

**INTEGRATED TEACHING STRATEGIES MODEL FOR IMPROVED
SCIENTIFIC LITERACY IN SECOND-LANGUAGE LEARNERS**

by

MARY GRACE FLORES VILLANUEVA

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PROMOTER: PROFESSOR PAUL WEBB

DEPARTMENT OF ACADEMIC ADMINISTRATION
EXAMINATION SECTION
SUMMERSTARND NORTH CAMPUS
PO Box 77000
Nelson Mandela Metropolitan University
Port Elizabeth
6013



Enquiries: Postgraduate Examination Officer

DECLARATION BY CANDIDATE

NAME: Mary Grace Flores Villanueva

STUDENT NUMBER: 204035708

QUALIFICATION: Doctoris Philosophae Educationis

TITLE OF PROJECT: Integrated Teaching Strategies Model for Improved Scientific Literacy in Second-Language Learners

DECLARATION:

In accordance with Rule G4.6.3, I hereby declare that the above-mentioned treatise/ dissertation/ thesis is my own work and that it has not previously been submitted for assessment to another University or for another qualification.

SIGNATURE: _____

DATE: _____

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ABSTRACT

The importance of a scientifically literate society is currently acknowledged both internationally and South Africa. The notion of scientific literacy in South Africa has emerged largely due to the government's recognition of the role that science and technology plays in economic growth, employment creation, social redress and social development. However, in light of South Africa's learner performance on international and national assessments such as TIMMS (2003) and PIRLS (2006), as well as the problems of teaching and learning in a second language, there appears to be a primary and pressing need to develop learners' fundamental sense of scientific literacy (Norris & Phillips, 2003). Expanding learners' ability to read, write and communicate in science may provide the necessary framework for engaging learners in the critical principles and foundations of the scientific endeavour (Hand, Prain, & Yore, 2001). As such, this study focuses on equipping and training grade six and seven science teachers to develop scientifically literate learners via professional development workshops with a strategy that supports reading, writing, talking and conducting ('doing') science through scientific investigations.

The typology of triangulation and the mixed method research approach was supported by a fully mixed, concurrent, and equal status design (Leech & Onwuegbuzi, 2007). Quantitative data were collected from the baseline and post-intervention testing of learners' problem solving skills, as well as their literacy skills in English and isiXhosa. Qualitative measures were generated through classroom observations, teacher interviews and learners' science notebooks. The study was conducted in two different milieus in the Eastern Cape, South Africa. The first setting, in the rural area of Tyumie Valley near the Hogsback

Mountains, was comprised of a sample of grade six and seven (multi-grade classrooms) teachers (n=7) and learners (n=168) from five experimental schools and two comparison schools. The second setting, in the urban townships area east of Port Elizabeth, was comprised of a sample of grade six teachers (n=8) and learners (n=675) from six experimental schools and two comparison schools. Mean differences between the experimental and the comparison groups were computed for the Raven's Standard Progressive Matrices (RSPM) and the literacy tests, and the data generated were treated with an Analysis of Covariance (ANCOVA).

The data suggest that the scientific literacy strategy improved the experimental learners' problem solving skills. Both experimental groups demonstrated greater gains than that of the comparison schools. However, statistically significant improvements were only detected in Port Elizabeth. Improvements in learners' literacy skills in isiXhosa and English varied according to each milieu. While the teachers initially identified challenges to learners' reading and writing abilities, the analysis of learners' science notebooks suggested that they used writings to support their investigations. Some teachers cited difficulties with certain aspects of the model, such as problems with developing an investigable question and argumentation, yet overall, teachers found the strategy useful for developing learners' language skills, as well for strengthening their pedagogical practices in science. Teachers' gradual improvements in the use of the model suggest that they were able to use the scientific literacy strategy to support the cognitive and linguistic development of second-language learners.

Key Words: Scientific literacy; English language learning (ELL); professional development; literacy; reading-to-learn science; writing-to-learn science; classroom discussion; argumentation; scientific investigations; inquiry-based teaching

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CHAPTER ONE

INTRODUCTION AND OVERVIEW

1. INTRODUCTION

Over the past twenty years, the notion of scientific literacy and its importance to technological societies has been a topic of academic and political research (Bybee, 1986; English, 2002; Fensham, 2008; Human Sciences Research Council [HSRC], 2005a; Hurd, 1998; Jegede & Kyle, 2007; Marharjan & Whittle, 2000; Organisation for Economic Co-operation and Development [OECD], 2003; Tinker, 1997; United Nations Educational, Science and Cultural Organisation [UNESCO], 1999). The OECD offers a comprehensive definition of scientific literacy as:

An individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science related issues, understanding of the characteristic features of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material, intellectual and cultural environments.

(OECD, 2003, p. 12)

Other literature and discourses suggests that to be scientifically literate implies an ability to apply scientific content and process skills to life, work, culture and society, and civic responsibility when making decisions that affect personal and political well-being (Department of Education [DoE], 2002; Fensham, 2002; Hazen & Trefil, 1991). While there has been a multitude of descriptions of what scientific literacy is and what it should 'do', a growing body of research is emerging which addresses pedagogical strategies and philosophical perspectives on how to incorporate the ideas of a scientifically literate society

to school science curricula. Researchers such as Yore and Treagust (2006) caution that curricula which stress human, social and political development place less emphasis on learners' cognitive tools and communication abilities in science. This argument is based on the contention that individuals who are able to make informed and sound decisions on scientific issues require the communication and cognitive skills necessary to read and interpret newspaper articles, understand radio and television commentaries, or construct letters to community leaders.

Recently a number of science education researchers have argued that science curricula which focuses on content and memorisation should be challenged with curricula which aims at addressing scientific literacy and empowering people to be fluent in the discourses of science, i.e. reading, writing and talking science (England, Huber, Nesbit, Rogers & Webb, 2007; Hand, Prain, Lawrence & Yore, 1999; Powell, 2006; Yore & Treagust, 2006; Yore, Pimm & Tuan, 2007). Norris and Philips (2003) contend that, by strengthening learners' fundamental sense of science, such as their ability to read, write and communicate, the overarching goals of understanding the 'big picture' of science, or the derived sense of science, will be achieved. Furthermore, if students are to participate and employ scientific 'habits of mind' in a wide range of social contexts, communication abilities should be further practiced in debates, discussions and the application of scientific concepts to provide effective argumentation, clarify relationships between claims, evidence and warrants (Hurd, 1998; Osborne, Erduran, Simon, Monk & 2001; Webb, Williams, & Meiring, 2008).

It is in the light of the above statements and arguments that this research study on the effects of a strategy on developing scientific literacy is framed, in terms of both teachers' ability to use the approach, as well as its effects on learner problem solving, science, and general literacy abilities.

2. BACKGROUND AND PROBLEM STATEMENT

Over the last 15 years poor performance in South African education, particularly in science and mathematics, has been documented in academic research (Christie, Butler & Potterton, 2007; Fleisch, 2008; Taylor & Vinjevold, 1999), government and NGO reports (HSRC, 2005a; HSRC, 2005b), as well as in the popular press (Finweek, 2008; Mail & Guardian, 2008). Statistics illustrate that, between 1999 and 2004, an average of 4,4% of grade 12 learners achieved mathematics passes adequate for gaining entry into natural sciences at university level (Mail & Guardian, 2008). The findings of the Third International Mathematics and Science Study in 1998, and the Trends in Mathematics and Science Study in 2003 (both referred to as TIMSS), revealed that of the 50 participating countries, South African grade 8 learners were the lowest scoring performers in almost all test items in mathematics and science, well below international benchmarks.

A national survey of performance also showed that nearly one-third of the learners in grade 3 did not achieve the required standard in numeracy (Long & Zimmerman, 2009). In addition, the required standard in literacy was met by less than half of the students (Finweek, 2008). More recently, the Progress in International Reading Literacy Study (PIRLS) 2006 indicated that South African learners in Grades 4 and 5 did not have the literacy competencies required for the successful transition to reading-to-learn in the Intermediate Phase (Zimmerman, Howie & du Toit, 2008). The dismal results of international assessments such as TIMMS and PIRLS suggest that South African learners lack the skills and competencies required to address the economic and human development strategies of the nation and recognises that the fundamental challenge to advancing science education is in improving the quality of the science teachers being produced, as well as the development of in-service teachers.

Research has shown that, in general, South African teachers appear unable to communicate attitudes of curiosity, respect for evidence, and critical reflection necessary for the development of higher-order cognitive skills (Taylor & Vinjevold, 1999). It has also been noted that in the early years of schooling pupils' listening, speaking, reading and writing skills were poorly developed in both their first language and in English (Alidou, Boly, Brock-Utne, Diallo, Heugh, & Wolff, 2006).

As further progress at school depends on these basic literacy skills, the majority of black South African children, who generally come from disadvantaged homes, are further handicapped by the practices prevalent in their classrooms (Taylor & Vinjevold, 1999). Other research has shown that learners' level of language competence in black schools is so poor that they are unable to read the learning material provided for them, and that the tasks and exercises they are given are often conceptually too difficult and beyond their competency (Taylor & Vinjevold, 1999). This leads to a heavy reliance on rote learning, the memorising of fact as opposed to understanding them, and makes the learners dependent on the teachers for everything they learn (Rodseth, 1995; Setati, 1998).

The South African National Curriculum Statement (NCS) attempts to address the issues of developing scientifically literate citizens through stated critical and learning area outcomes (DoE, 2002). In the natural sciences curriculum, the learning outcomes which focus on the development of process skills, the construction and application of scientific knowledge, and the appreciation of the interrelationships of science, society and the environment, were created with Freirian philosophical underpinnings of justice and equity within the education system (DoE, 2002). These outcomes are couched within the context of "[promoting] values... not only for the sake of personal development, but also to ensure that a national South African identity is built on a philosophy very different from those that

underpinned apartheid education” (DoE, 2002, p. 3). However, these policy changes have not equated to transforming science education in South Africa (Christie, Butler, & Potterton, 2007; Fleisch, 2008).

This study investigates a pedagogical strategy that attempts to address issues of poor learner and teacher performance in science education, low levels of literacy in both home languages and English, teaching and learning in a second language, and the apparent inability of teachers to communicate attitudes of curiosity, respect for evidence, and critical reflection necessary for the development of higher-order cognitive skills.

3. RESEARCH QUESTIONS

This research study focuses on equipping and training of grade 6 and 7 science teachers to develop scientifically literate students via professional development workshops on a strategy that supports reading, writing and applying (‘doing’) science through scientific investigations.

The primary question in this study is:

- *Can this integrated teaching strategies model of reading, writing, doing, and discussing science promote better scientific literacy teaching and learning in grade 6/7 classrooms?*

Secondary questions underpinning the primary question are:

- *Can teachers be developed professionally to use the strategy successfully in their science classrooms?*
- *What effect does the use of the strategy have on the way children engage in the processes and procedures required for scientific investigations?*
- *What effect does the use of the strategy have on the learners’ problem solving and general language and literacy abilities?*

4. RESEARCH DESIGN

This research study is situated within the pragmatic paradigm, which holds the position that the research question, or set of questions, should guide the researcher in choosing the most suitable methodological approaches to address the enquiry (Creswell & Plano Clark, 2007; Johnson & Onwuegbuzie, 2004; Tashakkori & Teddlie, 2003). Within the context of the study, knowledge is generated using empirical evidence and attempts to gain a deeper understanding of the social realities from which the evidence is drawn. The generation and analysis of the quantitative data places this aspect of the research within a positivistic framework, yet qualitative instruments, analysis and attempts at understanding ‘social reality’ also places this study within the interpretive paradigm. The use of both qualitative and quantitative research methods assists in providing a clearer understanding of the data (Creswell, 1994). This approach is in line with Hall and Howard’s (2008, p. 252) viewpoint, which posits that “neither approach inherently overrides the other as [value is placed on] the contributing epistemologies, theories, and methodologies equally all the time despite necessary fluctuations in the use of their quantitative or qualitative methods throughout the research process.”

As this study seeks to investigate factors which contribute to improving scientific literacy through the professional development of science teachers and the implementation of a new model, both qualitative and quantitative approaches added equally valuable and diverse perspectives to this study. The methods were conducted concurrently and the mixing of the qualitative and quantitative methods occurred during the interpretation of the data. For example, the quantitative analysis of the Raven’s Progressive Standard Matrices (RPSM) data was supplemented by rich descriptions of learner activities in the classroom. Additionally, the instruments used for the testing, classroom observations and learners’ science notebook

reflect Creswell and Plano Clark's (2007) notion of the embedded design's correlational model whereby qualitative data are rooted within a quantitative design to help explain the outcomes. The classroom observation and the science notebook instruments utilised a quantitative scale to measure performance and additional space on the instrument was provided for the researcher's qualitative descriptions and explanations, while interviews explored the participants' understandings of the process in depth.

There are, however, certain limitations when conducting such a study. The external validity of this research may be in question as the small sample of schools from the Tyumie Valley and Port Elizabeth areas cannot be considered representative of all classrooms in South Africa. Therefore, they cannot be generalised to the South African education system as a whole. This is addressed in section seven of this chapter. This research, however, may provide some insight into the factors which contribute to the successes or challenges of using an integrated teaching strategies model to improve scientific literacy. In addition, there may be a possibility that the classroom observations were not 'authentic' in the sense that the teacher may have prepared the lesson by rehearsing it with the learners prior to the formal observation. These limitations are noted, but it must also be considered that even the contrived use of the teaching strategies contribute to an understanding of the feasibility of these approaches in the types of classrooms in which this research study took place.

5. SAMPLE AND SETTING

The study was conducted in two different milieus in the Eastern Cape, South Africa. The first setting is in the rural area of Tyumie Valley near the Hogsback Mountains, approximately 250km northwest of Port Elizabeth. The second setting is in the urban townships area east of Port Elizabeth. These milieus were purposively selected in order to

investigate the science education practices in rural and township settings and to draw comparisons in terms of their teaching and learning needs, as well as strengths.

The schools in each setting were broadly matched as institutions that are from previously disadvantaged communities, and which were neither dysfunctional nor excellent. The schools were selected as a convenience sample in each area in terms of an easily accessible cluster, after which they were randomly allocated to either the experimental or comparison group. The teachers and learners from all participating schools in both milieus are isiXhosa first language speakers, while English is the language of teaching and learning in the schools. The small sample size of teachers from each milieu (n=15) made it possible to generate insightful and rich information about effective teaching strategies. A large sample of learners, namely the grade 6 and 7 from the Tyumie Valley (n=168) and grade 6 learners in Port Elizabeth (n=675) were given tests to assess their reasoning and literacy abilities before and after the interventions.

