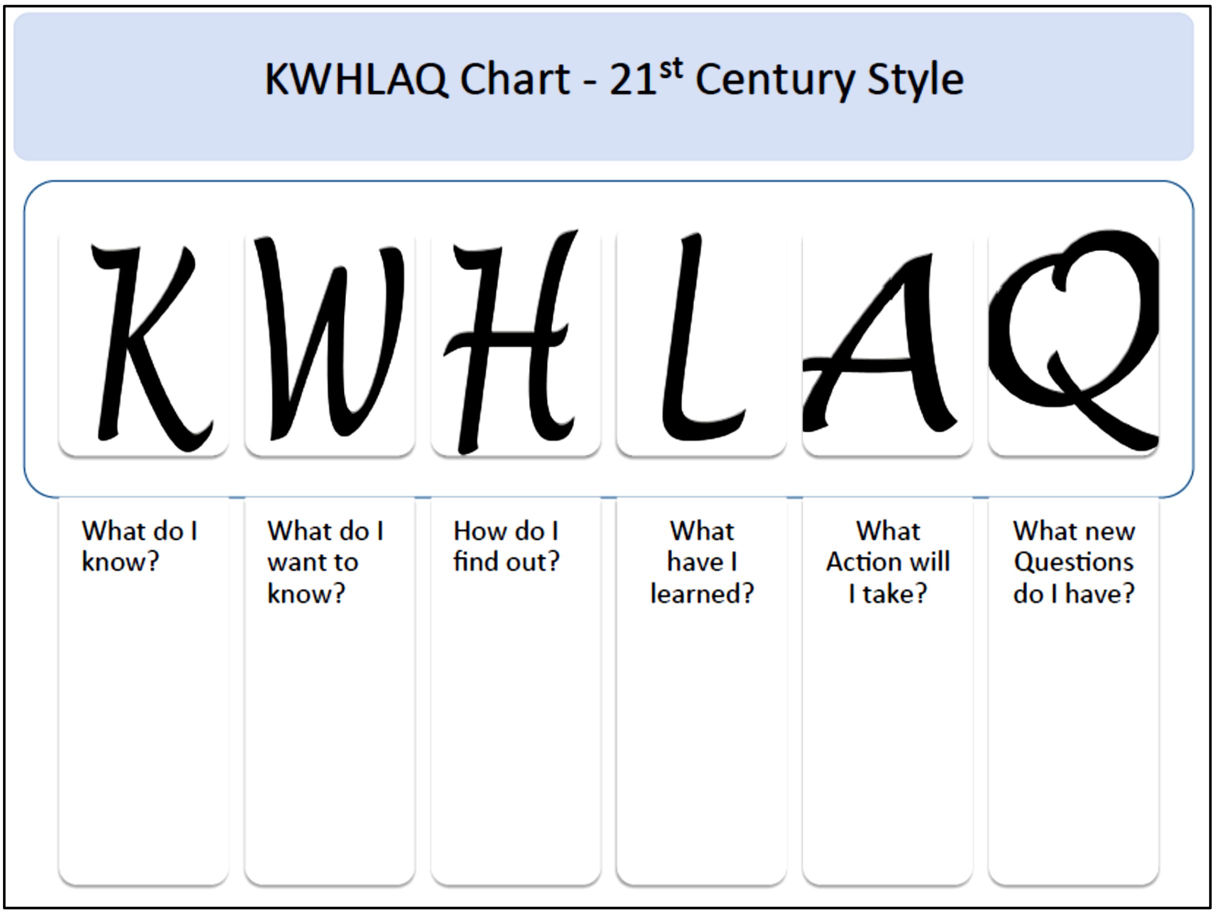
APPENDIX Y: KWL CHART

KWL Chart

What I know?	What I want to learn?	What I have learned?



(http://langwitches.org/blog/wp-content/uploads/2011/07/KWHLAQ-chart-template.jpg)

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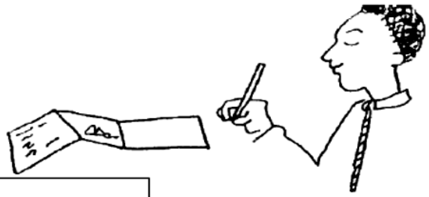
APPENDIX Z: ‘THE BIG EIGHT’

Multiple Intelligences

Howard Gardner, a Harvard University psychologist, identified seven different kinds of learning styles.

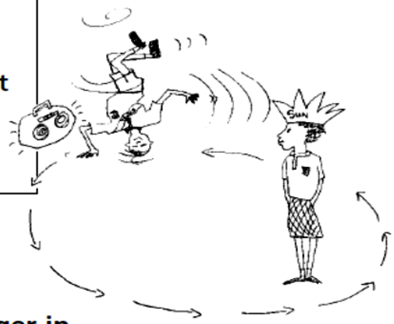
It is useful to be aware of these kinds of intelligences because we often wonder why some learners learn mathematics more easily than others, why some can draw well and some can speak or act easily.

Knowing about these multiple intelligences can help teachers to think of different ways in which learners can communicate what they know and can do.



The seven intelligences proposed by Gardner

- Linguistic intelligence (being able to use language well)
- Logical-mathematical intelligence (being able to think logically)
- Visual-spatial intelligence (being able to think in images and pictures
- Bodily-kinesthetic intelligence (learning through physical sensations)
- Musical intelligence
- “Intra-personal’ intelligence (to understand one’s thoughts and feelings and to use this in directing your own life)
- Naturalistic intelligence (to think about animals, clouds, rocks, stars and other natural phenomena)



☐ **When we notice learners who are stronger in one or more of the intelligences we should try to help them to develop and become strong at other intelligences as well.**

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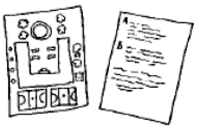
The Big 8

Useful forms or modes of communication for assessment

In order for us to assess learners' progress, they will have to communicate what they know and can do. There are a number of different forms of communication that they can use to do this.

Here are eight common forms or modes of communication, which are useful in science. They reflect the different ways of learning (from Gardner's Multiple Intelligences) and also different ways of communicating.



Acting out
Showing with your body by miming or gesturing or dramatising, etc

Speaking
Talking, singing, oral reports, explanations, discussion, description, role play, speeches, debates, etc

Drawing
Charts, graphs, diagram, maps, plans, etc

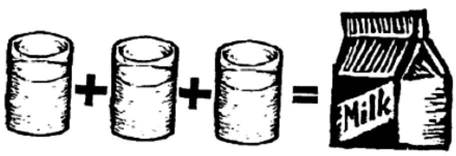
Models
Making or constructing things from different materials

Doing science practical work
Using a thermometer correctly, measuring, carrying out a procedure, making crystals, filtering dirty water, using a microscope, etc

Working in the environment
Looking after plants and animals, cleaning up the school grounds, making compost, growing a food garden, going on field trips and outings in the environment, etc

Writing
Writing a sentence, paragraph, poem, letter, dialogue, summary, report, explanation, conclusion, comparison, etc

Calculations
Calculating area, volume, average temperature over a week, how much electricity is used over a month, how much water the family uses per day, etc



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Assessment Tasks

Outcomes-based education (OBE) requires us to assess learners as part of our everyday classroom practice. So when we plan learning experiences for our learners, we have to plan our assessment tasks at the same time.

An Assessment Task brings together two things

Firstly, the task must allow learners to provide evidence that they have gained a certain attitude or knowledge or skill in line with the learning outcomes developed in the lesson. Secondly, learners will have to communicate this in a certain form or mode, for example by speaking or by writing.

How to develop an Assessment Task

The example below shows how to develop an assessment task about sequencing the life cycle of a butterfly.

Grade 6 LO2
Assessment Standard (AS) 3:
Interprets information by using alternative forms of the same information

↓

Content
eg correct knowledge of stages and processes in the life cycle of a butterfly
→ **Bring these together to develop an assessment task** ←
Mode of communication eg draw and label

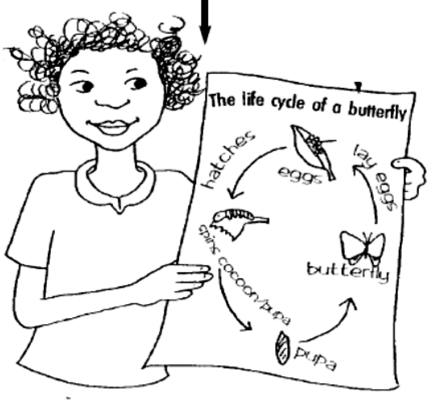
↓

Assessment task

- Draw a picture of the life cycle of a butterfly.
- Show the correct sequence of stages and processes.
- Label your picture.