6. SCIENTIFIC LITERACY INTERVENTION

As the primary focus of the study was to assess whether the integrated teaching strategies approach could be used to improve scientific literacy in terms of the effects of the teacher professional development process, as well as the learners' problem solving, science and general literacy abilities, teacher interviews were conducted exclusively with the experimental teachers. The comparison teachers did not participate in any treatment activities and no other science or literacy programmes were offered to either the comparison or experimental teachers in this region during the time of the study. After the completion of the study, the comparison group of teachers were given all materials and apparatus provided to the experimental group and were engaged in the teacher development process.

7. DATA GATHERING INSTRUMENTS

In line with the mixed methods design, a combination of different techniques and instruments were used to address the study's questions. Five instruments, namely the *Raven's Standard Progressive Matrices (RSPM)*, *General Literacy Test*, *Scientific Literacy Observation Schedule*, *Science Notebook Checklist* and the *Scientific Literacy Interview Questions* were used in the study to more fully assess teachers' implementation of the scientific literacy strategy, as well as to evaluate the effect of the strategy on learner performance and reasoning. The RSPM test consists of graphical puzzles and is widely used in education and psychology as a test to measure the ability to reason and solve problems involving new information. As such, it is an indicator of the capacity for systematic reasoning and logical thinking (Carpenter, Just & Shell, 1990). The RSPM test was chosen as it is a well-established and reliable test of reasoning abilities and problem solving and it can be used across a range of ages. It also correlates with measures of academic achievement (Carpenter, et al., 1990). The tests appear particularly appropriate for exploring links between language practices and the non-culturally biased tradition of research in cognitive development as they correlate well with similar tests of reasoning and with measures of academic achievement (Raven, Court & Raven, 1995; Richardson, 1991; Webb & Treagust, 2006).

The literacy tests used in this study were adapted from tests used for the evaluation of Mpumalanga Primary Schools Initiative (MPSI) in South Africa. As one of the objectives of this study was to assess learners' literacy levels in both their home language (isiXhosa) and in the language of teaching and learning (English), the test is replicated in both languages. The test contains four sections to assess literacy skills, namely in reading, listening, writing and speaking. Section A assesses learners' reading comprehension skills. The listening section,

Section B, has four subsections, which assess learners' ability to answer questions, follow instructions, and complete a diagram and a table of information. Section C evaluates the learners' writing abilities and, the final section, Section D, tests their speaking skills.

The Scientific Literacy Observation Schedule is an instrument designed to measure the degree to which educators implemented various teaching strategies during their lessons. The observation rubric consists of eleven components: the use of a stimulus, exploratory talk and class discussion, investigable question, planning an investigation, doing an investigation, learner writing with science notebooks, learner reading, questioning skills, teacher feedback to learners, line of learning relating to the teacher's subject knowledge, line of learning relating to student generated ideas, and learner subject knowledge as represented by their argumentation and presentation. The instrument was developed and validated by the Faculty of Education's Centre for Educational Research, Technology and Innovation (CERTI) at the Nelson Mandela Metropolitan University.

The Science Notebook Checklist was used to assess the extent to which the work in the learners' notebooks reflected principles of scientific inquiry and investigations (Reid-Griffin, Nesbit & Rogers, 2005). This five-item checklist was used to examine the degree to which the learners' teachers had guided them to use inquiry skills, to determine the degree to which the teachers assisted learners to construct science concepts when writing about science, and to evaluate learners' procedural and conceptual knowledge in science.

Semi-structured interviews were also administered to teachers with the objective of:

- Evaluating teachers' ideas and attitudes regarding scientific literacy;
- Eliciting the type of literacy and inquiry activities which occurred in the classroom to support science learning prior to the intervention; and

- Obtaining teachers' professional feedback regarding the implementation of the scientific literacy model.

8. ETHICAL CONSIDERATIONS

Scientists have a moral obligation to search for truth and knowledge. Yet this quest should not be at the expense of the rights of individuals in society (Mouton, 2001). In keeping with the accepted professional ethics of research, the aims of the study, as well as the research design and methodologies were communicated and discussed with the principals and teachers prior to any data collection taking place. The participants' right to anonymity, including their right to refuse participation in the study, were conveyed. Individual learner consent was not elicited as the teachers and principals served *in loco parentis* for the learners at their school. All of the participants used in this study were informed volunteers and were aware that their responses would be used for this study. The right to full disclosure about the research topic and the results of the study were also guaranteed.

9. RELEVANCE OF THE STUDY

Recent research on science literacy suggests that teacher education and professional development strategies should assign a more important role to language in terms of learning and teaching science (Yore & Treagust, 2006), and a number of investigators have reported on strategies for improving reading, writing, discussing and doing science (Hand, Prain & Yore 2001; Heselden & Staples, 2002; Marlow, 2005). Furthermore, it is believed that these strategies should assist in developing the 'habits-of-mind' required to construct understandings of science, to apply these big ideas to realistic problems and issues involving science, technology society and the environment, and to inform and persuade other people to take action based on these ideas (Hand, et al., 2001). It has been noted that:

To comprehend what we are taught verbally, or what we read, or what we find out by watching a demonstration or doing an experiment, we must invent a model or explanation for it that it organises the information selected from the experience in a way that makes sense to us, that fits our logic or real world experiences, or both.

(Osborne & Wittrock, 1993)

A number of studies into science and literacy supports the notion that, if learners are given authentic investigations and opportunities to learn through various strategies, their general scientific literacy may improve. Teachers who participated in professional development workshops which focused on the use of science kits and science notebooks, and topics pertaining to the integration of literacy, science and mathematics, and graphing in science and science assessment, produced learners with higher marks for reading, writing, mathematics and science on the Colorado Student Assessment Program (CSAP) (Kuerbris & Revak, 2008). Similarly, Cervetti, Pearson, Barber, Hiebert and Bravo's (2006) research findings on literacy and inquiry-based instruction pointed to learners making significant gains when exposed to their Seeds of Science/Roots of Reading literacy-based science teaching. In their four year study of teachers' professional development and learners marks in science education, Klentschy, Garrison and Amaral (1999) found that learners who participated in a combined kit-based and writing program scored a significantly higher pass rate on the 6th Grade Writing Proficiency Assessment than those who did not participate in the district science program.

While there are several international studies on the integration of science and literacy instruction, there appears to be little, if any, South African research that outlines scientific literacy strategies that are used locally. Based on previous research that maintains improved science acquisition and application through science and literacy, this study specifically focuses on the use of a pedagogic model that supports science teaching for educators and

which enables learners to read, discuss and conduct investigations, as well as write and argue within a scientific context.

10. OUTLINE OF THE STUDY

This research study is composed of six chapters. Chapter 1 describes the rationale and framework of this study. The aim of the study is discussed, the problem is stated, the research design and methodologies used, as well as ethical issues and the relevance of the study, are outlined. Chapter 2 reviews the existing scholarship on science education, scientific literacy and the strategies used in the model, and considers definitions and interpretations of scientific literacy within an international and South African context. Language issues, policies, and the role of language in science in South Africa are addressed, as are the various theories, models and hypotheses in the field science education relating to topics of reading and writing to learn science, including discussion and exploratory talk, inquiry-based activities, and argumentation. The data and empirical findings that have been produced by previous research with respect to these topics are also discussed. In chapter 3, the paradigmatic approaches used in the study, as well as the methodology and instruments used when collecting data, are explained while the results obtained from the various data collection instruments are presented in chapter 4. The findings are discussed in chapter 5 and, finally, conclusions are drawn and recommendations are made in chapter 6.

CHAPTER TWO

THEORETICAL FRAMEWORK

1. INTRODUCTION

This chapter highlights international and domestic perspectives of scientific literacy by examining international policy documents, assessments and current research in science education. Thereafter, the varying arguments and cited definitions of scientific literacy are discussed, as are the implications these ideas have for the teaching of science at school level. The history of curricular stances to science investigations and scientific literacy in South African schools are traced and the current preparedness of educators to teach this aspect of the curriculum is interrogated.

With respect to the proposed pedagogic model for improving scientific literacy, the concepts of reading and writing in science, discussion, inquiry-based learning and argumentation are also discussed using reviewed literature. The integrated teaching strategies approach for improving scientific literacy is explained, as is the rationale behind utilising this approach for second language English learners.

2. INTERNATIONAL CRISIS IN SCIENCE EDUCATION

In response to the scientific community's pronouncement of an abating public respect and understanding of science in the 1980's, the popularisation of science has been a major focal point of reform in science curricula (Turner, 2008). Science education has attempted to provide a more holistic picture of science, thereby making science accessible to more learners, by including the nature of science, as well as science, technology and society (STS)

issues to the traditional curriculum focused on content (Millar, 2004). However, despite the attempts to improve ‘science for all’, policy-makers and educationists agree that improvements in science education have been largely unproductive (Roberts, 2007) and that education in science and technology has failed to address the societal issues of the 21st century (Fensham, 2008). The current and central themes for improving science education worldwide calls for greater focus on issues that address learners’ waning interests in science, the promotion of the scientific and technological knowledge required of citizens to make informed decisions and the inclusion of a socio-cultural or a more humane perspective to science.

2.1 Waning interests in science education

The notion that school science is too abstract, difficult, and irrelevant are familiar criticisms of science education (Millar, 2008) and researchers posit that these negative perceptions not only impact learner motivation, but it also hinders successful learning and learners’ ability to make the connection of science and mathematics as it shapes or relates to their worldview (Araujo-Jorge, 2000; Fensham, 2008; Jegede & Kyle, 2007; Keane, 2008; Kozoll & Osborne, 2004). Consequently, there has been a decline in learners who pursue careers in the sciences, as well as their value of science as a life-long interest (Fensham, 2008; OECD, 2003).

In efforts to revive an interest in science and under the umbrella of popularising science, movements such as the public understanding of science, ‘science-for-all’ and scientific literacy seek to address and de-mystify the negative connotations about education and professional careers in science. As a result, policy-makers and educationalists have made recurrent efforts to revise the science curricula and improve teaching strategies to support it (Fensham, 2008). Curricular guides and national frameworks reflected these changing

perspectives by de-emphasising content, university preparation and professional recruitment and by focusing on a heightened appreciation of science and technology, responsible citizenship, and the imperative to train a more globally competitive workforce (Turner & Sullenger, 1999).

While learners' lack of interest, negative perceptions and poor performance appear to be global challenges, developing countries or countries in transition face additional challenges to improving learner participation in science. Access to quality education and the insufficient amount of qualified educators to teach science appear to be a primary challenge in rural communities (Earnest & Treagust, 2007). Moreover, the issue of relevance of the science curriculum proves to be an additional hurdle (Kallaway, 2007; Keane, 2008). Indeed, relevance appears to be a worldwide issue. However, science - which should be used for the betterment of society - does very little to address primary issues of poverty and sickness in rural areas (Kallaway, 2007; Keane, 2008).

According to Keane's (2008) work in the South African rural Transkei, community members complained that the current science curriculum is irrelevant and the knowledge gained in school did not equate to generating income or employment. Hence, what is advocated are literacies, including scientific literacy that is easily understood, utilised on daily basis, and transferable to other settings (Bhola, 1989). Contextualised science, which is interconnected, participatory and practical, encourages authentic learning in science and contributes directly to individual and social wellbeing (Roberts, 2007; Zeidler, 2009). This supports the notion that that policy-makers and curriculum reformers should:

Ask what... ordinary people need to know about science, both as a body of established knowledge and as an approach to enquiry that will be functionally useful in their present and future lives, and will seem valuable and interesting to them as new insights about their situation as human beings.

(Millar, 2008, p. 2)

2.2 Science and quality of life

As societies are steeped in science and technological advancements, learners' interest and performance in science plays a weighty role in the development of these societies. The recognition that societies require skilled individuals to produce goods and services, and specialists such as doctors and biologists to secure and maintain health and the environment (Kerre, n.d) suggests that science education, which has traditionally focused on a selected group of students, should be extended to all students and future workers (Millar, 2008; Turner, 2008). Additionally, for industrial and economic development to occur in a socially and an environmentally sustainable way, professionals in the field of science and technology are required to serve as key decision makers. Equally as important, average citizens must have general knowledge of issues revolving around science and technological problems in order to be included in political and social decision-making (Jegede & Kyle, 2007). Millar (2008) pointedly classifies the 'decision makers' and the 'average citizens' in society as *producers* and *consumers* of science. This classification suggests that school science curricula should be re-evaluated to accommodate the different groups of learners who study science for distinct purposes (Millar, 2008).

2.3 The “humanness” perspective

Between the 1960's and the 1980's, science education curricula underwent a shift from learning science concepts and acquiring scientific knowledge to focusing on methodology and understanding what scientists do (Hodson, 1985). Underlying this focus is

the view that if learners had an understanding and appreciation of science as a human activity – whereby scientists perform specialised techniques, make decisions and provide explanations – then learners would be more inclined to think scientifically (Powell & Aram, 2007). Furthermore, it is believed that if a personal and social-oriented approach were adopted, then recruitment in the sciences would also improve (Brush, 1979; Entwistle & Duckworth, 1977). The arguments for the inclusion of social-scientific issues are still relevant in contemporary science education discourse. However, these perspectives have extended from simply recruiting more learners into the field of science to developing a full appreciation of the discipline through the integration of science content, process and methods, direct experience of science activity, appreciation for the relationships between science and society, and fostering positive attitudes towards the public understanding of science (Fensham, 2008).

As such, a broader science curriculum reflecting a balance and interconnection between education *about* science, as well as education *in* science is supported by conceptual frameworks such as the Nature of Science (NoS); Science, Technology and Society (STS); and the History and Philosophy of Science and Technology (Solomon, 1993; Solomon & Aikenhead, 1994). These frameworks are underpinned by the ideas that the process of learning science involves self-identity formation by learners (Brickhouse, 2007; Brown, Revels & Kelly, 2005; Kelly, 2007) and that science is learned in order to create and develop relationships with the world (Aikenhead, 2007). The use of topical stories or contemporary socio-scientific issues in which to frame and personalise lessons in and about science have been promoted (Millar & Osborne, 1998) as a way to teach the understandings required by laypersons in dealing with science-related issues (Ryder, 2001). Yet, detractors contend that socio-scientific instruction places greater importance on political and moral considerations

than on issues of scientific uncertainty (Zinman, 1994) or the development of substantive scientific knowledge (Donnelly, 2005).

Marrying content with the characteristics of science as a process of inquiry, knowledge production, and the interrelationship between science, technology and society (Millar, 2008; Solomon, 1993) appears to be the central challenge to the STS debate on the level of curricula reform and implementation. In addition, researchers continue to question whether the inclusion of STS has reached its aim at promoting a greater understanding or appreciation of science (Turner, 2008). STS supporters contend that ideas about science have been and will continue to be largely unsuccessful in the classroom until a philosophical shift occurs in the way in science education is viewed by policy makers and the public (Solomon, 2003). STS supporters maintain that a strong underlying philosophy of university preparation and careers in science continues to emphasise a content-rich curriculum. Further, they argue that NoS and STS perspectives, when perceived as “add-ons” to the curriculum, provide for an unrealistically extensive programme of study, which is difficult for teachers and unattractive to students (Fensham, 1997, 2002). In spite of these challenges, policy makers and the educationalists have recognised the value of the socio-scientific context and these values are reflected in science curricula worldwide (American Association for the Advancement of Science [AAAS], 1993; Australian Science Teacher Association, 2007; DoE, 2002; Levinson, 2006).

3. SCIENCE EDUCATION IN SOUTH AFRICA

The 1994 democratic elections put an end to apartheid in South Africa. However, its remnants are still pervasive throughout the nation (HSRC, 2006). Statistics indicate that, in a country of over 49 million inhabitants, 24.5% of the population is unemployed (Statistics South Africa, 2009). Additionally, South Africa has one of the highest Gini coefficients

(0.57) suggesting that the nation has one of the most unequal income distributions in the world (United Nations Development Programme [UNDP], 2007). In other words, the Gini coefficient suggests that approximately 45% of the South African population obtains only 25% of the country's income. Black South Africans are the most affected group and, as a consequence of apartheid rule, continue to be affected by inequalities in terms of employment, income and education (Reddy, Juan, Gastrow & Bantwini, 2009).

Within the past 15 years, the national government has attempted to address educational disparities through systematic curriculum reform and resource provision. Post 1994, issues of access and participation in education were addressed by developing a unified educational system, establishing a National Qualifications Framework (NQF) (a system whereby the acquisition of knowledge and skills, across varying levels, is registered and nationally recognised), and by introducing an outcomes-based curriculum. Furthermore, since 1999, the Department of Education has focused on the quality of teaching and learning and inputs at the local level (DoE, 2002). The transformative efforts also reflect the nation's economic and human development strategy, which emphasises the centrality of science and mathematics and recognises that the development of mathematical, scientific and technological skills require intervention at school level (Reddy, 2006). However, despite government's reconstructive policies and efforts to improve science and mathematics education, black South African schools still face "crippling" backlogs of resources, infrastructure and qualified teachers, all of which are necessary conditions to improve participation and achievement in science and mathematics (Reddy, 2006, p. 76).

3.1 Academic performance

There is a dire need for an improvement in science and mathematics, as proven by the poor academic results achieved in schools. Over the last 15 years, poor performance in South

African education, particularly in science and mathematics, has been documented in academic research (Christie, et al., 2007; Fleisch, 2008; Taylor & Vinjevoold, 1999), government and NGO reports (HSRC, 2005a; HSRC, 2005b), as well as in the popular press (Finweek, 2008; Mail & Guardian, 2007). Statistics illustrate that between 1999 and 2004, an average of 4,4% of grade 12 learners achieved mathematics passes adequate for gaining entry into natural sciences at university level (Kallaway, 2007). The findings of the Third International and Mathematics and Science Study in 1998, and the Trends in Mathematics and Science Study in 2003 (both referred to as TIMSS), revealed that of the 50 participating countries, South African grade 8 learners were the lowest scoring performers in almost all test items in mathematics and science, well below international benchmarks.

A national survey of performance also showed that nearly one-third of South African learners in grade 3 did not achieve the required standard in numeracy (Long & Zimmerman, 2009). In addition, the required standard in literacy was met by less than half of the students (Finweek, 2008). More recently, the Progress in International Reading Literacy Study (PIRLS) 2006 indicated that South African learners in Grades 4 and 5 did not have the literacy competencies required for the successful transition to reading-to-learn in the Intermediate Phase (Zimmerman, et al., 2008). Researchers (Kallaway, 2007; Taylor & Vinjevoold, 1999) affirm that the improvements in education must be met not only with sufficient allocation of resources, but also training to those expected to deliver educational change, namely science and mathematics teachers.

3.2 Teacher preparedness

A fundamental challenge to advancing science education in South Africa is improving the quality of the science teachers being produced, as well as developing in-service science teachers (Reddy, 2006). As a whole, primary educators lack the necessary confidence and

knowledge of science (Fensham, 2008; Taylor & Vinjevold, 1999) and the anxiety or apathy towards science amongst schoolteachers may be attributed to several key factors. Firstly, teachers, who were charged with teaching science due to staff shortages, in many cases did not seek to be specialist educators of science and were trained as generalist teachers of children (Fensham, 2008). Secondly, many teachers with a background in science finished their pre-service training without having completed aspects of science, which are central to the scientific enterprise, such as investigations (Villanueva & Webb, 2008). Finally, as learners these very teachers were taught in a traditional, rote fashion. The adage of ‘we teach as we were taught’ suggests that these teachers did not have exposure or role models of effective learner-centred teaching. As a result, the lack of science training and experience in conducting investigations, coupled with the changes to outcomes-based pedagogy, contributes to the problem of having science teachers who have minimal skills in conducting inquiry-based activities or strategies to promote them (Webb & Glover, 2004).

Research suggests that educators who lack experience, confidence and general pedagogic content knowledge will often resort to methods of expository teaching, rote learning, and avoiding classroom situations where something might go ‘wrong’ (Taylor & Vinjevold, 1999). While this traditional approach to teaching places a greater focus on the mastery of content, it places less emphasis on the development of skills, the nurturing of inquiring attitudes and conceptual understandings (Baxter, Bass, & Glaser, 2000; Maree & Fraser, 2004). Although many South African educators of previously disadvantaged communities have not had the appropriate training or experience in scientific literacy and inquiry, they are still charged with understanding and teaching the broad themes of the National Curriculum Statement’s learning outcomes of the Natural Sciences, namely Scientific Investigations, Constructing Science Knowledge and Science, Society and the Environment (Webb, 2009).

In a recent report on the Rights to Basic Education (HSRC, 2006), educators maintain that outcomes-based education (OBE), inclusive of the Natural Sciences Learning Area, cannot be successfully executed whilst many of them have not had sufficient training on the implementing the curriculum. Morrow (2005, p. 94) argues that, while “a king’s ransom” has been poured in training and re-training science, mathematics and technology education teachers in OBE, the quality of teaching still remains inadequate as a high proportion of teachers have not yet accomplished the paradigm shift required to fulfil and implement the National Curriculum. For all these reasons, the professional development of teachers becomes a vital aspect of science education.

4. LANGUAGE ISSUES IN THE SOUTH AFRICAN CONTEXT

Although quality of teaching, poverty and access to resources contribute to poor performance, fluency in English is the most significant factor in learning science and mathematics (Howie & Plomp, 2005). The current language in education policy in South Africa allows schools to select their own language of learning and teaching and, as an extension to this policy, requires schools to address the principle of additive bilingualism, which involves the maintenance of home language and access to an additional language (DoE, 1997). While these language policies were developed to promote multilingualism and to recognise the eleven official African languages of South Africa (Constitution of the Republic of South Africa, 1997), English and Afrikaans continues to dominate communication at national level and government public services (Banda, 2000; De Klerk, 2002; Probyn, Murray, Botha, Botya, Brooks, & Westphal, 2002). With regard to education, the teaching and learning materials used in South African schools are printed in English or Afrikaans. This practice is particularly problematic as these languages are not the primary languages of the majority of learners and teachers (Setati, Adler, Reed, & Bapoo, 2002).

In addition to the challenges of teaching and learning in a different language, learners in South Africa are also forced to grapple with utilising different *types* of languages each day. The casual and informal verbal communication at home or within personal social circles are unlike the instructional language that happens between teachers and peers in the classroom. Furthermore, the language of science is yet another context in which learners are challenged to use specialised language to communicate various content and process skills (England, et al., 2007). In the course of moving from informal to instructional or scientific language, learners are continually engaged in language ‘border crossing’ (Yore & Treagust, 2006). The three-language problem and border crossing exists for most science language learners, but the problem is often magnified for learners who are taught in a language, which is not their mother tongue (England, et al., 2007). For example, in the Eastern Cape, isiXhosa is the widely spoken indigenous language and home language to 83.8% of the population, yet the official medium of instruction in the majority of schools from the beginning of grade 4 (ages 9-10) to grade 12 is English (Probyn, 2004). Learners who have very little or no exposure to English are placed at a serious disadvantage when one considers that these learners have minimal opportunity to speak, read or write in a second language. Furthermore, researchers (Zimmerman, et al., 2008) stress the relationship between under-achievement and having being taught and assessed in a second or additional language.

In efforts to address issues of language and learner performance, the practice of code switching is often used in South African classrooms. The principle of the practice is to expose learners to words, concepts and ideas in English or the language of instruction, yet reinforce these ideas with the learners’ language of familiarity (Setati, et al., 2002). This practice allows learners to communicate freely and places less emotional burden if learners are not able to pronounce English words (Probyn, 2001). However, while code switching is meant to assist in strengthening learners’ language abilities and cognitive understanding,

critics warn that this practice provides little opportunity for learners to build a firm academic or cognitive foundation in their mother tongue or the additional language (Cummings, 1984; Heugh, 2000). Furthermore, a greater instructional and time-consuming burden is placed on teachers to translate materials and concepts from the official language of instruction to the language learners understand (Holmarscottir, 2003). Notwithstanding the criticisms of code switching, the practice is regarded as an important aspect of a bilingual or multilingual classroom. The practice is especially valuable, yet challenging in science classrooms in which teachers have the responsibility of moving learners from informal spoken language to formal written language and discourse specific talk (Gee, 2002).

5. SCIENTIFIC LITERACY

Declining pass rates, poor achievement scores on international assessments, as well as governments' calls for economic growth and productivity through science and technology have prompted movements to improve the scientific literacy of all learners (Turner, 2008). In an attempt to improve learners' understanding of the scientific content, method, institutional function and social impacts of science and technology, the *Science for All* slogan of the 1980's was used to suggest that science should be accessible and understood by the critical masses (Fensham, 2008). The ideological push to popularise science encouraged various initiatives to define and shape how everyday citizens and learners could understand science (Koulaidis & Dimopoulous, 2002). Some initiatives included the movement of the public understanding of science (Cross, 1999; Layton, Jenkins, Macgill, & Davey, 1993), history and philosophy of science in science education (Hodson, 1985; Matthews, 1994) and science-technology-society (STS) curricula (Bybee, 1986; Solomon & Aikenhead, 1994). The progression and transformation of these movements led to the operational phrase, *Scientific Literacy*.

5.1 Interpretations of scientific literacy

The review of literature suggests that there have been critical attempts to define and describe its meaning and that there are multiple interpretations of what constitutes scientific literacy. Brown, Reveles, and Kelly (2005) broadly categorised a number of intellectual perspectives regarding scientific literacy. These perspectives include: the ability to conceptualise phenomena and reason from a scientific epistemology (Ballenger, 1997; Warren, Ballenger, Ogonowski, Rosebery, & Hudiourt-Barnes, 2000), to construct scientific ideas and arguments consistent with those of the scientific community (Bazerman, 1988; Latour & Woolgar, 1979), to analyse and interpret evidence (Germann & Aram, 1996; Jackson, Edwards, & Berger, 1993), to participate in the social structures that guide scientific enterprise (Eisenhart, Finkel, & Marion, 1996; Roth & Lee, 2002) and to engage in the specific literacy practices that underscore scientific endeavours (Halliday & Martin, 1993; Heath, 1983; Norris & Phillips, 2003;). An amalgamation of these perspectives is reflected in the OECD's definition of scientific literacy as:

an individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues, understanding of the characteristic features of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material intellectual, and cultural environments, and willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen.

(OECD, 2006: 12)

The extensive list of what it means to be scientifically literate suggests that it has no fixed meaning and perhaps another factor which makes it difficult to attain. However, Bybee (1997) and DeBoer (2005) assert that 'scientific literacy' is, and always has been, the intrinsic goal of science education. The value of the 'scientific literacy' slogan, Bybee maintains,

rests in its ability to initiate contemporary reform and to reaffirm the purpose of science education. Literature suggests that learning science is vital for people to make connections and to understand the natural world (Powell & Arum, 2007) and also to enable citizens to become informed and participate in the public debate about science, technology and environmental issues within the society (Yore, et al.; 2007; Zeidler, 2007). The process of becoming ‘informed’ and ‘participating’, however, suggests that there are specific sets of scientific literacies required of a reflective citizen (Fensham, 2008).

According to Norris and Phillips’ (2003) there are two interrelated components of discipline-specific literacy: the *fundamental sense* and the *derived sense*. The latter involves knowing, understanding and applying content and the ‘big ideas’ of science and is dependent on the former which deals with being literate in the discourses or the abilities of speaking, reading, writing in and about science. In Table 2.1, Yore, et al. (2007) illustrates the interrelatedness of Norris and Philip’s (2003) the fundamental and derived sense of science.

Table 2.1

Interacting Senses of Scientific Literacy (from Yore, Pimm & Tuan, 2007, p. 568)

Fundamental Sense	Derived Sense
Cognitive and Metacognitive Abilities	Understanding the Big Ideas and Unifying Concepts of Science
Critical Thinking/ Plausible Reasoning	Nature of Science
Habits of Mind	Scientific Inquiry
Scientific Language Arts (reading, writing, speaking, listening, viewing and representing in science	Technological Design
Information Communication Technologies	Relationships among Science, Technology, Society, and Environment (STSE)

In terms of scientific literacy, the fundamental sense refers to the use of language in science contexts, whereas, the derived sense deals with understandings or abilities relative to science (Norris & Phillips, 2003). While there is agreement on these distinctions and the roles the fundamental and derived senses play in science education (Kelly, 2007; Yore, et al., 2007), Lerman (2007) cautions that the compartmentalisation of the fundamental and the derived senses may emulate the problematic and recurrent separation of *content* and *process in science*. The 1990's produced similar paradigmatic distinctions: the 'cognitive deficit' model which, again, stressed content and an individual's factual understanding of scientific information and principles, and the 'contextualist model' which focused on individuals' experiences, needs, expectations and cultures (Turner, 2008). The senses of science, however, are not meant to be viewed as separate and distinct. Rather, the interacting clusters (Yore, 2008) suggest a connection between the 'reflective citizen' goals of scientific literacy and the uses of written and spoken language in educational and societal settings (Norris & Philips, 2003).

5.2 Scientific literacy in the curriculum

Although the term "scientific literacy" has been used to characterise the aim of science education, there is still considerable uncertainty about its meaning and implications for the curriculum (Millar, 2006). Many science educationists and curriculum developers simply coupled content with methods courses, rather than viewing scientific literacy as a basic level of learning in science (Fensham, 2008). The existing definitions of scientific literacy commonly point to using science for personal or civic decision making (AAAS, 1993; OECD, 2003), therefore, suggesting that the basic level of science should involve teaching science that is relevant and appears in the popular domain (Solomon, 1993; Thomas & Durant, 1987; Yager, 1992). In addition to teaching within a contextualist model, school

science should prepare learners to function in society (OECD, 2003; UNESCO, 1999; Yore, et al., 2007).