For successful completion of the task above, the learners must meet these assessment criteria:

- There must be a heading about the life cycle
- Each stage must be clearly and correctly drawn and labelled, i.e. egg, larva, pupa and adult
- The processes must be labelled using key words such as: hatch, lay eggs, spin a cocoon, emerge from the cocoon, feed, grow bigger, change, etc
- The drawing must be in the form of a cycle
- The stages must be in the correct sequence.



Some criteria refer to the content part and some to the communication skill part.

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Developing learning experiences and assessment tasks

A learning experience is a series of activities in which learners develop competence in knowledge, skills and attitudes and from which we can develop an assessment task.

Learners must <u>do</u> something

ACTIVITIES

Include these strategies

Acting out
- Drama
- Role-plays
- Dialogue
- Play
- Mime
- Gestures
- Acting out
- Whole body movements
- Etc

Speaking
- Describing a process
- Telling
- Oral reports
- Explanations
- Role-play
- Debates
- Singing
- Discussions
- Dialogues
- Speeches
- Etc

Models
- Making or constructing things from different materials, etc.

Drawing
- Charts
- Graphs
- Diagrams
- Maps
- Plans
- Directions
- Posters
- Illustrations
- Etc

Doing calculations
- Calculating area
- Average temperature over a week
- Average rain over a week
- Calculating how much electricity is used over a month
- Calculating how much water the family used over a month
- Etc

Writing
- Sentences
- Paragraphs
- Poetry
- Letters
- Summaries
- Reports
- Speeches
- Dialogue
- Debate
- Explanations
- Conclusions
- Comparisons
- Etc

Working in the environment
- Looking after plants and animals
- Cleaning up the school grounds
- Making compost
- Growing food gardens
- Going on field trips and outings in the environment
- Etc

Doing science practical work
- Using a thermometer
- Measuring
- Carrying out a procedure
- Making crystals
- Filtering dirty water
- Using a microscope
- Carrying out an investigation
- Etc

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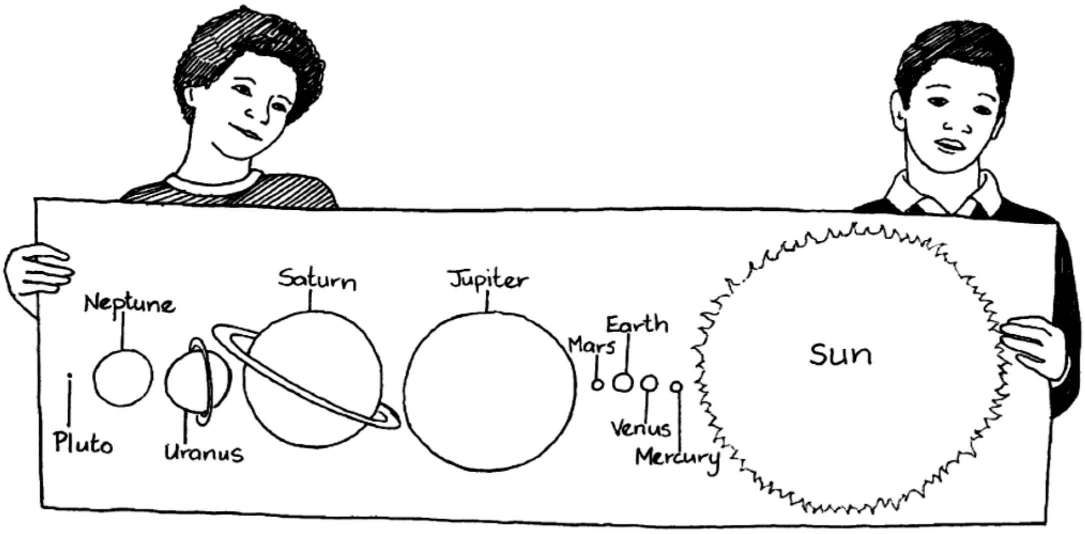
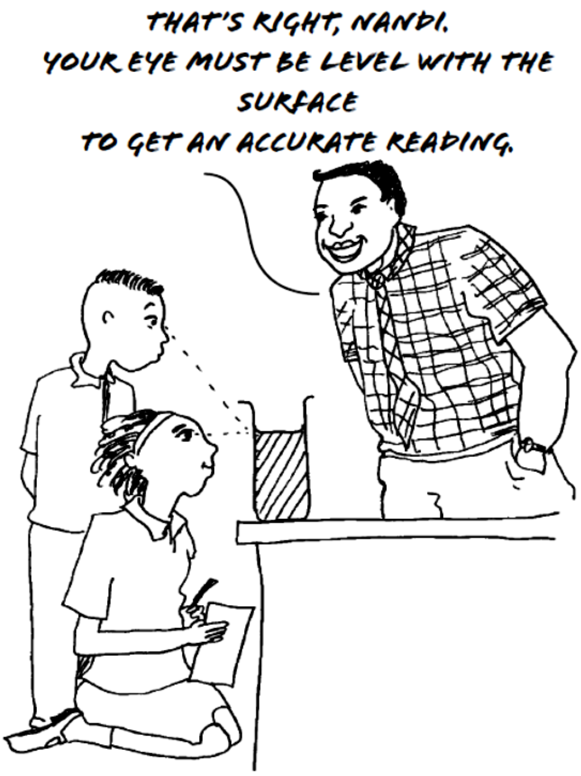
Assessing a product or a process

Assessing a product

Some tasks result in the learners producing something such as a paragraph of writing, or a model or a drawing. These are called the products of the Assessment Task. We can take these products and assess them.





Assessing a process

However some tasks do not result in a product but rather in processes. For example, using a thermometer to measure the temperature is a process. Carrying out a procedure is also a process. You will have to assess this by watching what the learner is doing whilst he or she is measuring or carrying out the procedure, and assess whether s/he is doing it correctly and with confidence.

This is the moment where you give the learners immediate feedback so that they can correct their mistakes and feel encouraged. Then they can try again if necessary.

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Doing science practical work

Using a thermometer, measuring, carrying out a procedure, making crystals, filtering dirty water, using a microscope

Descriptors that apply to science practical work

- Relevant to the topic – show correct understanding of the science knowledge and concepts
- Can follow instructions
- Can carry out a method or procedure
- Can design or devise a method or procedure
- Is actively involved in doing the practical work, e.g. measuring, manipulating equipment, etc.
- Can use objects, materials and apparatus appropriately
- Can manipulate the apparatus appropriately
- Can work in a careful, patient, logical way
- Can make the appropriate observations
- Follow the correct safety measures
- Can keep to the allotted time

Etc

Examples of contextualised criteria developed from descriptors above

LO1
Assessment Task Investigate the best way to grow crystals from a saturated solution of alum
Criteria Learner must: ✓ Devise his/her own method to grow the crystals ✓ Set up and carry out the procedure, for example 1. Make a saturated solution 2. Grow alum crystals by evaporating some of the solution 3. Tie the alum crystal onto a thread and suspend it in the solution to grow bigger 4. Patiently see the process through to its successful conclusion.

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Working in the environment

Looking after plants and animals, cleaning up the school grounds, making compost, growing food gardens, going on field trips and outings in the environment, etc

Descriptors that apply to working in the environment

- Relevant to the topic – show correct understanding of the science knowledge and concepts
- Shows empathy for plants and animals
- Shows interest in growing plants and caring for them
- Cares for animals or keeps pets, etc
- Takes initiative in caring for living plants and animals in the environment eg feeds birds, rescues animals, etc
- Enjoys being part of the natural environment
- Shows concern about threats to plants and animals and environment
- Notices and records natural phenomena
- Is keen to participate in solving social issues to improve the local environment, as well as the provincial, national and international environments
- Is keen to raise awareness about plants, animals, and the environment
- Is keen to co-opt other people into caring for plants and animals and the environment

Examples of contextualised criteria developed from descriptors above

LO1
Assessment Task Think of many ways to attract birds to your school garden. Write these ideas on a mind map. Show at least two ideas on the mind map that you could investigate further to see which would attract the most birds. Write down how you would do these investigations to find out which is the best way to attract birds. You can write your plans of action in point form.
Criteria Learners must: ✓ Produce a mind map of feasible ideas for attracting birds to the school garden ✓ Show the two ideas on the mind map that would be possible to investigate further in the school time. (eg provide different types of food in a bird feeder or put bird feeders in different places) ✓ Write a method in point form showing the sequence of steps in each investigation.

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Speaking

Telling, singing, oral reports, discussions, explanations, describing a process, dialogues, role play, speeches, debates, etc

Descriptors that apply to speaking

- Relevant to the topic – show correct understanding of the science knowledge and concepts
- Speaks audibly
- Speaks freely / openly / spontaneously (in the language of choice)
- Makes sense
- Speaks logically
- Uses keywords (in English)
- Uses eye contact
- Uses dialect of the community
- Uses body language / expressions
- Presentation
- Creativity/initiative

Etc

Examples of contextualised criteria developed from descriptors above

LO1
Assessment Task Investigate the best way to make dirty water clean again. Explain the steps you used to make the water clean again.
Criteria ✓ Speak clearly, audibly and must make sense ✓ Explain the method of making water clean (Explain all the steps correctly and in detail) ✓ Use relevant key words such as: dirty, clean, filter, solute, solvent ✓ Use eye contact and relevant gestures.

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Models

Making or constructing things from different materials, etc

Descriptors that apply to models

- Relevant to the topic – show correct understanding of the science knowledge and concepts
- Represents the object
- Scale/proportion
- Labels (in English)
- Colour
- Key
- Explanations (paragraph)
- According to specifications (e.g. size, materials, etc)
- Cost effective
- Creativity/initiative
- Environmentally friendly
- User friendly
- Own effort
- Presentation

Etc

Examples of contextualised criteria developed from descriptors above

LO2
Assessment Task Describe the Earth by making a model of the Earth showing the continents, the oceans and the air. Colour the water and the land in different colours and label them. Label any other features that you think are important.
Criteria Learners must be able to describe the Earth in terms of a labelled model. The model must have the following features ✓ The Earth must be a sphere ✓ The continents and oceans must be more or less in the correct position ✓ The continents and oceans must be labelled correctly as well as other features chosen by the learner ✓ The land and water must be coloured differently ✓ Only biodegradable waste materials can be used (eg paper) ✓ The model must show that the learner has made an individual effort.

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Forms of assessment

Different forms of assessment are recommended for each of the different Learning Areas. The following forms of assessment are recommended for the Natural Sciences.

Aspects to be assessed	Description	Links with Learning Outcomes	Special notes
Investigations and projects	• Full investigation (10 notional hours) eg Comparing the heat given out by 3 different fuels • Testing the boiling points of different solutions • Counting and classifying the number of plants and animals at your home • Making observations of the Moon over a month, etc. • Research projects.	Mainly the following skills • Planning • Gathering and manipulating data • Analysing data • Problem solving • Communicating results • Managing and using resources.	One full investigation should require learners to solve problems and make decisions. The other should cover a national priority and reflect values and attitudes. A short investigation should address a local environmental problem. The research project should focus on the scientific investigative process.
Assignments	Assignments are short written problem-solving exercises with clear guidelines and a specific length e.g Researching information from any source: What medicines come from plants, and how they are used in medicine? Finding out about dinosaurs and comparing how they differ from present day reptiles, etc.	Focus is on: • Information processing skills • Problem-solving • Communicating • Applications • Comprehension • Ethics • Impact of science • Managing and utilising resources.	Activities are ongoing and can be assessed in a formative way. Problems are identified and plans of action to address them are formulated.
Tests and examinations	Tests should be standardised (all learners write the same test at the same time).	Focus is on: • Knowledge • Comprehension • Application • Synthesis • Evaluation.	An examination can replace at least one of the tests. One of the tests should be of a practical nature. Assessment is criterion-referenced.
Presentations and performances	Examples include oral and written presentations, debates, demonstrations, etc.	Focus is on: • Communicating • Analysing • Synthesising • Evaluating.	Best assessed over a period of time as part of other forms of assessment.
Translation tasks	Work supplied in one form is presented in another form e.g. work given in the form of a table, picture of words, etc is presented in another form such as a graph, diagram or drawing, etc.	Focus is on: • Process skills • Analysing data • Predicting • Designing experiments.	Best assessed over a period of time as part of other forms of assessment.

Source: Western Cape Primary Science Programme (PSP). (2007).Tools for Planning your Natural Sciences Curriculum. Pages 60 -78.

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APPENDIX AA: SAMPLE ASSESSMENT TASK

Assessment task

Teacher .... **Learning Area/s** Natural Sciences

Name of learner .... **Grade and class** 6

Focus strand Planet Earth and Beyond

Date .... **LO/s** 2 **AS/s** 1, 2, 3

Topic/Title of task: Igneous, sedimentary and metamorphic rocks

Instructions

1. *Look at the examples/pictures of different rocks. Sort them into igneous, sedimentary and metamorphic rocks. Then complete the table below.*

Questions	**Igneous Rocks**	**Sedimentary Rocks**	**Metamorphic Rocks**
Draw and label examples			
Write: *What do they look like?*			
Write: *How are they made?*			

2. *What would you still like to know about rocks? Write at least three questions that you still have about rocks.*

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Example continued

3. Look at the picture of the rock cycle. Write the labels in the correct places.

Labels:

River
Lake
River delta
River estuary
Magma (molten rocks)
Volcano making igneous rock
Mountains made of rock
Rain causing weathering
Sediment washing down in the river to the sea
Sediment deposited on the flood plain
Land
Seashore
Land under the sea
Sediments deposited under the sea in layers to make sedimentary rock.
Some sediments are melting and bending to make metamorphic rock

To earn 80% or more

Write to explain what is happening in the rock cycle and how the different kinds of rocks are made.

Learners with barriers:

1. Draw the pictures of the different kinds of rock
2. Make labels to tell something about each one
3. Teacher provides the information in the table and learners sort it into the correct column in the table.
4. Information for the table for learners with barriers. Information to be supplied by teacher.

Questions	Igneous Rocks	Sedimentary Rocks	Metamorphic Rocks
Draw and label examples	Pumice and granite	Sandstone and coal	Marble, slate and gemstones
What do they look like?	They have small crystals in them. Pumice is grey and feels light. Granite is black and grey mottled.	They have layers (strata). Sandstone is rough and coal is black.	They are very hard, smooth, shiny or glassy.
How are they made?	Made from molten rock that is pushed up into the crust or through volcanoes onto the surface of the Earth.	By weathering of the rocks. The pieces and particles are washed into rivers and into the sea and deposited in layers. Layers are squashed over time.	By bending and heating igneous and sedimentary rocks deep in the Earth's crust

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Assessment tool

Name of learner .... **Grade** 6

Learning Area/s Natural Sciences **Focus strand** Planet Earth and Beyond

Assessor .... **LO/s** 2 **AS/s** 1, 2, 3 **Date** ....

Assessment task *Naming, describing and sorting rocks.* *Interpreting a diagram of the rock cycle* *Writing about the rock cycle*	**Y/N** *(tick if done, cross if not done)*
Assessment criteria ***AS 1 and 2*** *The learners must be able to:* • *Correctly describe information in a table about each kind of rock.* • *Correctly describe at least two distinguishing features of each rock type.* • *Correctly describe in a table how each rock type is made (igneous from molten rock, sedimentary from weathering and deposition, metamorphic rocks form from heat and bending and squeezing of rocks in the Earth's crust.)* • *Write three appropriate questions that they still have about rocks.* ***AS 3*** • *Learners write the given labels on the diagram of the rock cycle.* **Learners with barriers** ***AS 1 and 2*** • *Learners draw examples of igneous, sedimentary and metamorphic rocks. Teacher helps learners to write correct headings and labels to describe rocks correctly. (Colour, textures, etc.)* • *Learners sort the given information from the table into the correct column in the table.* **To earn 80% or more** • *Learners write and draw a correct description of the rock cycle.* • *The writing follows a logical sequence.* • *Learners use the key words correctly when describing the processes in the rock cycle.*	
Reporting Code	**1/2/3/4**
Comments	