Efforts to concretise this functional role of science in the curriculum have been advanced by Millar and Osborne's (1998) *Twenty First Century Science* curriculum project, which proposes that there is a "core" set of knowledge and skills of science that all members of society should attain. Their curriculum utilises contemporary socio-scientific issues as a platform to discuss ideas about science, scientific explanations, as well as scientific evidence and values. The development of rational criteria to test claims (Gott, Duggan, Roberts, & Hussain, 2008) and the meta-cognition required to generate, verify or refine knowledge (Klein, 2006; Wallace, 2004) are key to making decisions and are central to the scientific endeavour (Yore, 2008).

In addition to addressing ideas about science as it relates to civic and citizenship issues, citizens also require a broad, qualitative grasp of major conceptual themes in the physical, biological and earth-space sciences (Millar, 2006; Yore & Treagust, 2006). Yet, the question of *what content* and *how much content* is required in the curriculum is a topic of continual debate. In relation to scientific literacy, having a deep conceptual understanding is elemental to making connections and identifying the unifying concepts and themes in science such as the nature of science, scientific inquiry, as well as major science explanations. The recognition and development of a knowledge-centred perspective is necessary to realise the sociocultural-centred perspective, which considers how these literacies are relevant to particular tasks in relevant social contexts (Brown, et al., 2005; Yore & Treagust, 2006).

5.3 The language and literacy aspect of scientific literacy

A science curriculum, which focuses on content and memorisation, should be challenged with a curriculum that aims at addressing scientific literacy and empowering

people to be fluent in the discourses of science, i.e. reading, writing and talking science (England, et al., 2007; Hand, Prain, Lawrence & Yore, 1999; Powell, 2006; Yore & Treagust, 2006; Yore, et al., 2007). Norris and Philips (2003) contend that by strengthening learners' fundamental sense of science, such as their ability to read, write and communicate, the overarching goals of understanding the 'big picture' science, or the derived sense of science, will be achieved. Furthermore, if students are to participate and employ scientific 'habits of mind' in a wide range of social contexts, communication abilities should be furthered through practice in debates, discussions and the application of scientific concepts to provide effective argumentation and clarify relationships between claims, evidence and warrants (Hurd, 1998; Osborne, Erduran, Simon, Monk & 2001; Webb, Williams, & Meiring, 2008).

Inherent to these ideas, however, is how language plays a principle role in reading, writing and arguing in science. Science, as a discipline, possesses a specialised language with particular functions, yet students bring their own socio-cultural language to the science classroom (Halliday & Martin, 1993). While students often cross casual/informal, instructional and scientific language borders (Yore & Treagust, 2006), Wallace (2004) maintains that the measure for successful learning is when a child is able to use scientific language to communicate about personally meaningful science events. As a result, teachers have the responsibility to cultivate the application of scientific language to everyday experience. By providing rich scientific cultures in the classroom, students will have a need and a purpose for communicating in scientific discourses (Gee, 2002). Gee (2002) further posits that students who have difficulty communicating in academic genres may not have had sufficient experience in school to foster their authentic use of language.

There have been a number of studies into science and literacy that supports the notion that, if learners are given opportunities which incorporate language, literacy and science, their

general scientific literacy may improve. Examples of such studies include Revak and Kuerbris' (2008) professional development programme for teachers, training them in the use of science kits, science notebooks, integration of literacy, science and mathematics, graphing in science and science assessment. The results from their research indicate that educators who participated in the development programme produced learners with higher marks for reading, writing, mathematics and science on their state assessment. Similarly, Cervetti, Pearson, Bravo, & Barber (2006, p. 2) developed and implemented a curriculum that utilised literacy instruction "in the service of acquiring knowledge, skills and dispositions of inquiry based science." Their findings also signalled that learners exposed to literacy-based science teaching made significant gains compared to their control group counterparts. In Klentschy, Garrison and Amaral's (1999) four year study of teachers' professional development and learners' marks in science education, they found that learners who participated in a combined kit-based and writing program scored a significantly higher pass rate on the 6th Grade Writing Proficiency Assessment than to those who did not participate in the district science program. In addition, the results of the treatment group showed a narrowed gap between the scores of English-speaking students and the English Language Learners (ELL).

What these studies suggest is that learning science cannot be a mere transition of facts stemming from teacher-centred instruction (Crawford, 2008). Rather, it proposes that various pedagogical approaches should enable learners to develop and apply cognitive practices. The applied cognitive science framework of integrating language and science expands the habits of mind required by learners to construct scientific understandings (Cervetti, et al, 2005; Yore & Treagust, 2006; Yore, Bizanz & Hand, 2003). Furthermore, these understandings can be applied to realistic socio-cultural issues and used to inform and persuade other people to take action based on these ideas (Yore & Treagust, 2006).

5.4 Scientific literacy in the South African context

Similar to the international trends which emphasise the importance of a scientifically literate society, the notion of scientific literacy in South Africa has emerged largely due to the government's acknowledgement of the role that science and technology plays in economic growth, employment creation, social redress and social development (Department of Arts, Culture, Science and Technology, 1996). While natural resources and agriculture has traditionally been pillars of the country's economy, the Department of Science and Technology's Ten Year Plan for South Africa (2008-2018) outlines the shift from a resource-based economy towards the development of a knowledge-based economy that "must help solve society's deep and pressing socioeconomic challenges" (Department of Science and Technology, 2007, p. 1). Explicit in the plan is the increased development of human capital in higher education and careers in science and technology. Yet, one of the greatest challenges to the plan is the fact that South Africa currently has a shortage of qualified and skilled people in science and technology to consolidate such a knowledge-based economy (Reddy, et al., 2009).

The growth of a skilled and educated workforce is highly dependent on the quality of science instruction and the development of scientifically literate learners at the school level. The South African Department of Education (DoE, 2002) asserts that the underpinning philosophy of Natural Science Learning Area is to promote scientific literacy through the development and use of science process skills, the development and application of scientific knowledge and understanding, and the appreciation of the relationships and responsibilities between science, society and the environment (DoE, 2002). These learning outcomes appear to mirror prevailing definitions about what it means to be 'scientifically literate' insofar as developing enquiry skills, content knowledge, as well as values and attitudes in science.

However, in practice, the South African approach to the curriculum reveals a stronger emphasis on integrating science and incorporating the experiences of different groups, as opposed to understanding science concepts and knowing basic facts (Reddy, 2006). The focus on socio-scientific perspectives over a content-based approach may be an attempt at offering the greater population a more functional approach to scientific literacy (Kallaway, 2007; Keane, 2008; Roberts, 2007). Yet, in light of South Africa's learner performance on assessments such as TIMMS (2003) and PIRLS (2006), as well as the problems of teaching and learning in a second language, there appears to be a primary and pressing need to develop learners' fundamental sense of science. Expanding learners' ability to read, write and communicate in science may provide the necessary framework for engaging learners in the derived sense of scientific literacy (Webb, 2009).

6. SCIENTIFIC LITERACY STRATEGY USED IN THIS STUDY

In South Africa, science and mathematics teachers face the double challenge of working within the instructional framework of English while their learners are still developing their skills in this language (Setati, et al., 2002). As a result, learners' reading, listening, speaking and writing skills in both their first language and English is usually poor (Mayaba & Webb, 2009). Research into educating second language learners affirms that teachers are required to define language and content objectives, as well as plan activities, which are experiential, hands-on, collaborative/cooperative, context embedded and cognitively engaging (Cummins, 1981; Met, 1998). As such, an integrated teaching strategies approach was developed for the dual purposes of providing a pedagogic model for science teachers to implement in their classrooms and to promote learners' scientific literacy in the fundamental sense. The strategy used in this study synthesises various pedagogical approaches such as reading, writing, talking and arguing in science, as well as the 'doing'

aspect of conducting investigations, and is underpinned by various theoretical positions, which suggest that:

- 1) Pedagogical practices, relating to science and literacy, can be used to develop and scaffold learners ideas (Cervetti, et al., 2006; Hand, Wallace, Yang, 2004; Hand, et al., 1999);
- 2) Language is a powerful tool for developing science knowledge and understandings (Halliday & Martin, 1993; Mortimer & Scott, 2003; Yore, 2008);
- 3) Metacognitive knowledge is essential to become effective science learners (Klein, 2006; Yore, et al., 2007; Wallace, 2004)

The following figures illustrate the conceptual frameworks used in this study. Figure 2.1 represents the strategy used in this study in its most basic form. The strategy begins with the premise that learners read content specific literature to foster ideas about the topic while improving language through written text. The ideas gained through the reading encourage learners to discuss and ask questions; thus prompting an investigation to test and answer these questions. Through the process of reading learners' may gain a deeper understanding of the content and relevant terms, while writing assists them to organise their understandings. Furthermore, the process of argumentation allows learners to share their knowledge in a structure that requires evidence, backings and warrants to support claims. As a result, the integrated teaching strategies approach is used to assess learners' ability to read, write, discuss and communicate their conceptual and procedural understandings in science.

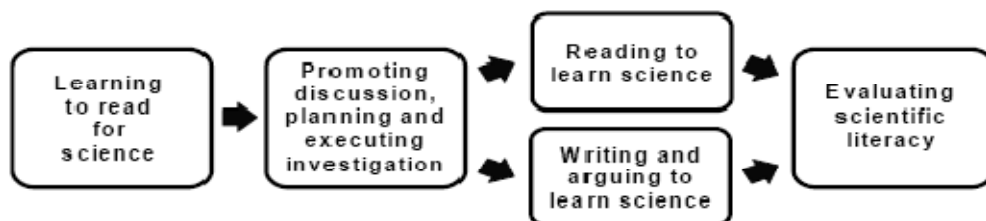


Figure 2.1 Simplified representation of the scientific literacy strategy used in this study

Figure 2.2 depicts an expanded view of the integrated teaching strategies approach to include pedagogical and assessment practices. In this model, specific activities are related to each component of the strategy. For example, in the line of learning, teachers may bridge the ideas and words generated by learners during investigations to the scientific community's accepted views and vocabulary of the target concept. The new knowledge that is gained is applied to new contexts and may prompt new questions. Activities in the line of learning may be achieved through teacher-lead discussions, demonstrations and additional reading.

The underlying assumption in this Figure, as well as in Figures 2.1 and 2.3, is the idea that learners are engaged in “doing” or constructing their understanding through reading, writing, talking and participating in investigations. Learners are active in these processes, and teachers are therefore able to formally or informally assess learners' ability to construct an investigable question through the process in which they answer their questions and through the line of learning. This formative process of assessment is helpful for both learners and teachers. Teachers are able to identify “gaps” or misconceptions in learners' understanding, thus re-evaluating their pedagogical approaches. Learners, on the other hand, can identify areas which require additional attention and where they should revise their understanding. Finally, through formalised communication, such as writing reports or presentations to a specified audience, teachers can summatively assess whether learners were able to meet the proposed outcomes of the lesson or learning strand.

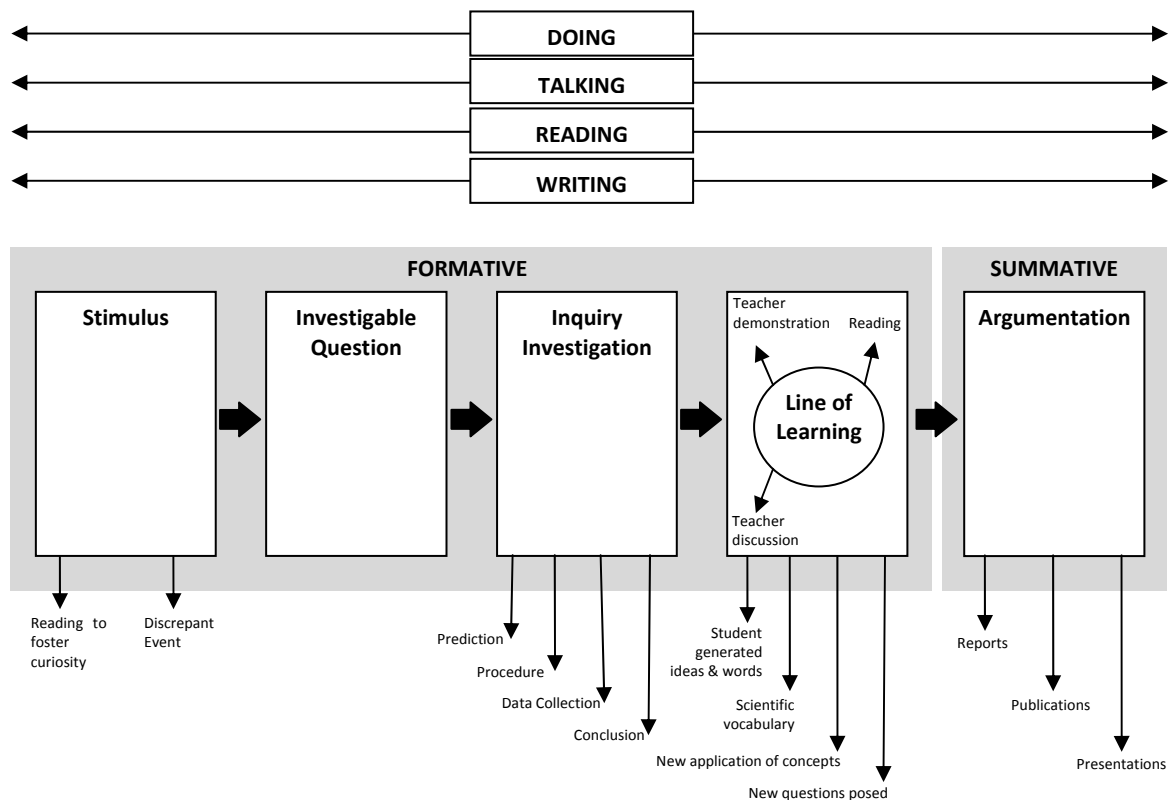


Figure 2.2 Pedagogical and assessment strategies approaches associated with the scientific literacy strategy

Figure 2.3 highlights topics relating to the professional development of teachers. Researchers suggest that teachers' ability to think within a model is central to improving teachers' thinking and acting in class (West & Staub, 2003; Duit, Komorek & Müller, 2004). In light of this statement, Figure 2.3 recognises that there are key instructional practices in which teachers must develop and engage in order to teach science effectively. Learners' ability to develop their fundamental and derived senses of literacy is dependent on teachers' awareness of second-language issues and techniques; reading, writing and discussion strategies; methods for promoting inquiry and argumentation; as well as effective questioning, assessment and feedback practices.