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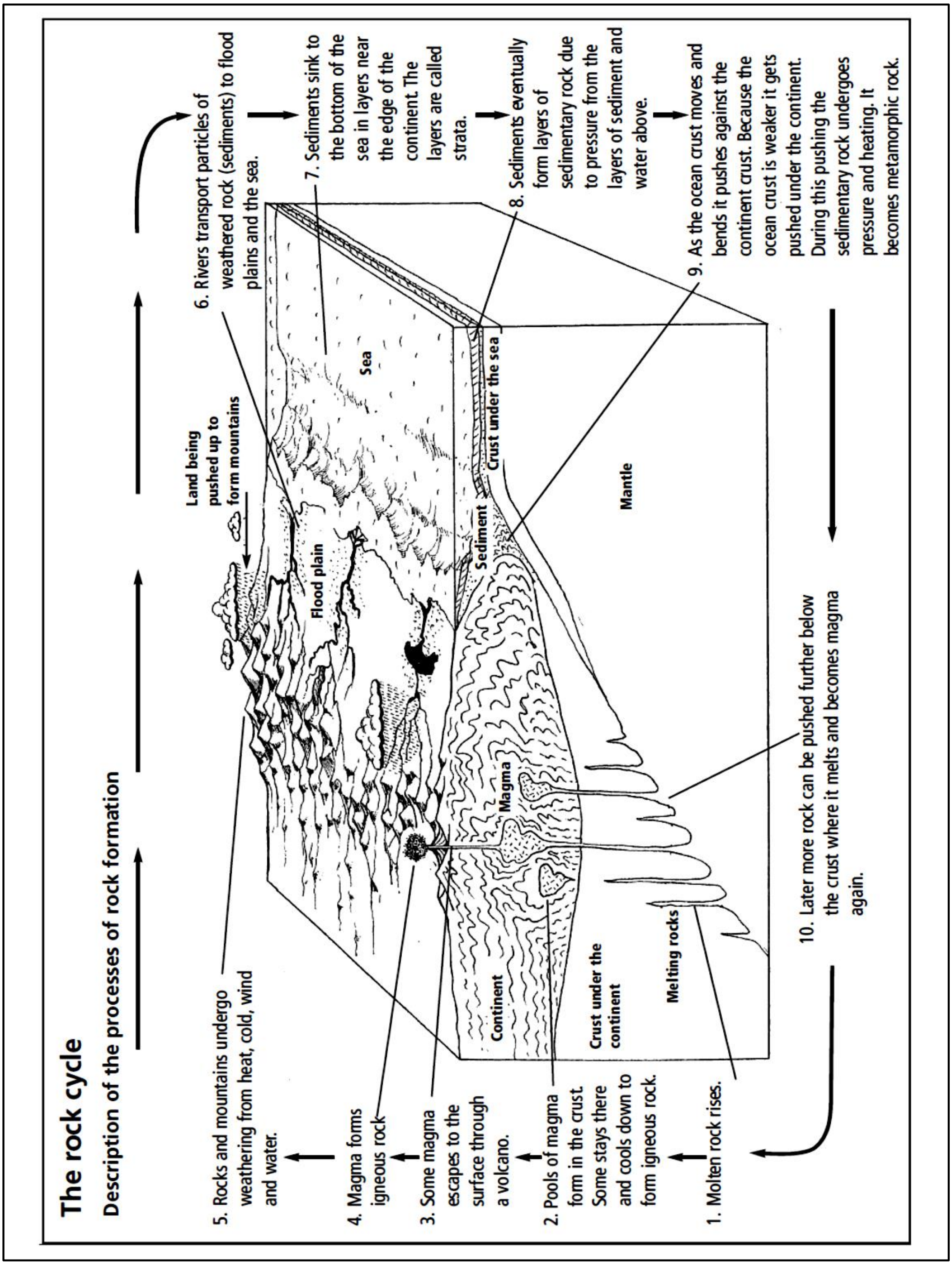

Source: Western Cape Primary Science Programme (PSP). (2007).Tools for Planning your Natural Sciences Curriculum. Pages 60 -78.

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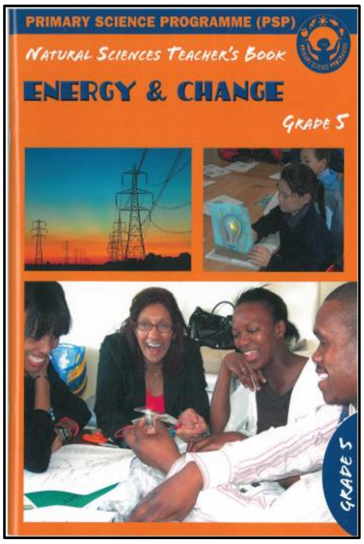
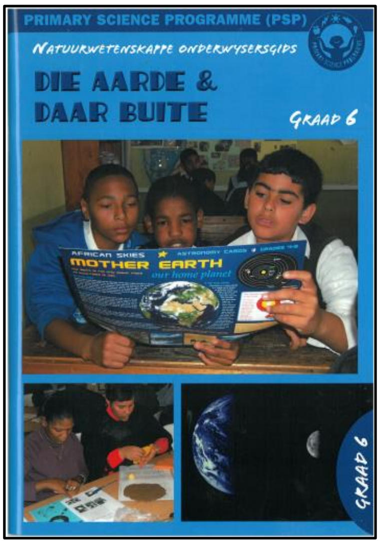
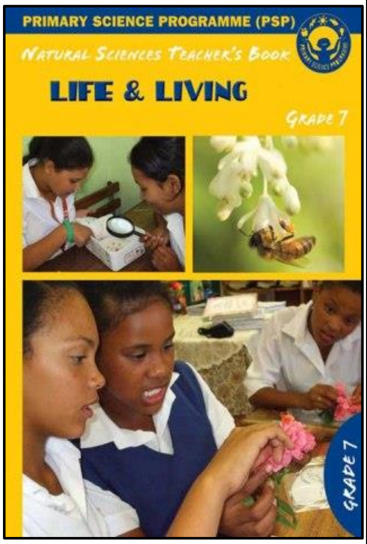
APPENDIX BB: PSP SCIENCE FOCUSED BOOKS







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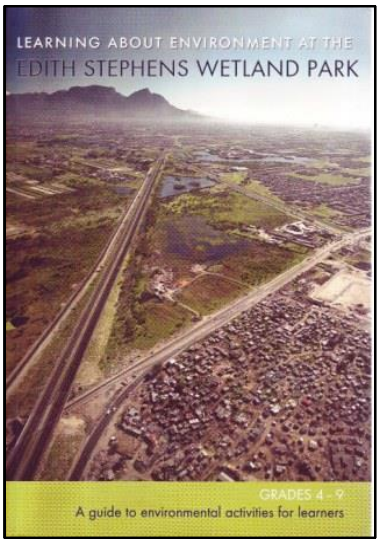
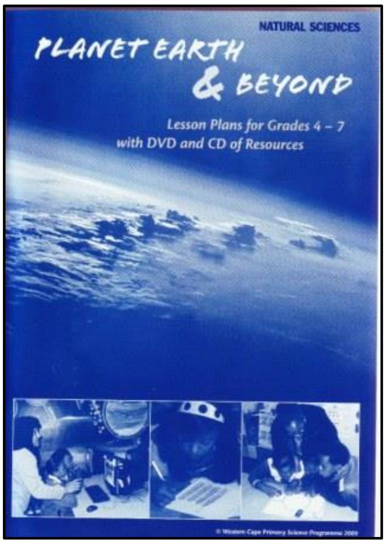
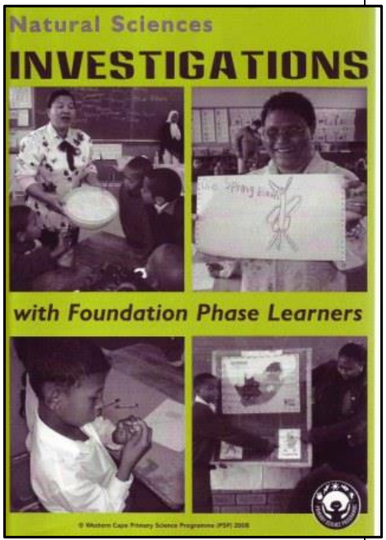
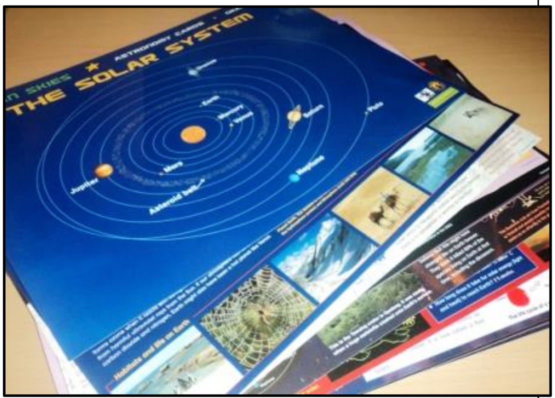
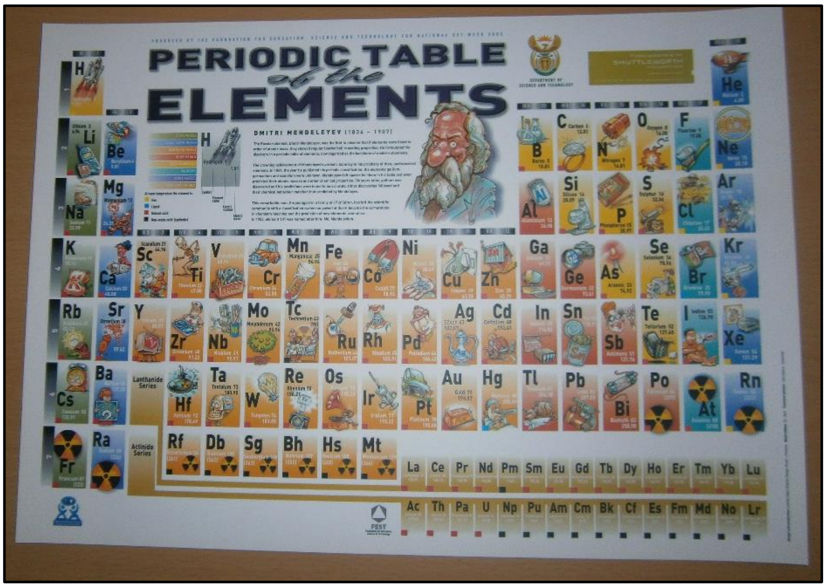
APPENDIX CC: ADDITIONAL RESOURCES DEVELOPED BY THE PSP