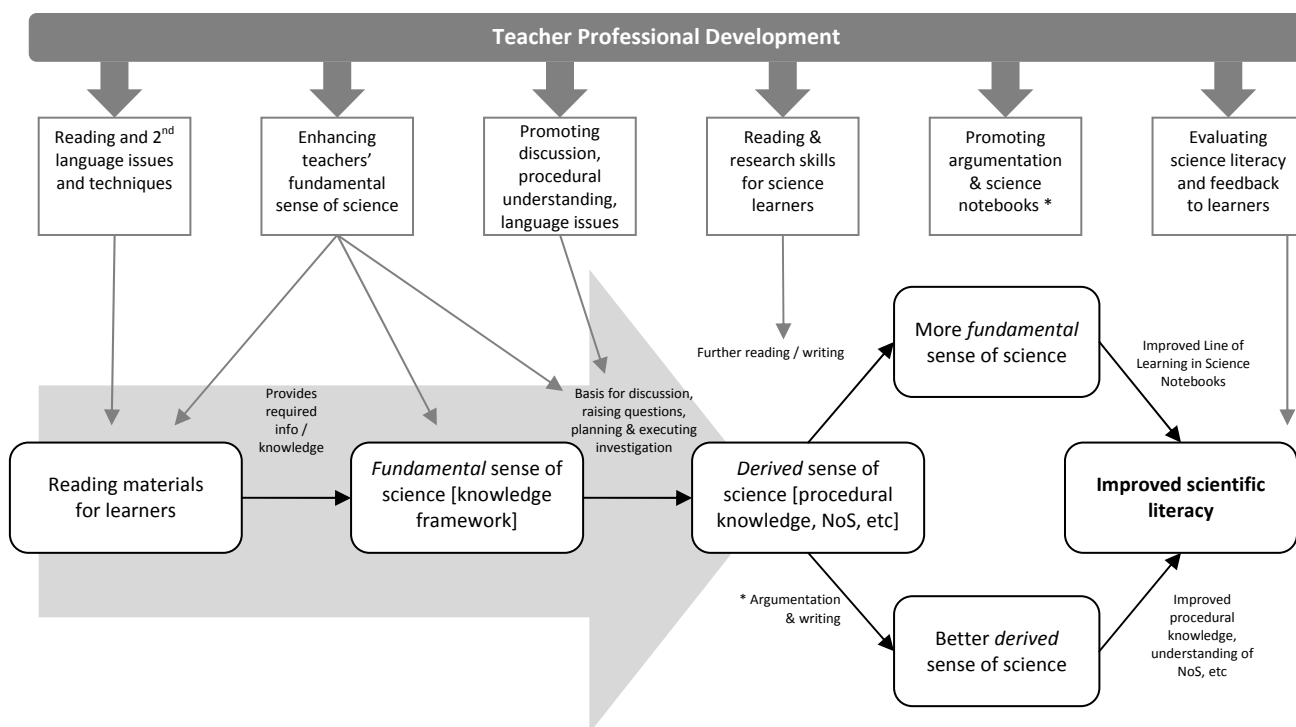


Figure 2.3 Issues related to the professional development of teachers in relation to the scientific literacy strategy

With respect to general science education, researchers such as Duit, Gropengießer and Kattmann (2005, p. 2) contend that there is an imbalance between “science orientation and orientation on the students’ needs, interests, ideas and learning processes.” Therefore, the strategy used in this study attempts to address these issues based on a number of theoretical perspectives.

6.1 Scaffolding scientific understandings through science and literacy

Functional literacy has become a prominent aspect of defining the role of scientific literacy in science classrooms. If one of the goals of scientific literacy involves civic engagement, then a dimension of that construct includes understanding basic scientific vocabulary to be able to comprehend scientific media coverage (Brossard & Shanahan,

2006). While Brossard and Shanahan (2006) analysed and identified scientific terms which people would be frequently exposed to in the media, Norris and Phillips' (2003) notion is inclusive of scientific vocabulary and posits that the development and use of scientific terms in the discourses of science is also crucial for the "understandings or abilities relative to science" (Sadler, 2007, p. 55). The focus on the literacy aspect reflects not only Norris and Phillip's (2003) idea of developing the fundamental sense of science, but also mirrors Halliday's (1994) critical ideas regarding the development of meaning through systems of literacy, such as communication and social interactions, as well as within written text. This interactive approach allows readers to make sense of text and writers to build knowledge while they produce text (Keys, 1997; Ruddell & Unrau, 1994; Yore, 2000; Yore & Treagust, 2006).

6.1.1 Reading and writing in science

Despite the growing research advocating this expanded view of scientific literacy in the fundamental sense (Norris & Phillips, 2003), Sadler (2007) suggests that teachers often equate reading in science to simple text decoding. Fiction, non-fiction or picture books are generally used to enhance learners' content knowledge and process skills in science (Sackes, Trundle & Flevares, 2009). However, Powell and Aram (2007) suggest that educators are sceptical about including language instruction in science as the focus might shift from science to basic literacy or reading class. This is often the case in many South African classrooms where academic instruction differs from home language of the learners (Probyn, 2001). In this situation, the teachers' are still focused on decoding printed language, translating print into sounds, and teaching alphabetic principles associated with sound-symbol relationships (Lerner, 2003). As a result, less emphasis is placed on constructing meaning from text (Bloch, 1999). However, that the successful decoding of text does not automatically imply

that reading comprehension has been achieved (Pretorius, 2002). As such, an interactive approach, which recognises the dynamic construction between texts and the readers' interpretation of it, has been promoted as a way to address the dichotomy of learning to read phonetically and for reading comprehension (Macaro, 2003). Furthermore, the interactive approach to reading incorporates multiple knowledge sources (Long & Zimmerman, 2008) and requires a personal frame of reference when trying to understand text (Macaro, 2003). Multiple knowledge sources can be stimulated, scaffolded and negotiated from classmates, teachers and individuals that are more expert in science (Mortimer & Scott, 2003). The negotiation of these ideas allows learners to make sense of their current experiences and prior knowledge and allows for movement between the oral, print, symbolic, visual, and physical representations of these ideas (Prain, 2006; Waldrip, Prain & Carolan, 2006).

As learners construct the meaning of text through personal experiences and a variety of learning opportunities and perspectives, the integration of reading and science can be used to expand children's scientific thinking and cognitive development (Gee, 2004; Powell & Aram, 2007; Yore, et al., 2007). Research has shown that the two disciplines of science and literacy share similar problem solving and cognitive processes, such as observing, classifying, inferring, predicting, and communicating, as indicated in Table 2.2 (Cervetti, et al., 2006; Padilla, Muth, & Lund Padilla, 1991). As a result, the use of children's literature has been promoted as effective instructional tools to teach science concepts to young children (Bricker, 2005; Castle & Needham, 2007). Despite researchers having identified various limitations to some children's science books, such as scientific misconceptions embedded in the text (Kazemek, Louisell, & Wellike, 2004), inaccurate illustrations (Trundle & Troland, 2005), fantasy (Broemmel & Rearden, 2006), and anthropomorphism (Gomez-Zweip & Straits, 2006), books, if carefully selected, have the ability to stimulate learners' curiosity and offer opportunities for inquiry (Sackes, et al., 2009). In addition, researchers contend that science

texts, including school science textbooks, are effective sources for teaching about the relationship among science concepts (Klein, 2008).

Table 2.2

Illustrations of the Shared Cognitive Functions of Inquiry and Comprehension Strategies (from Cervetti, Pearson, Bravo, & Barber, 2006, p. 21)

Shared Strategy	Common Questions	Example in Science	Example in Literacy
Activating prior knowledge	What do I already know? What do I know now that I didn't know before?	Students use an anticipatory chart to monitor their growing knowledge of shoreline and the organisms that live on shorelines.	Before reading a book about earthworms, students discuss what they have learned from their hands-on observations of earthworms.
Establishing purposes/goals	Why am I reading/doing this? What am I trying to learn? What information am I seeking?	Before engaging in guided investigations of their shoreline organisms, students write about what they want to learn through their investigations.	Having investigated the effects of oil spills through a series of hands-on science activities, students discuss what they still want to know before reading the book, <i>Black Tide</i> .
Making/ reviewing predictions	What do I think is going to happen?	Students continually make, review and revise their predictions about what will happen in a worm bin – and they document the growing evidence that soil is being made.	Students make predictions about what a habitat scientist is and does before reading the book, <i>Habitat Scientists</i> ; they review and revise those predictions during and after reading.
Drawing inferences and conclusions	What does this mean? How do I explain x?	Students gather evidence from a bucket of beach sand to answer the question, "What is sand made of?"	Students use a scientist's sand journal to make inferences about the origins of sand samples.
Making connections-recognising relationships	What caused x? How are x and y related? How is x like/unlike y?	Students compare the adaptations of different isopods.	Students use a reference reader about substances to select ingredients that will help them make paint with particular properties.

While research suggests multiple pedagogical advantages to include reading in science, writing-to-learn strategies appear to have similar and associated benefits (Powell & Aram, 2007). Researchers suggest that the use of reading and writing develops the reasoning skills necessary for scientific inquiry, as well as providing an effective means to expand and assess learners' thinking and conceptual knowledge in science (Nesbit, Hargrove, & Fox, 2004). While reading has the ability to strengthen learners' acquisition of scientific concepts and vocabulary in a narrative context (Klein, 2006), the development and application of these concepts can be established through learners' writing (Cervetti, et al., 2006; Hand, et al., 2004; Hand, et al., 1999). The iterative and constitutive process of writing allows the author to construct new and richer understandings of the written topic (Hand, Hohenshell, & Prain, 2004; Hand, et al., 2004). Researchers such as Gee (2004) and Alverman (2002), however, suggest that the process of learning through writing activities is influenced by a number of factors, including learners' prior knowledge, language and representation abilities, motivation, and by sociocultural contextual factors. As a result, a number of science education researchers have proposed various pedagogical practices to support authentic and meaningful writing strategies (Galbraith, 1999; Hand, et al., 2001).

Writing in science has traditionally been characterised by either a recollection of steps and procedures associated with laboratory reports, or short, narrative, informational pieces for teachers to assess learners' knowledge about a particular topic (Yore, et al., 2003). While these writing approaches may have been useful for evaluation, simplistic writing approaches did little for elaborating and enriching classroom learning (Yore, et al., 2003). Klein (2006), however, contends that informal writing, which has properties that blend features of speech with features of science text, serves as necessary bridge between speech, writing and cognitive practices. In spite of the differing perspectives, Klein (2006), Yore, et al. (2003) and other contemporary writing-to-learn science researchers suggest that writing should be an

interactive and constructive process in which learners use their prior knowledge, negotiated meanings, and language to communicate their current understandings (Mortimer & Scott, 2003). As learners are provided with opportunities to mediate existing knowledge with new information or misconceptions, learners are able to further develop their knowledge base and demonstrate the recursive nature of writing (Hand, et al., 2001). This theoretical perspective is demonstrated in the writing-to-learn strategy of Science Notebooks.

Popularised by elementary science instruction in the United States, the science notebook strategy has been found to offer a comprehensive understanding of science concepts (Fulton & Campbell, 2003; Miller & Calfee, 2004; Mintz & Calhoun, 2004) by offering numerous opportunities to emulate and communicate conceptual and procedural understandings of inquiry-based investigations (Ruiz-Primo, Lin, & Shavelson, 2002). The science notebook strategy uses a writing heuristic, which outlines the procedural aspects of an investigation. While learners document the steps of their investigation, record their data and offer conclusions, they are also required to develop their “line of learning”, which serves as the last component of the framework. Table 2.3 provides a summary of descriptions for the seven science notebook components.

Table 2.3

Components of the science notebook framework

Component	Description
Date and time	Date and time of the investigation used for reference purposes.
Question	The key problem to be investigated. Questions may be posed by teacher or generated by learners.
Prediction	Learners make an educated guess and provide an explanation or reason to their prediction.
Procedure	All materials and steps of the investigation are recorded. The procedure gives insight to the design and fair test of the investigation, as well as its validity.
Results	Data are recorded in this section. One may check for reliability of the results. Data is communicated in graphs, tables and/or scientific drawings.
Conclusion	Learners use the results of their investigation and their scientific understandings to explain what happened in the investigation. The discussion in this section may include a comparison between learners' predications and results. Learners may use operational definitions to describe the results.
Line of Learning	Learners develop deeper understanding about the target concept. Teachers facilitate the application of the concept to new situations and the development of new vocabulary.

The line of learning denotes that learning can be extended from procedural aspects of an investigation to more substantive understandings (Gott, et al., 2008), such as the development and application of the scientific concepts and vocabulary associated with the investigation. During the line of learning, the teacher may also incorporate additional reading activities, facilitate questions and discussion, and conduct demonstrations to clarify or bridge the concepts to other themes or ideas in science (Nesbit, 2007). From a teaching perspective, science notebooks lead educators away from the unsophisticated notion of science as a process in which learners simply learn skills such as observing, inferring and hypothesising (Villanueva & Webb, 2008). Instead, it is a move towards combining process skills with scientific knowledge, reasoning and critical thinking to construct a richer understanding of

science (Bybee, 1997). While it is suggested that the science notebook strategy allows learners to engage in processes similar to scientists (Nesbit, Hargrove, Harrelson, & Maxey, 2004), the significance of the strategy lies in its effectiveness as a tool used to create other communication products such as publications, reports or oral presentations for a greater audience (Shepardson & Britsch, 1997).

6.1.2 *Inquiry-based activities*

Learning through inquiry is promoted in a number of international science curricula (OECD, 2003), including the South African national curriculum for the Natural Sciences (DoE, 2002). The main thrust of inquiry-based learning suggest that learners are able to develop testable questions and find the most appropriate way to solve problems generally relating to problems of four different types:

- 1) Problem of making (or developing inventions or improvements to solve personal or societal problems);
- 2) Problems of observing, surveying or measuring (or using predominately quantitative means to answer a question);
- 3) Problems of comparing (or testing the strengths and challenges of various items, products or even ideas); and
- 4) Problems of determining the effects of certain factors (or establishing the consequence of altering variables)

(DoE, 2002)

While various curriculum statements advocate that learners' understanding of the nature of science is best developed through participation in the scientific endeavour (Moss, 2002), many science educators are still entrenched in mechanistic models of learning (Meiring, et al., 2002). Research suggests that the concept that the scientific enterprise is a process that blends logic and imagination whilst demanding evidence to support claims, ideas

which are often overlooked in classrooms (AAAS, 1993). As such, learners develop authentic questions through stimuli such as readings, discussions or discrepant events (Meiring, et al., 2002) and they remain active participants in the planning, development, conducting and evaluation of the project and activities. It is also suggested that learners learn to formulate their own theories, become aware and take ownership of their learning process through gathering data and observing patterns in the results (Suchman, 1996). In addition, research suggests that if learners initiate questions, own their learning and are actively involved in the knowledge-seeking process, they may then be intrinsically satisfied (Suchman, 1996). While individual and social constructs have been deemed as effective teaching and learning practices in science, Ford (2007) and other researchers (Abd-El-Khalick & Akerson, 2006; Osborne, 1996) highlight the challenges of awarding learners the authority to construct knowledge as scientists do. Pedagogically, learners often generate misconceptions or incorrect accounts about their own sense of nature and, relatively, the credibility of the scientific account is questioned if learners have authority to construct their own knowledge (Ford, 2007). What Ford (2007) stresses then is the importance of teaching learners about the accountability of their claims.