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Materials Development at the PSP

Over the years the PSP has developed a wide range of resource materials for teachers and classroom innovation. During 2008 the PSP sold 2105 materials items.

During 2008 the following materials were published:

- The PSP re-developed the Indigenous Plant and Animal Cards with a new Teacher's Guide in partnership with the City of Cape Town. This set of 32 Plant and 62 Animal cards provides a range of information in an aesthetically pleasing, accessible and interesting way. The Teachers' Guide contains a unique glossary in three languages (English, isiXhosa and Afrikaans).
- Population for Grades 5 & 6
  This booklet provides interesting practical activities as it deals with population distribution and density in the world, why people live where they do, leading to various activities in map work.
- Planet Earth & Beyond Grade 4
  This booklet has been revised to include assessment of the Learning Outcomes and astronomy activities. It has been translated into Afrikaans, and we hope to have an isiXhosa translation soon.
- Investigations in Natural Sciences
  This popular booklet reflects nine successful science investigations in the Foundation Phase. It has been translated into Afrikaans – Natuurwetenskappe Ondersoeke – and will be available in isiXhosa later this year.
- Getting Foundation Phase Learners Writing
  This booklet has been revised and republished.

Source: PSP Annual Report, 2008:5.

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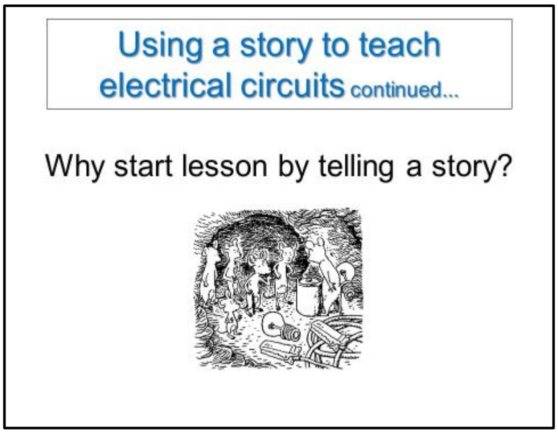
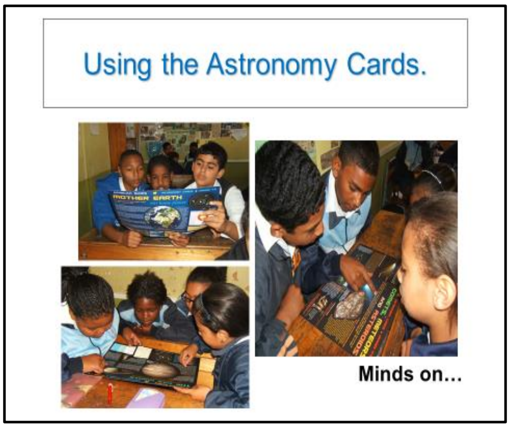
APPENDIX DD: CLUSTER PROJECT CONFERENCE

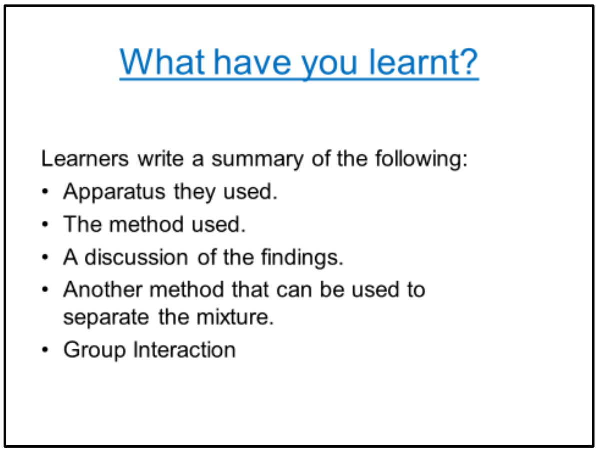
1. Teaching about circuits in the Intermediate Phase



2. Using the PSP Astronomy Cards in lessons



3. Separating mixtures in Grade 7



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APPENDIX EE: IMPORTANT ASPECTS OF THE CLUSTER PROJECT SCHOOLS

(Detail compiled from the WCED website, 2014)

Schools	Region	Number of Learners	Number of Classrooms	Section 21	Medium of Instruction	Science Lab	Computer	Library	Specialist Rooms
1.	Witzenberg	963	28	Yes	Afrikaans	1	1	1	
2.	Witzenberg	87	6	Yes	Afrikaans		1		
3.	Witzenberg	275	7	Yes	Afrikaans		1	1	
4.	Witzenberg	289	7	Yes	Afrikaans		1	1	
5.	Witzenberg	238	8	Yes	Afrikaans		1		
6.	Breede Valley	144	5	Yes	Afrikaans		1	1	
7.	Breede Valley	82	3	Yes	Afrikaans				
8.	Breede Valley	828	22	Yes	Afrikaans	1	1	1	
9.	Breede Valley	698	24	Yes	Afrikaans		1	1	
10.	Langeberg	**22**	4	No	Afrikaans				
11.	Steenberg	887	84	Yes	Afr / Eng	1	2	1	2
12.	New Crossroads	673	29	No	IsiXhosa / Eng		1		
13.	Retreat	490	22	No	Afr / Eng		1	1	
14.	Grassy Park	549	16	Yes	English	1	1	1	2
15.	Tafelsig, Mitchells' Plain	956	27	No	Afr / Eng		1	2	
16.	Eastridge, Mitchells' Plain	1,167	40	Yes	Afr / Eng	1	1	1	
17.	Maitland	374	19	Yes	Afr / Eng		1	1	1
18.	Langa	**1,677**	29	Yes	IsiXhosa / Eng		2		
19.	Kensington	973	27	Yes	English		1		
20.	Athlone	492	18	Yes	English		1	1	
21.	Manenberg	809	28	Yes	Afr / Eng	1	1	1	
22.	Manenberg	956	27	Yes	Afr / Eng		1		
23.	Surrey Estate	859	32	Yes	English		1	1	
24.	Bishop Lavis	545	15	No	Afrikaans		1	1	
25.	Elsies River	1,037	33	Yes	Afr / Eng		1		
26.	Delft	1,301	30	No	Afr / Eng / isiXhosa		1	1	
27.	Delft	1,292	31	No	Afr / Eng / isiXhosa		1		

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28.	Delft	1,445	50	No	Afr / Eng / isiXhosa		1		
29.	Delft	1,367	35	Yes	Afr / Eng		1		
30.	Delft	865	24	No	Afr / Eng / isiXhosa		1		
31.	Mfuleni	1,451	28	No	isiXhosa/ Eng		1	1	
32.	Khayelitsha	1,066	31	No	isiXhosa/ Eng		1		
33.	Khayelitsha	909	23	No	isiXhosa/ Eng		1	1	
34.	Khayelitsha	1,215	34	No	isiXhosa/ Eng		1	1	3
35.	Khayelitsha	796	26	Yes	isiXhosa/ Eng		1	1	
36.	Khayelitsha	884	28	No	isiXhosa/ Eng		1	1	
37.	Lwandle, Strand	1,357	34	Yes	isiXhosa/ Eng		1		

(English: Eng.; Afrikaans: Afr)

APPENDIX FF: SCHOOLS AND CONTEXT

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APPENDIX GG: A TEACHER'S DILEMMA

(Included with permission from the Western Cape Primary Science Programme (PSP))

WHAT MUST I DO? …

I am a teacher…have been for 20 odd years. I teach at a XXX school, not far from XXX. We live in a community where alcohol and drug abuse, gangsters, and child headed families are an ongoing acceptable part of everyday life.