An additional challenge to inquiry-based teaching and learning is developing an investigable question to initiate the investigative process. The challenge for teachers is to ask meaningful questions that are testable or investigable, as opposed to broad questions, which cannot be answered in the context of the classroom or may not be in line with the curriculum or educators' intended outcomes (England, et al., 2007). Heil, Amorose, Gurnee and Harrison (1999) suggest that questions must be guided and refined by the educator, but learners must maintain ownership of what they want to investigate.

Results from inquiry-based instruction research are generally supportive of improved attitudes in science (Shymansky, Yore & Hand, 2000) and favour the development of meaning through the manipulation of objects and artifacts (Roth & Lawless, 2002). However, Lederman and Lederman (2009) posit that learning by inquiry does not yield results that sufficiently conclude that learners' conceptual knowledge is strengthened more by inquiry than through direct instruction. They further recommend that additional research is necessary to support such claims. Nesbit, et al. (2004) assert that educators are required to play a decisive role in the development of conceptual and procedural understandings, suggesting that explicit instruction of variables and other concepts of evidence may be helpful for learners to become familiar with the procedural issues; thus strengthening their conceptual knowledge. Matthews (1994), however, cautions that learners require a prior conceptual framework to discover anything and that it is impractical to believe that learners are able to construct scientific knowledge for themselves. It is only within prior conceptual frameworks that learners can hypothesise, have a notion of whether their ideas are bold or cautious, and derive appropriate attempts to falsify their hypotheses (Webb & Glover, 2004). Furthermore, Yore, et al. (2007, p. 64) criticises an unsophisticated view of inquiry suggesting that:

Teachers are often overwhelmed with the difficult task of implementing the more interactive and unpredictable teaching methods associated with inquiry and constructivism. Implementing this type of learning involves sophisticated integration of pedagogical skills and deep content. Learning and understanding do not come to students simply by the doing of activities.

The use of inquiry in this model recognises Yore, et al.'s (2007) perspective and is aligned to the notion that learners require multifaceted personal experiences and the assistance of skilled teachers to mediate their understandings.

6.2 Language as a tool for constructing knowledge and understanding in science

Although it is widely accepted that one of the aims of education should be introducing ways in which children can use language for seeking, sharing and constructing knowledge, observational studies of classroom life reveal that this induction is rarely carried out in any systematic way (Mercer, Wegerif, & Dawes, 1995). According to researchers (Barnes & Todd, 1995; Edwards & Mercer, 1987; Sheeran & Barnes, 1991), learners' conversational interactions are often stifled due to the lack of guidance and explicit, shared understanding of the purpose of various classroom activities, and the criteria by which they are being assessed by their educators. Furthermore, learners are often confused, unfocused and unproductive in their use of language (Mercer, et al., 1995). Fullerton (1995), however, suggests that through science talk, reading and writing, learners are encouraged to make sense of their thinking and to bridge new concepts and clarify thought while also developing their scientific vocabulary. Accordingly, the development of science discourses through content-based language instruction has been promoted as an effective teaching and learning approach for all learners, but especially those who are learning through a medium of language which is not their own (Gianeli, 1991). Deborah Short describes this approach (1991, p. 1) as follows:

The integration of language and content involves the incorporation of content material into language classes, as well as the modification of language and materials in order to provide for comprehensible input to LEP (Limited English Proficiency) students in content classes. The former is often referred to as content-based language instruction; the latter can be referred to as language-sensitive content instruction. An integrated approach bridges the gap that often separates the language and content classrooms.

Douglas Barnes' (1975) seminal work *From Communication to Curriculum* introduced that there are specific kinds of 'talk' that occur in the classrooms and acknowledges the social aspects of learning and sharing information. His term 'exploratory

talk' distinguished the category of language used by learners when talking to their peers as opposed to the language or 'presentational talk' used when talking to the teacher (Edwards & Jones, 2001). Mercer's (1996) later analysis of exploratory talk represents a scaffolded model of learning whereby learners explain and justify their decisions to one another through *disputational*, *cumulative* and *exploratory* talk. Disputational and cumulative talk are characterised by disagreements between learners and the exchanges are brief, consist of assertions, and counter assertions (disputational) and by repetitions, confirmations and elaborations which build and reinforce each other's ideas, but are generally uncritical of what their peers say (cumulative), exploratory talk occurs when learners are engaged in critical and constructive discussion. Learners' ideas are discussed, challenged and alternative viewpoints are offered for consideration.

When learners are engaged in exploratory talk, decision-making is a collective process through which learners can come to a consensus about the idea. In comparison to the two previous forms of talk, in exploratory talk, knowledge is made public and therefore learners become accountable for their ideas, and reasoning becomes a more important part of the talk while progress emerges from the eventual joint agreement reached (Mercer, 1996). In this process, learners' contributions and ideas are accepted, challenged, negotiated and the group is held accountable for their assertions. Researches assert that this socio-linguistic process of exploratory talk improves group and individual reasoning in children (Webb & Treagust, 2006; Wegerif, Mercer, & Dawes, 1999).

The issue of exploratory talk is especially important in the South African context as research suggests that there is little evidence of meaningful discussion in the classrooms of schools, which were previously disadvantaged under the system of Apartheid and where both teachers and learners officially operate in their second language (Taylor & Vinjevold, 1999).

Under the Apartheid education system, the authoritarian teaching and learning environment was characterised by rote propositions that brooked no analysis or critique (Webb, 2008) and generally followed the teacher-led triadic exchange of initiation-response-evaluation, IRE (Edwards & Mercer, 1987; Mehan, 1979; Mortimer & Scott, 2003; Sinclair & Coulthard, 1975). IRE commonly refers to the teacher posing a close-ended or lower-order thinking question, to which student replies with an answer and the teacher offers feedback in a one word, or shortened response. This type of classroom environment fostered little discussion and would explain why international research has found that learners have a vague understanding of the purpose behind their classroom activities and so are often perplexed, unfocused and unproductive in their use of language (Barnes & Todd, 1995; Edwards & Mercer, 1987; Sheeran & Barnes, 1991). Educators employing IRE in their classrooms do so as a way of controlling the classroom and avoiding situations where the teacher may not know the answer (Dillon, 1994; Edwards & Mercer, 1987). This type of ‘talk’ poses challenges to the nature of science, as learners may perceive science knowledge as fixed and without room for questioning, discovery or “incorrect” answers (Lemke, 1990).

Through compromise and cooperation, learning occurs when the participants, either learner/learner or learner/teacher, negotiate meaning and a mutuality of meaning or a new hybrid meaning is constructed (Edwards & Jones, 2001). Osborne and Wittrock (1993) identified this construction of meaning through the negotiation of prior knowledge and sensory output as *generative learning*. This view respects the learners’ experiences and epistemology through multiple discourses (Bhabha, 1994) and provides opportunity for authentic learning to occur. Edwards and Jones (2001) suggest that educators are compelled to accept learners’ understandings even if they are not in line with conventional scientific authority, yet educators still have the responsibility of assisting learners in organising and interpreting their personal experiences successfully and in a manner which makes sense to the

learner (Webb & Glover, 2004). In exploratory talk, this may mean directing learners' attention to the topics of discussion and drawing on learners' current knowledge to construct personal meanings and evaluating that meaning (Webb & Glover, 2004).

Through the process of utilising prior knowledge, exploratory talk and evaluation of the discussion, learners must be reasonable both in giving statements and being open and responsive to others. This 'communicative rationality' allows learners' reasoning to be made visible and publicly accountable through the discussion of alternatives (England, et al., 2007). The use of discussion also provides a platform for learners to ask questions for clarification, curiosity, explanations, and in order to challenge ideas, as well as to produce an investigable question, or what some researchers describe as a 'profitable question' (England, et al., 2007). Profitable or investigable questions are a natural progression in the process of inquiry and can be used to test ideas in the form of authentic scientific investigations.

6.3 Cognitive and metacognitive strategies in science

It has become widely recognised that learners need to develop metacognitive knowledge in order to become effective learners (Klein, 2006; Wallace, 2004). The results from research in writing (Bangert-Drowns, Hurley & Wilkinson, 2004; Hand, et al., 2001) and argumentation (Hand, et al., 2001; Webb, et al., 2008) in science suggest that the effects of student learning are greater when learners are engaged in the dual practices of reflection and modification subsequent cognitive actions (Butler & Winne, 1995). The metacognitive strategies used in the scientific literacy model are associated with learners' ability to write informally using the science notebook framework and then drawing on that information to construct scientific arguments through oral presentations or school reports and publications.

Researchers suggest that metacognition is necessary for the construction of scientific arguments in the sense that the learner must monitor and evaluate the connection between the

logical parts of an argument, such as the claim and the evidence (Hand, et al., 2001; Klein, 2006; Pintrich, 2002; Wallace, 2004). As learners use inquiry-based activities to test questions and gather supporting evidence, Simon, Erduan and Osborne (2002) posit that the use of an argumentation-based framework, such as a revision of Toulmin’s (1958) model in Table 2.4, engages learners in the coordination of conceptual and epistemic goals.

Table 2.4

Argumentation framework – revised version of Toulmin’s (1958) argumentation model

Toulmin Model	Translated	Writing Framework
Claims	Explanations	“My idea is...”
Warrants	Reasons for doing the investigation. What has already been found out by others (from books, etc.) that back up my claims	“We already know that...”
Rebuttals	Possible counter arguments against the claim	“Arguments against my idea might be...”
Data	What I found out from the investigation	“My evidence is that...”
Backings	What I did so that you will believe me (validity, fair test, reliability)	“Evidence that backs up my claim is that...”

On a conceptual level, learners are tasked with strengthening their claims by using warrants based on previous research or conventional scientific understandings. In addition to applying their own data and backings to these claims, learners are also charged with anticipating any possible counter-claims. On an epistemic level, the process of argumentation informs learners about how we know and why we believe (Driver, Leach, Millar & Scott, 1996; Millar & Osborne, 1998). These aspects may assist in improving the quality of learners’ understanding of the nature of scientific arguments and, thus, equip

learners with the tools to interrogate public claims. However, Koslowski (1996) cautions that arguments and reasoning are dependent on knowledge of scientific theory, fluency of the supporting evidence and opportunities to develop and evaluate conceptual understandings and data. What is recognised is that the construction of valid arguments does not come naturally (Kuhn, 1991). As such, the effective teaching of argumentation as a form of discourse is dependent on explicit instruction, task structuring and modelling (Simon, et al., 2002).

7. CHAPTER SUMMARY

This chapter highlighted international and domestic perspectives pertaining to science education and discussed how the movement of scientific literacy emerged in response to the decline of learners' knowledge, skills, values and attitudes in science. International and domestic policy documents, assessments and current research in science education were reviewed. Thereafter, interpretations of scientific literacy were discussed, as were the implications these ideas have for the teaching of science at school level in South Africa. Furthermore, language and literacy were examined as a critical and functional aspect of scientific literacy. The history of curricular stances to science education and scientific literacy in South African schools were traced while language issues and the current preparedness of educators to develop learners' scientific literacy for the 21st century and global economy were interrogated.

Accordingly, the literature review was used to discuss reading and writing in science, discussion, inquiry-based learning and argumentation in light of the integrated teaching strategies approach for improving scientific literacy. The proposed pedagogic model was explained, as was the rationale behind utilising this approach for second language English learners.

CHAPTER THREE

RESEARCH METHODOLOGY

1. INTRODUCTION

This chapter describes the research design and the methodological process of this study. The process is informed by consideration of the theoretical frameworks underpinning the research traditions within which this research is based. An outline of how the effect of the integrated teaching strategies approach was assessed in terms of improving scientific literacy for second language learners, developing teachers professionally to use the approach, and the way learners effectively engage in the processes and procedures required to develop their fundamental sense of science, is provided.

The procedures and instruments used for data collection, as well as the sample type and size, are discussed and justified. In addition, the assumptions made in selecting the particular research method, which determined the type of data that were collected through classroom observations, interviews, comprehensive field notes and learner testing, are substantiated. The ethical considerations of the study are discussed, as are the methodological limitations of the study.

2. RESEARCH PARADIGMS

Methodological practices in research are influenced by the set of beliefs and practices that guide a particular field (Morgan, 2007). These sets of beliefs and practices, or paradigms, are defined by metaphysical considerations, including how knowledge is generated (epistemology), a patterned set of assumptions concerning reality (ontology),

values (axiology) and the particular ways of knowing that reality (methodology) (Guba, 1990; Hanson, Creswell, Plano Clark, & Creswell, 2005). Researchers suggest that these metaphysical beliefs represent a system of ideas which inform our reality and that, ultimately, one's mental framework influences the paradigm in which one works (Mertens, 2005). In other words, the conceptual model that a particular theorist accepts and employs determines not only their research methods, but also dictates the research technique adopted (Morgan, 2007; Mouton, 2001).

Although there is a commonality of purpose that binds the work of theorists together (Burrell & Morgan, 1997), researchers generate and approach their data from a variety of theoretical perspectives (LeCompte, Millory & Preissle, 1992). Figure 3.1 illustrates Burrell and Morgan's (1979) depiction of sociological paradigms which they situate in four distinct quadrants.