I have 45 learners in my grade 4 class. I love them all dearly and just want the best for them. I have a reading corner and a nature table in my very overcrowded class. But my problem is that 15 of my learners are at grade 1 level, 9 at grade 2 level, 4 at grade 3 level and only 6 are on the right level of grade 4.

I need to teach, teachers are expected to teach…but where do I start….at what level do I pitch my lesson? If I pitch at grade 4 level (which I should) 41 learners would not cope! If I pitch at grade 1 level, 30 learners would find it too easy. I have a dilemma. In the public's eye, I am a teacher and we are responsible for our youth and their learning, and the public is always criticizing teachers for not doing their work properly. But do the public know what kinds of dilemmas we have in our classes, that we have **grade 4 learners charged with murdering an elderly person absent from school because they have to appear in court**, that 12 of my learners will never be able to read or write properly, that the overwhelming look on my learners' faces is that of foetal alcohol syndrome.

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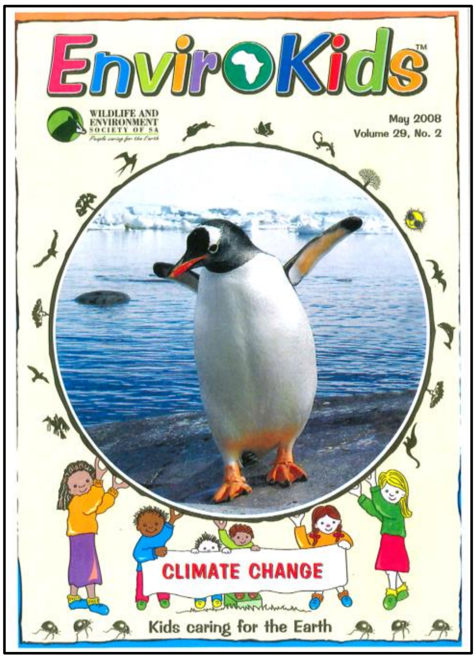
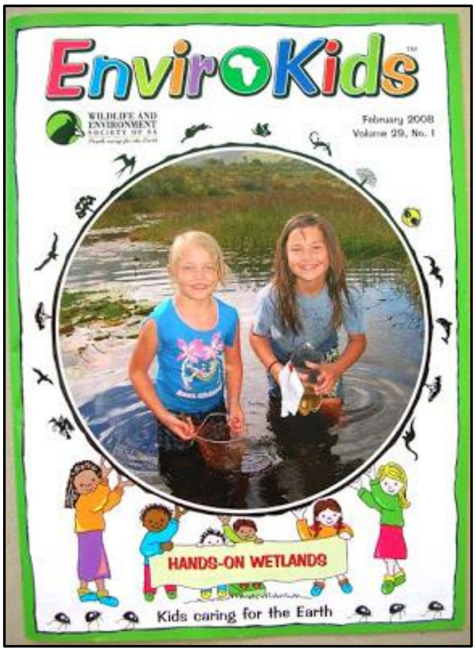
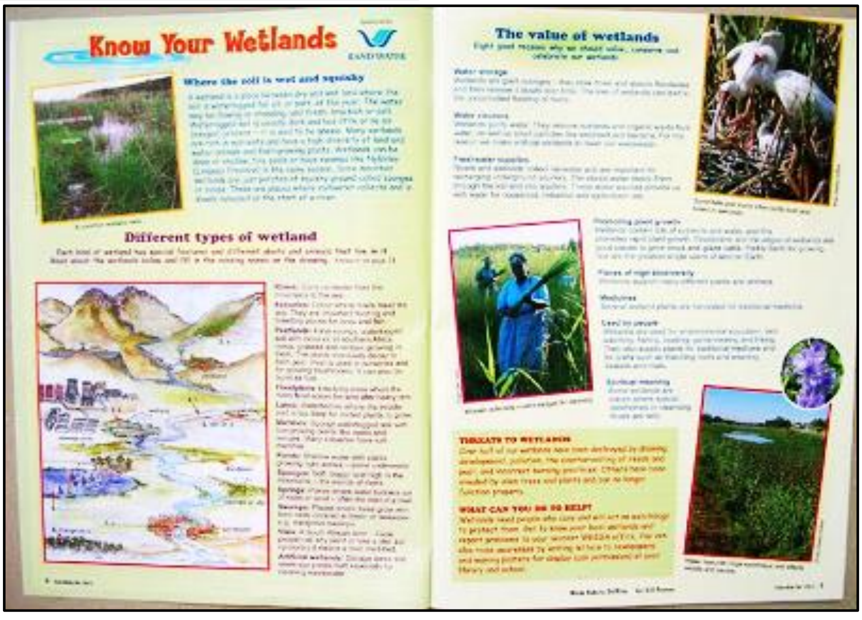
APPENDIX HH: ENVIROKIDS







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Guidelines on integrating the EnviroKids resource provided to teachers:

ENVIROKIDS - OCEANS AND CLIMATE CHANGE

p.3 : Comprehension / Reading with understanding- The importance of our oceans.

p.4+5 : Read for facts and write a summary on how CLIMATE CHANGE affects our oceans.

p.8+9 : Read and make a mind map of how the changing oceans will influence people's lives.

p.10+11: Read the information, then design a colourful poster about sharks and rays.

p.12 : Find out and list how climate change affects the shells of sea creatures.

p.13 : Find the sms number you can use to check whether fish served in a restaurant comes from sustainable fisheries.

p.14 : Read the comic for information and write a paragraph about the coelacanth.

p.16+17: Read the story 'Saving Seabirds' and write a story about how you saved an animal.

p.18+19: Read the story 'Kingsley Holgate' and list the places he visited. Also, draw a map and show the location of places.

p.20 : Colour the picture and make a marine mural, add more pictures of sea creatures.

p.22 : Read about Mopane Intermediate School and list all their environmental projects.

p.23 : Read the page and explain how you will do your bit for the environment. Give feedback to your classmates.

p.24 : Read 'Saving penguin chicks', and make a poster to advertise SANCOBB.

Describe the work of the organization, where it can be found and how we can help them.

p.25 : Choose any marine animal, make a colourful drawing and write a short poem about it.

p.26 : Enlarge the picture. Make a mural. Learners can add more drawings and/or paste pictures.

p. 27 : Do the word search. Learners can write their own sentences using the words in the list.

p.28+29: Choose one activity and let the learners do it practically in class.

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APPENDIX II: QUESTIONNAIRES / TEST SAMPLES

1. Cluster Project Evaluation

Project Outcome Two: Teachers improve their concept knowledge.

Certain questions in the pre- and post – tests are designed to evaluate teachers' concept knowledge.

1. Concept knowledge: Planet Earth & Beyond

Explain what you know about the Solar System and the movement and light of the heavenly bodies. Use labelled drawings to strengthen your explanation.

2. Concept knowledge: Matter & Materials

Explain what you know about the particles of matter in solids, liquids and gases. Use labelled drawings to strengthen your explanation.

3. Concept knowledge: Life & Living

Explain what you know about photosynthesis and its importance for all life on Earth. Use labelled drawings to strengthen your explanation.

4. Concept knowledge: Energy & Change

Explain what you know about energy, forms of energy and the sustainability of our energy sources. Use labelled drawings to strengthen your explanation.

*****

2. Natural Sciences Course for Intermediate Phase Educators: Pre / Post-test: Life & Living — Total 35 marks

1. Explain what you know about photosynthesis and its importance for the survival for all life on Earth. You can use labelled drawings and examples to strengthen your explanation. (15)

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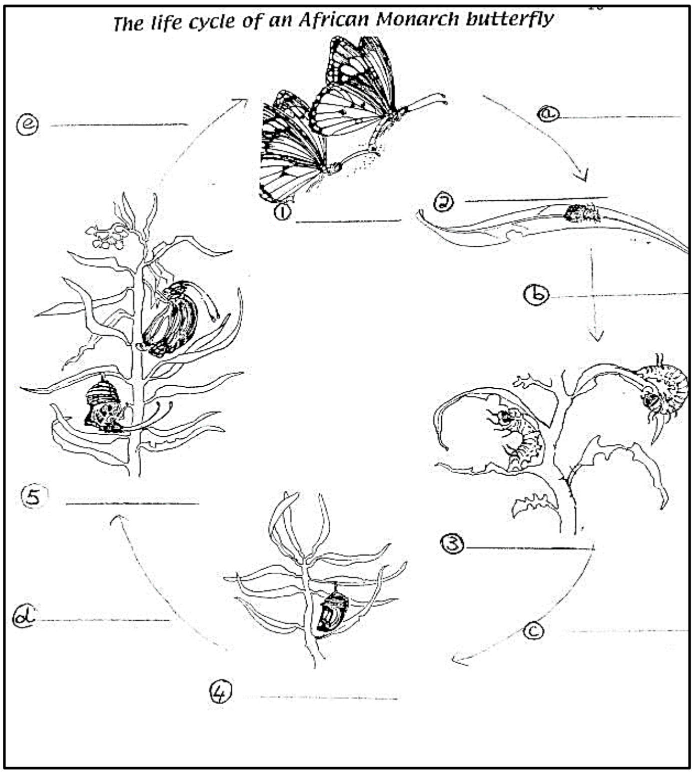
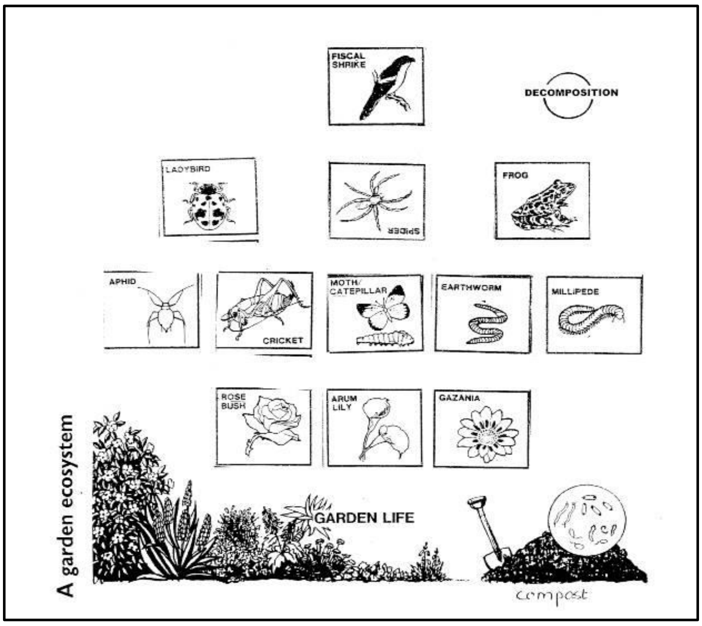
2. Life Cycles (10)

On the diagram of the life cycle label the following:
Each stage in the life cycle (1-5)
The different processes that take place as the insect develops from one stage to another (a-e)



3. Food Webs (5)

a) On the diagram of the food web draw arrows to show what each organism feeds on.
b) Explain why we use arrows and what the arrows represent.
c) Indicate which organisms are producers and which are consumers (primary, secondary and tertiary).



4. Reproduction (3)

Explain what we mean by asexual (vegetative) reproduction.

____

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5. The Skeleton. Explain why it is important for an animal to have a skeleton. (2)

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3. Natuurwetenskappe-kursus vir opvoeders Intermediêre Fase: Toets

Konsep kennis: Energie en verandering 35 punte

1. Energie

Verduidelik wat jy weet van energie, die vorms van energie and die volhoubaarheid van ons energiebronne. Jy kan tekeninge met byskrifte maak en voorbeelde gebruik om jou verduideliking te versterk.

(15)

2. Energie oordrag sisteme

- Verduidelik wat bedoel word met ‘n sisteem (2)
- Gee twee voorbeelde van energie oordag sisteme. (2)
- Waarom het ons energie oordag sisteme nodig? (2)
- Verduidelik wat ‘n elektriese stroombaan is. (2)

3. Teken ‘n diagram met byskrifte van ‘n elektriese stroombaan waar ‘n gloeilampie, elektriese draad en ‘n sel gebruik word. Maak gebruik van pyltjies om die vloei van die stroombaan aan te dui.

(4)

4. Klimaatsverandering en volhoubare ontwikkeling

Wat verstaan jy onder die term aardverhitting? (2)

5. Verduidelik hoe klimaatsverandering en aardverwarming mekaar beinvloed. (4)

6. Verduidelik waarom daar besorgheid is oor die invloed wat bio-brandstof op voedselsekuriteite kan he. (2)

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APPENDIX JJ: SCHOOL VISIT REPORT

REPORT: SCHOOL VISIT

NAME OF SCHOOL: ……………………………… FACILITATOR: ………………………

FOCUS STRAND: …………………………………………..

DATE OF VISIT: (1ST; 2ND; 3RD; 4TH) term: ……………………………………………………

WORKSESSION: ………………………………………………………………………………

1. ATTENDANCE:
2. BRIEF COMMENT:
3. HIGHLIGHTS:
4. CONCERNS:
5. ANECDOTES:
6. NUMBER OF TEACHERS VISITED: ………..; NOT VISITED: ………………

TEACHER	**GRADE**	**NUMBER OF LEANERS**	**TOPIC**	**SUPPORT**	**COMMENT**

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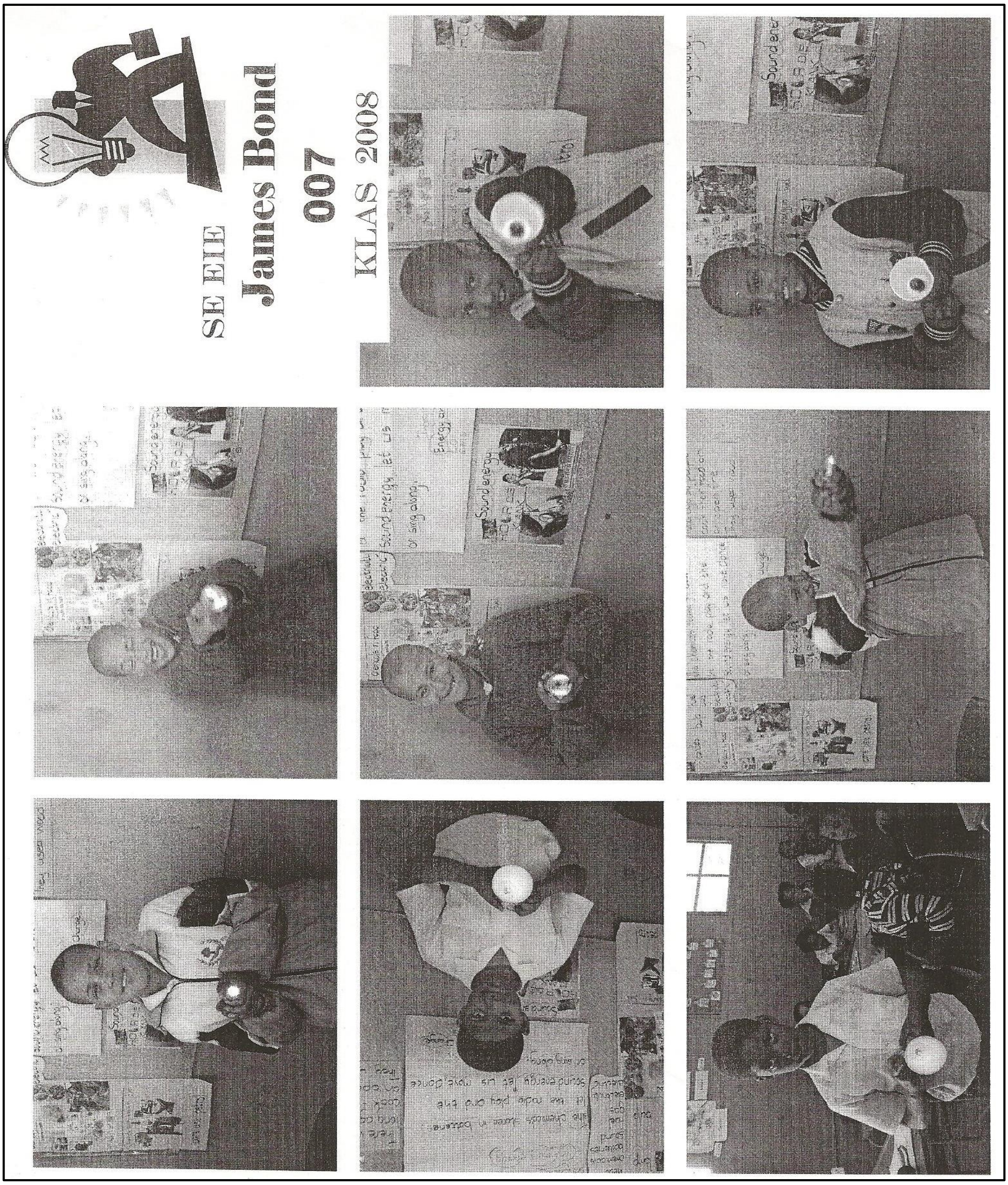
APPENDIX KK: TORCHES MADE BY LEARNERS