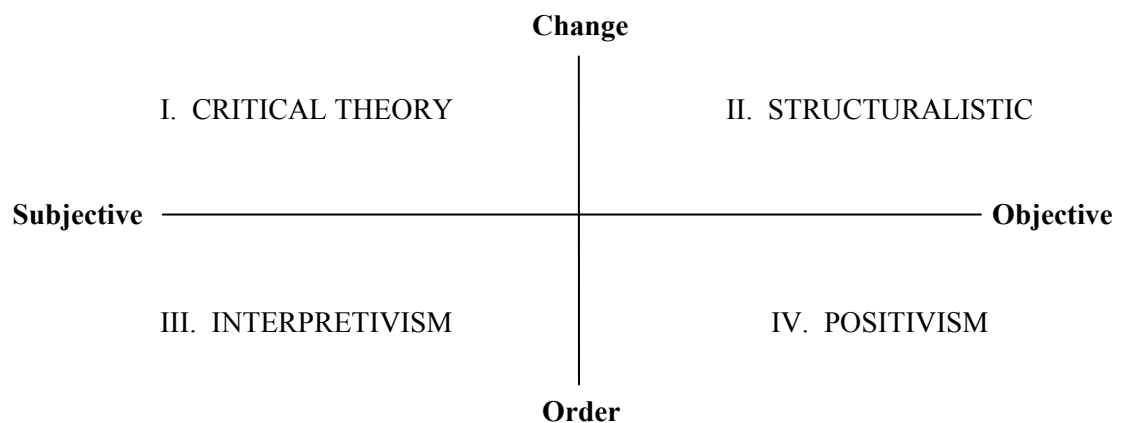


Figure 3.1: Research paradigms (from Burrell & Morgan, 1979)

Burrell and Morgan's (1979) matrix is based on four established debates in sociology (Heinemann, 1979), and the following paragraph summarises how these debates inform the components of the matrix. The first discussion deals with the notion of reality. It questions whether one's reality is developed by means of societal construction or that reality is what

one perceives it to be. The second debate focuses on how one begins to understand a new idea, concepts or practices and questions whether it is necessary for one to experience something in order to understand it. The next argument deals with the concept of free will. It focuses on whether individuals are guided by free will or whether their decisions are determined by their environment. Finally, the debate surfaces on how understanding is best achieved. Is it through a systematic way of thinking, or through practice-based knowledge and understanding through direct experiences? The way in which one analyses these four debates is addressed along the axes of the matrix. The fundamental basis investigates social theories that emphasise regulation and stability (Order) to theories that emphasises radical change (Change). These theories are then juxtaposed to individualistic (Subjective) or structural (Objective) theories (Burrell & Morgan, 1979).

As this study is situated in the lower quadrants of order, as well as along the continuum of individualistic and structural theories, interpretivism and positivism will be discussed as separate and distinct organising frameworks. However, with respect to this study, these paradigms were not used exclusively. Instead, a mixed-method approach, which includes the qualitative dimension of interpretivism and the quantitative dimension of positivism, may best describe the set of combined beliefs and practices used.

2.1. Interpretivism

The interpretivist framework and interpretivist-based research focuses on meanings and attempts to understand the context and totality of each situation by employing a variety of qualitative methods (Mouton, 2004). Similar to theories of constructivism, naturalistic and micro-ethnography, a key feature in the interpretivist tradition pays particular attention to the social construction of knowledge (Easterby-Smith, Thorpe, & Lowe, 2002; Lather, 1991). It views the objective of research as an attempt to understand and interpret social situations by

becoming part of situations, by listening to the participants, and by sharing their perceptions and their experiences (McFarlane, 2000).

The epistemology of this tradition focuses on the relative nature of knowledge and understands that knowledge is created, interpreted and understood from a social as well as an individual perspective. As such, this paradigm seeks to explain the participant's behaviour from their individual viewpoint, as opposed to viewing them as passive actors who are completely determined by the situation in which they are located. The participants in an interpretive approach are seen as active agents who are autonomous and able to create their social reality (Denzin & Lincoln, 2003).

In order to gain a better understanding of individual behaviour, interpretivist researchers attempt to observe ongoing processes, and researchers within this tradition generally select a small sample to provide an in-depth description and insight into the participants' social reality (Appleton & King, 2002). As interpretivists attempt to understand individual behaviour and social realities, interpretivist researchers accept Hume and Popper's seminal arguments which suggest that one's prior knowledge and biases shape what one decides to study, a researcher's hypotheses or expected outcomes, as well as how one chooses to conduct the investigation (Chalmers, 1976). As such, the interpretivist researcher acknowledges that an individual is subject to their prejudices, opinions and perspectives and openly recognises that human interests and values drive science.

2.2. Positivism

The 19th century French philosopher, Auguste Comte, is credited with developing the term positivism to describe the philosophical position which focuses efforts to verify or falsify a prior hypothesis (Howe, 2009; Moring, 2001) and uses scientific 'evidence' to explain phenomena or situations (Cohen, Manion, & Morrison, 2000). According to

McFarlane (2000), when used in the social sciences, the positivistic paradigm seeks to emulate the objectiveness in the natural sciences and aims to find certainty through observable patterns. This paradigm often makes use of quantitative methods to prescribe, predict and control situations, and generally identifies variables as the causal factors for specific types of behaviour.

Positivism is associated with the idea that laws govern social reality (like physical reality), and that these laws influence the behaviour of people who, in turn, set up social systems that reflect these principles (Goodman, 1992). Positivism, therefore, adopts an ontology that describes the world as an entity external to individual cognition and comprises hard, tangible and relatively immutable structures (Easterby-Smith, et al., 2002). This thinking has led to the general doctrine, which states that all genuine knowledge is based on sensory experience and that progress in the accumulation of knowledge can only be made by means of observation and experiments (Cohen, et al., 2000). Arguments against positivism, however, suggest that the descriptions of reality are mere inferences and cannot be separated from the individual noting the observations.

2.3. Pragmatism and the mixed method approach

Pragmatism is generally regarded as the philosophical underpinnings for mixed method research. The paradigm is based on the notion that the research question or set of questions should guide the researcher in choosing the most suitable methodological approaches to addressing the enquiry (Creswell & Plano Clark, 2007; Johnson & Onwuegbuzie, 2004; Tashakkori & Teddlie, 2003). Tashakkori and Teddlie (2003) suggest that the researchers within the pragmatist tradition abide by what they term ‘the dictatorship of the research question’, meaning that they place more importance on the research question than the method or paradigm that underlies the investigation. Additionally, they believe that

a practical combination of methods may offer greater insight, or the best chance of answering specific research questions (Johnson & Onwuegbuzie, 2004).

2.3.1 Mixed method approach

Research methodologies and approaches are grounded in the philosophical assumptions underpinning existing research (McFarlane, 2000). Therefore, the objective and subjective theories have been conventionally distinguished, as in Burrell and Morgan's (1979) matrix, as purely quantitative approaches that are based on a philosophy of positivism to purely qualitative approaches, which are, in turn, based on a philosophy of interpretivism (Johnson & Onwuegbuzie, 2004). However, a growing number of mixed method researchers suggest that research should not be restricted to exclusive paradigms and limited methodological practices (Creswell, 1994; Creswell & Plano Clark, 2007; Greene, Caracelli, & Graham, 1989; Tashakkori & Teddlie, 2006). Rather, they state that one should choose a combination of methods that provides sufficient evidence for answering the research question given "the inquiry objectives, research context, and the available resources" (Jang, McDougall, Pollon, Herbert, & Russell, 2008, p. 222).

The mixed method approach incorporates a distinct set of ideas and practices that separate it from the traditional qualitative-quantitative dualities. Leading mixed methodologists such as John Creswell, Jennifer Greene, Burke Johnson, David Morgan, Anthony Onwuegbuzie, Abbas Tashakkori, Charles Teddlie and others offer defining characteristics of the mixed method approach. Descombe (2008, p. 272) adequately summarises these characteristics of the approach, which involves the use of:

- Quantitative and qualitative methods within the same research project;
- A research design that clearly specifies the sequencing and priority that is given to the quantitative and qualitative elements of data collection and analysis;

- An explicit account of the manner in which the quantitative and qualitative aspects of the research relate to each other, with heightened emphasis on the manner in which triangulation is used; and
- Pragmatism as the philosophical underpinning for the research.

Mixed method researchers posit that the majority of research questions generally cross paradigmatic boundaries and cannot be adequately addressed using exclusively the positivist or interpretivist philosophies. In fields such as sociological and educational research, where evaluation and achievement scores are as important as its contributing factors, mixed methods research is increasingly used as a legitimate alternative to conventional mono-methods (Creswell & Plano Clark, 2007; Howe, 1988; Jang, et al., 2008; Reichardt & Rallis, 1994; Teddlie & Tashakkori, 2006).

2.3.2. *Rationale for using a mixed method approach*

There are many ways in which social researchers use mixed methods research. Primarily, the incorporation of both qualitative and quantitative approaches or methods are employed throughout the process of collecting and analysing the data, integrating the findings and drawing inferences within a single study (Tashakkori & Creswell, 2007). The prevailing rationales for methodological pluralism include improving the accuracy of ‘mutually illuminating’ data (Bryman, 2007) and producing a more holistic picture of the phenomenon under investigation (Creswell & Plano Clark, 2007; Descombe, 2008). Greene, Caracelli, and Graham (1989) and later Bryman (2006) identified a number of purposes for conducting mixed methods research designs. Yet, the most prominent reasons for a mixed method design points to issues of illustration of data, explanation of findings, offsetting weaknesses and providing stronger inferences, as well as strengthen triangulation.

Triangulation is used to verify or support a single perspective of a particular social phenomenon (Jang, et al., 2008) and allows for greater validity through corroboration (Doyle, et al., 2009). In addition to increased validity, the use of qualitative and quantitative methods provides a clearer illustration of the data and, as some researchers suggest, may neutralise the weaknesses in singular approaches while building on their strengths (Creswell, 2003). This is deemed useful when providing qualitative explanations to quantitative findings (or vice versa). For example, in this study, teacher interviews were conducted to elucidate the qualitative results from the learners' literacy and reasoning tests. While triangulation is the most common and well-known design, there are three additional types of mixed method designs, which will be discussed further in section three of this chapter.

2.3.3. Challenges to the mixed method approach

As paradigms influence 'how we know', our interpretation of reality and our values and methodology in research, traditional methodologists posit that the combination of two distinctive perspectives, such as an interpretivist and positivist paradigms, offer philosophically incompatible assumptions about human nature and the world (Howe, 1985; Lincoln & Guba, 1989). For example, a predominant challenge of utilising a mixed method design centres on how the researcher is able to adopt an objective position of distance and neutrality (positivist) from the process and the participants, while promoting a subjective level of closeness and reciprocity when attempting to understand or make sense of the participant's social realities (interpretivist) (Patton, 1990). Challenges such as this lead paradigmatic purist to posit that integrity of positions should be maintained and knowledge claims cannot be mixed (Smith, 1983; Smith & Heshusius, 1986). Additionally, researchers are cautioned to use different research methods in such a way that the resulting combination

has complementary strengths and not overlapping weaknesses (Brewer & Hunter, 1989; Johnstone & Turner, 2002; Webb, Campbell, Schwartz, Sechrest, & Grove, 1981).

2.4. Paradigmatic approaches to this study

This research study is situated with the pragmatic paradigm, which holds the position that the research question, or set of questions, in a specific problem space should guide the researcher in choosing the most suitable methodological approaches to addressing the enquiry (Creswell & Plano Clark, 2007; Johnson & Onwuegbuzie, 2004; Tashakkori & Teddlie, 2003). Within the context of the study, knowledge is generated using empirical evidence and attempts to gain a deeper understanding of the social realities on which the evidence is based. The generation and analysis of the quantitative data places this aspect of the research within a positivistic framework, yet qualitative instruments, analysis and attempts at understanding ‘social reality’ also places this study within the interpretive paradigm. The use of both qualitative and quantitative methods assists in providing a clearer understanding of the data (Creswell, 1994). This approach is in line with Hall and Howard’s (2008, p. 252) viewpoint, which posits that “neither approach inherently overrides the other as [value is placed on] the contributing epistemologies, theories, and methodologies equally all the time despite necessary fluctuations in the use of their quantitative or qualitative methods throughout the research process.”

3. RESEARCH DESIGN

According to Mouton (2001), the aim of science is to generate truthful (valid and reliable) descriptions, models and theories of the world, yet it is not possible to produce scientific results that are infallible and true for all times and contexts (Chalmers, 1976). In spite of the relativity of these descriptions, there is some agreement within current methodological researchers that multiple methods are useful to achieve greater understanding

of events under investigation (Denzin & Lincoln, 1994). Research methods drawn from a range of paradigms, primarily of the mixed methods approach, make more in-depth understandings of events possible and can produce different sources and kinds of information (Fraser, 1996).

Hall and Howard (2008), along with other mixed methodologists, maintain that the careful consideration of typological designs are essential for making research design decisions and working in a comprehensive structure. The first of three design considerations deals with determining the 'weight' (Creswell, 2003; Creswell & Plano Clark, 2007) and the priority of each approach used in the study (Morgan, 1998). For example, it must be decided whether the qualitative or quantitative aspects are of equal status or if more emphasis is placed over one than the other.

The next consideration involves identifying the stages in which the qualitative or quantitative approaches are mixed. Caracelli and Greene (1997) offer two approaches to design: component design and integrated design. In the component design, the qualitative and quantitative methods remain discrete through data collection and analysis while the mixing takes place at the level of interpretation and inference. Conversely, the integrated design allows for incorporating and mixing methods throughout the research process. Teddlie and Tashakkori's mixed-strands matrix (2006) expand on Caraceli and Greene's (1997) ideas to include other forms of design, such as concurrent, sequential, conversion, and fully integrated designs. While the concurrent and fully integrated designs are consistent with Caracelli and Green's (1997) notion of the component and integrated designs (respectively), the sequential and conversion designs offer additional practical approaches. In the sequential design, qualitative and quantitative strands are used chronologically. For example, a quantitative analysis of surveys and questionnaires may be used to formulate

questions, develop instruments or form hypotheses to be tested qualitatively through interviews or focus groups. In conversion, data are analysed accordingly and results are transformed for further analysis using the other methodological approach. The last considerations focus on ‘the timing decision’ (Creswell & Plano Clark, 2007) and ‘the sequence decision’ (Morse, 1991) which address the stages and the order in which the qualitative and quantitative methods are used.

3.1. Typology of mixed methods research

In addition to the timing, weighting and mixing decisions of qualitative and quantitative methods, the typology of mixed method designs is also attributed to Creswell and Plano Clark (2007). Triangulation was discussed earlier in the chapter, but the three additional designs include 1) the embedded design, 2) the explanatory design and 3) the exploratory design. Caracelli and Green (1997) first described the embedded design as having one dominant method, with the other data set playing a supportive role (Doyle, et al., 2009). Within the embedded design are the embedded experimental (quantitative emphasis with a secondary qualitative data set) or embedded correlational (qualitative data embedded within a qualitative design set) data.

Creswell (2003) describes the explanatory design, which consists of two phases: the initial phase is qualitative and the final is quantitative. Both phases are then used to explain or enhance the qualitative results. Two variants of the explanatory design include the follow-up model (specific quantitative findings which require further exploration using qualitative methods) and participant selection model (the quantitative phase used to identify and purposefully select participants). Finally, the exploratory design (Creswell, 2003) also uses two phases, but begins with the qualitative phase that assists in the development of the quantitative phase. This design is most often used in the Instrument Development Model

(developing and testing research instruments) and in the Taxonomy Developmental Model (creating a classification system).