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APPENDIX LL: GUIDING QUESTIONS FOR PRACTICAL SCIENCE CLASSROOM ACTIVITIES

Reviewing science practical activities

- What are the main science concepts and content being addressed in the activity?
- Where are the topics located in the Natural Sciences curriculum? (Phase, Grade, Natural Sciences / Technology strand)
- How useful is the activity / strategy for achieving the learning objectives?
- How can the teaching activity / strategy be adapted for different contexts?
- How might children respond to the activity?
- What questions might leaners ask? What questions might the teacher ask to guide thinking?
- What other activities / strategies might achieve or be even better for achieving the learning objectives?
- What difficulties might teachers and learners encounter?
- What activities / strategies can be suggested for these challenges?
- How should the science concepts and content be assessed? What form should the assessment take? How would you design the assessment task? What are the criteria for assessment?
- What are the links between the issue / topic (s) and the real-world?

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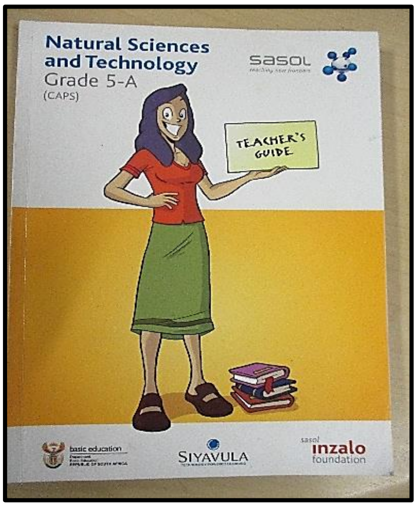
APPENDIX MM: SASOL INZALO SPONSORED NATURAL SCIENCES LEARNER WORKBOOKS DEVELOPED BY SIYAVULA, AND WCED TEACHERS' GUIDES & WORK SCHEDULES

Natural Sciences and Technology

Intermediate Phase: Grade 4, 5 & 6



WCED Teachers' Guides & Work Schedules

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	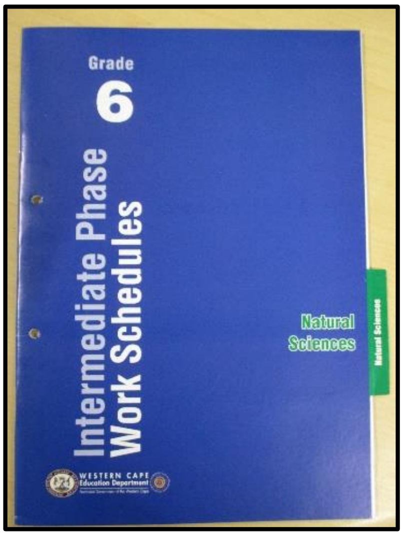

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APPENDIX NN: NEW VOICES IN SCIENCE

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FEATURE

by Zorina Dharsey

Making **primary school science** an experience, regardless

There's a buzz of excitement in the classroom. Shining, inquisitive eyes focus on the teacher as she is about to begin the lesson. The Grade 3 learners listen with rapt attention to her instructions. They pair off and collect their 'science apparatus': a set of 1,5 volt batteries, small light bulbs and connecting wires.

The learners have to connect all of these in such a way that the bulbs light up. Their small fingers work together excitedly, testing different possibilities. Excitement builds.

Suddenly, there's a great whoop of delight.

First one pair of learners, then another, manages to get the bulbs to

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The children in this class have just experienced the joy of scientific discovery. Learning through experience becomes a lesson for life.

glow. Others peep over their shoulders to see how it was all done. Instructions fly to and fro across the classroom. There's total amazement and wonder on their faces. The occasional 'wow' escapes from their lips.

The children in this class have just experienced the joy of scientific discovery. Learning through experience becomes a lesson for life.

Teaching science

It should be possible for all teachers to provide their learners with similar educational experiences, regardless. However, teaching science in disadvantaged primary schools can be a daunting task. Many South African teachers lack a basic knowledge and understanding of important science concepts. The outdated practice of reading aloud from text books or asking learners to copy sections of text from the board is still common. Teachers also feel that a lack of basic science equipment restricts their ability to use more practical teaching methods.

This is a very disturbing situation. Educational researchers have found that practical science learning experiences foster the kind of thinking and reasoning needed in science. Child development experts confirm that an experiential approach is more appropriate for young children, and can help them to build a sound knowledge of science and its processes.

The Primary Science Programme (PSP) in Philippi in the Western Cape is a teacher development organisation. It is committed to supporting educators to teach science well, regardless of the challenges they may encounter in their schools.

The PSP encourages a 'hands on, minds on, words on' approach to teaching primary science. The experience of doing science promotes deeper reflection. Throughout, conversations to draw out the science in the experience are encouraged. This can be done through questions such as "What do we know?", "What would we like to know?", "How can we find out?" and "What have we learnt?"

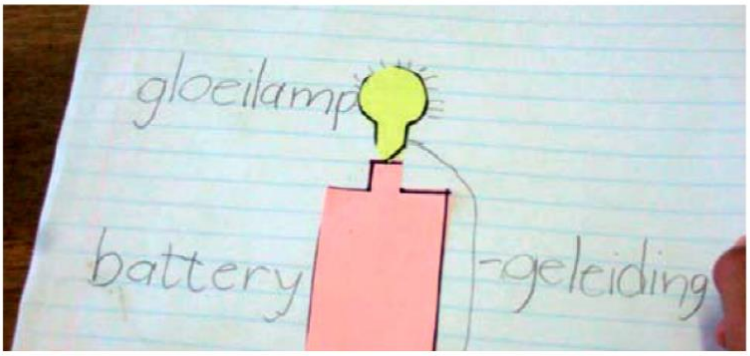
Practical science remains a challenge without the necessary resources and equipment. To overcome this challenge, teachers are encouraged to use waste material creatively and innovatively while staying true to the science concepts being taught.

The experience of practical science helps educators to understand that good science teaching does not depend on expensive equipment, but rather on a sound knowledge of basic science concepts. This must be combined with a measure of creativity about instructional materials, activities, and strategies for effective science teaching and learning.

From household waste to science equipment

The Primary Science Programme (PSP) encourages teachers to use waste material creatively and innovatively when they teach science. Household waste can become handy science apparatus. Different sized plastic bottles, for instance, can be used in a variety of ways in the classrooms, for instance as containers or measuring apparatus. Some are used to temporarily house insects for observation, while others are trimmed and used to germinate seeds and growing plants in. A plastic bottle can quite easily become an earthwormery, a filter funnel, a beaker, a rain gauge, a sand filter or even a test tube.

For more information, visit www.psp.org.za



Zorina Dharsey (zorinad@mweb.co.za) is the director of the Primary Science Project. She is completing her PhD in curriculum studies in the Faculty of Education and uses PSP's support of primary science education and continuing teacher development as a case study.