3.2 Design approaches in this study

As this study seeks to investigate factors which contribute to improving scientific literacy through the professional development of science teachers and the implementation of a new model, both qualitative and quantitative approaches added equally valuable and diverse perspectives to this study. The methods were conducted concurrently and the mixing of the qualitative and quantitative methods occurred during the interpretation of the data. For example, the quantitative analysis of the Raven's Progressive Standard Matrices data was supplemented by rich descriptions of learner activities in the classroom. Additionally, the instruments used for the testing, classroom observations and learners' science notebook reflect Creswell and Plano Clark's (2007) notion of the embedded design's correlational model whereby qualitative data are rooted within a quantitative design to help explain the outcomes. The classroom observation and the science notebook instruments utilised a quantitative scale to measure performance and additional space on the instrument was provided for the researcher's qualitative descriptions and explanations, while interviews explored the participants' understandings of the process in depth.

The following table summarises how the study utilised both qualitative and quantitative approaches during the data collection, analysis and interpretation. The typology of triangulation and the mixed method design supports Leech and Onwuegbuzi's (2007) fully mixed, concurrent, equal status design.

Table 3.1

Summary of mixed method approaches used in this study

	Data Collection and Analysis		Interpretation and Inferences	
	Qualitative	Quantitative	Qualitative	Quantitative
Raven's Standard Progressive Matrices		√	√	√
Literacy Tests		√	√	√
Classroom Observations	√	√	√	√
Learners' Science Notebooks	√	√	√	√
Teacher Interviews	√		√	

Both qualitative and quantitative methods were used in order to gain the most accurate insight into the training and use of the scientific literacy model as well as the teachers' perceptions of scientific literacy. During the data collection and analysis, quantitative research methods were exclusive to learners' tests of reasoning (Raven's Standard Progressive Matrices) and literacy, while qualitative methods were exclusive to teacher interviews. Mixed methods were embedded in the data collection and analysis of the classroom observations, as well as the learners' science notebooks.

Throughout the interpretation and inferential process, data were also merged for the RSPM, literacy tests, classroom observations and learners' science notebooks. Although responses in the teachers' interviews were quantified to some degree, e.g. "Four out of six teachers stated that they employed reading strategies daily", the importance was placed on achieving an understanding of their qualitative responses rather than the frequency.

In *Qualitative thought and human understanding*, Eisner (1998) states that research into schools and school environments require direct and intimate contact with role players such as teachers, school management and learners. Through classroom observations and

interviews, an attempt was made to understand what educators and learners do in the settings in which they work. This approach also enhanced the researcher's insights into the participating teachers' thinking processes, as well as how these processes may or may not influence their teaching practice. In this study, detailed descriptions of the observations, interviews, intervention process and interaction between teachers and researcher, as well as descriptions of the learners' notebooks, were recorded. Concurrently, qualitative information from classroom observations, interviews and processing sessions with teachers following observations of their practice in the classroom, plus an examination of 50 randomly selected learners' science notebooks, were used to support and triangulate the quantitative findings.

4. SAMPLE AND SETTING

In studies where qualitative or quantitative methods are used exclusively, sampling procedures are often divided into two respective groups: purposive and probability. However, the rise of the pragmatic paradigm and mixed method research design defies this split. Mixed method sampling strategies combine, or suggests intermediary points of, the probability and purposive sampling positions, which can be used to best address the research question (Teddlie & Fen, 2007). Figure 3.2 depicts Teddlie's (2005) Purposive – Mixed – Probability Sampling Continuum.

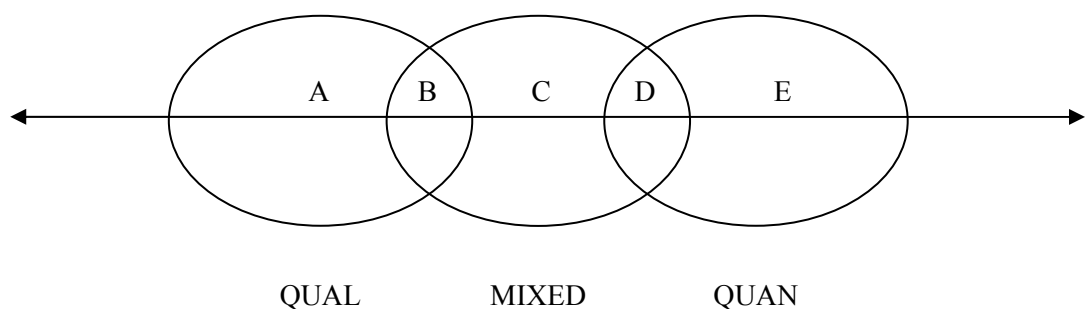


Figure 3.2: Purposive – Mixed – Probability Sampling Continuum (from Teddlie, 2005)

Teddlie (2005) explains that the Probability Sampling continuum has various zones which represent respective sampling strategies. The opposite ends of the continuum depict separate and distinct research methods. Pure qualitative research and purposive sampling characterises Zone A, whereas total quantitative research with probable sampling characterises Zone E. Zones B and D represent an overlap or partial integration of methods, in which priority is given to one method, but supported by the other. In Teddlie's (2005) example, qualitative research is dominant, but supported by quantitative components in Zone B, while, conversely, qualitative research is prominent in Zone D and uses qualitative components to substantiate the methodology and sampling. At the centre of the continuum is Zone C which denotes fully integrated mixed methods research and sampling and with which this study is situated. Teddlie and Yu (2007) suggest that the combination of these orientations allows the mixed method researcher to "generate complementary databases that include information that has both depth and breadth regarding the phenomenon under study" (p.85).

4.1. Sampling strategies used in this study

The study was conducted in two different milieus in the Eastern Cape, South Africa. The first setting is in the rural area of Tyumie Valley near the Hogsback Mountains, approximately 250km northwest of Port Elizabeth. The second setting is in the urban townships east of Port Elizabeth. These milieus were purposively selected in order to investigate the science education practices in rural and township settings and to draw comparisons between their teaching and learning needs, as well as their strengths.

The government funded schools in each setting were broadly matched as institutions that are from previously disadvantaged communities, and which are neither currently dysfunctional nor excellent. The schools were selected as a convenience sample in each area

in terms of an easily accessible cluster, after which they were randomly allocated to either the experimental and control group. Teachers and the learners from all participating schools in both milieus are isiXhosa first language speakers while English is the language of teaching and learning in the schools. In addition, all the participating schools follow the national curriculum which dictates the study of Natural Sciences, a combination of four core knowledge and concepts: Matter and Materials, Energy and Change, Planet Earth and Beyond, and Life and Living, for Intermediate Phase learners.

A small sample size of teachers from each milieu (n=15) was selected to seek information-rich cases and to yield the most information about effective teaching strategies for science teachers from previously disadvantaged Xhosa communities. To illuminate the narrative data generated by interviewing the small sample of teachers, a larger sample of learners, namely the Grade 6 and 7 (Tyumie Valley) and Grade 6 (Port Elizabeth) learners of the participating teachers, were given tests to assess their reasoning and literacy abilities. Data generated from the tests were used not only to validate the qualitative data gleaned from the teachers, but also to achieve representativeness and reflect the characteristics of the population of interest (Teddlie & Fen, 2007; Wunsch, 1986).

4.2. Setting

As noted earlier, the overall research was conducted within two milieus: the rural area of Tyumie Valley and the urban township in Port Elizabeth. The following sections describe each milieu.

4.2.1. Tyumie Valley

The Tyumie Valley study was conducted between January 2007 and November 2007 and data were generated throughout the academic year. The study was conducted with Grade

6 and 7 teachers and learners from seven primary schools in Tyumie Valley, of which five were experimental schools ($n = 5$) and two served as comparisons ($n = 2$). Both grade 6 and 7 learners were included as the classes in Tyumie Valley at this level are multi-grade (combined grade 6 and 7) in all of the schools. The ages of the learners in both the experimental ($n = 122$) and comparison groups ($n = 46$) ranged between 8 – 17 years, and the median age for learners is that of a Grade 6 learner, which is twelve years old. The large range in age is due to several learners' repeating the grade or starting school later than their counterparts. The approximate size of the multi-grade 6 and 7 classes were 20 to 40 learners per class and the average number of years teaching experience for the participating teachers is twenty-one years, with experience ranging from 29 years to 14 years.

The mother tongue language for both learners and teachers in the Tyumie Valley is isiXhosa, while a few teachers and learners possess communicative skills in other African languages. English, however, is the predominant additional language for the teachers and learners in this region and is also the language of learning and teaching in these schools for learners in grades 4 – 7.

4.2.2. Port Elizabeth

The second study was conducted with Grade 6 learners from eight primary schools in Port Elizabeth, six of which were experimental schools ($n=6$), while the other two served as comparisons ($n=2$). The ages of the learners in the experimental ($n=479$) and comparison groups ($n=196$) ranged between 9 – 17 years, and 11 years was the median age for this group. Similar to the Tyumie Valley sample, the large range in ages are attributed to learners' repeating Grade 6 due to academic or developmental challenges or entering school later than their classmates. The approximate sizes of the Grade 6 classes were 30 to 40 learners per class.

The average number of years teaching experience of teachers in the experimental and comparison groups was 22 years. The teacher with the most years teaching experience has taught for 27 years and, the least experienced has taught for 14 years. The mother tongue language for both learners and teachers is isiXhosa and, while a small number possess communicative skills in other African languages, English is the predominant second language for the teachers and the learners. The study took place in the academic year of February 2008 – November 2008.

5. SCIENTIFIC LITERACY INTERVENTION

As the primary focus of the study was to assess whether the integrated teaching strategies approach could be used to improve scientific literacy in terms of the effects of the teacher professional development process and the learners' problem solving, science and general literacy abilities, teacher interviews were conducted exclusively with the experimental teachers. The comparison teachers did not participate in any treatment activities and no other science or literacy programmes were offered to either the comparison or experimental teachers in this region during the time of the study. After completion of the study, the comparison group of teachers were given all materials and apparatus provided to the experimental group and were engaged in the teacher development process.

5.1. Experimental group

Professional development workshops on the integrated teaching strategies approach were conducted with each group at the beginning of the academic school year in Tyumie Valley in February 2007 and in Port Elizabeth in 2008. In an attempt to measure any changes which may have occurred subsequent to the workshops, data from the experimental teachers' pedagogic activities and their ability to apply the integrated teaching strategies approach were

collected throughout the intervention via classroom observations. The classroom observations, which were only conducted with the experimental teachers, will be discussed in section 6.1.3.

According to Desimone (2009, p. 182), research in teacher training “casts a wide net” for what might be regarded as professional development. With respect to this study, professional development reflects characteristics that are essential to develop or improve teacher content knowledge and pedagogic skills; thus improving teacher practice and possibly increasing learner achievement (Jeanpierre, Oberhauser, & Freeman, 2005; Johnson, Kahle, & Fargo, 2007). As such, the experimental teachers were engaged in classroom support and mentoring, plus fourteen hours of professional development on the use of the integrated teaching strategies approach model. The researcher and an isiXhosa-speaking literacy lecturer from the Nelson Mandela Metropolitan University facilitated the workshops. The workshops consisted of discussions, lectures and practical work on constructivist methods concerning reading, writing, talking and ‘doing’ in science, *viz.* the strategies of Reading to Learn Science, Exploratory Talk, Inquiry and Authentic Investigations, Science Notebooks and Argumentation.

Each teacher was provided with a science kit which included, amongst others, materials such as equipment to conduct investigations on surface tension and magnetism and fictional books on magnetism for shared and individual reading. Additionally, teachers were supplied with *Scientific literacy: A new synthesis* (England, et al., 2007) as a theoretical guide and reference tool for implementing the discussed science and literacy-embedded strategies. Each item in the science kit, including the theoretical guide, was used as an integral part of the workshops. Research into teacher education suggests that teacher preparation should “create intensive and focused opportunities to experiment with aspects of practice and then

learn from that experience” (Grossman & McDonald, 2008, p. 190). For this reason, the facilitators modelled the use of the material and instruction during the training and the teachers were engaged in the investigations and learning strategies which they would be conducting with their learners.

5.2. Comparison group

Besides for baseline observations, the comparison group of teachers were not formally observed during the course of the intervention. The reason for this is that the principle objective of the study is to gain information and insight on the implementation of the integrated teaching strategies approach on the teachers who participated in the workshops and the possible effects it had on student learning. The comparison group was only used to measure any possible differences in learner cognitive gains throughout the year. Experience in other professional development programmes, school evaluations and South African literature indicates that public schools, such as the schools in the study, share common factors such as poor classroom environment, i.e. physical structure, as well as lack of resources used for teaching. The overall standard of teaching is also generally low (Schindler, 2007) and the levels of reading, writing, discussion and scientific investigations are minimal in these classrooms (Webb & England, 2007). The comparison teachers were not initially part of the professional development workshops. However, they were afforded the opportunity to receive training and were each provided with a science kit at the completion of the study.

6. DATA COLLECTION PROCEDURES

In order to gather comparative data, the methodology and use of instruments were replicated for both studies. However, the collection and intervention for each group occurred sequentially, during the academic years of 2007 and 2008. The sequential studies were planned and conducted based on the researcher’s capacity to collect data across each milieu.

During the course of both studies, there were no significant changes to the science curriculum or educational policy in terms of teaching and learning. Data were generated from both studies to provide baseline information on the participating teachers' classroom practice prior to the intervention. This allowed insights into the classroom activities of the teachers in the experimental and control groups after the intervention, and, finally, allowed the researcher to monitor the progress of the experimental teachers' ability to apply the integrated teaching strategies approach in the classroom. Table 3.2 summarises the data collection techniques used in this study.

Table 3.2

Summary of the data collection techniques used in this study

	Baseline	Intervention	Post-Intervention
Raven's Standard Progressive Matrices	√		√
Literacy Tests	√		√
Classroom Observations	√	√	
Learners' Science Notebooks			√
Teacher Interviews	√		√

The techniques included data collection prior to the intervention, during the intervention phase as well as post-intervention. Baseline information was collected in the form of learners' reasoning (RSPM) and literacy abilities, classroom observations and teacher interviews. During the intervention phase, the professional development workshops were conducted and classroom observations were performed. During this time, the teachers and researcher engaged in dialogue in response to: 1) what had been observed in their classrooms, 2) possible strategies to improve the implementation of the model, and 3) clarification of the events that took place in the classroom. After three classroom observations were completed over three terms, post-tests were conducted to assess learners' reasoning and literacy abilities.

As there was no prior evidence of learner writing with respect to experiments or investigations, learners' science notebooks were evaluated at the end of the study to investigate performance and to substantiate the data generated from the classroom observations. Finally, teacher interviews were conducted post-intervention to discern any changes in attitudes or ideas regarding scientific literacy and the strategies they used to promote it in the classroom.

In order to ensure accuracy of the assessments, a research team comprised of the researcher and an isiXhosa speaking research assistant administered the RSPM and the literacy tests for learners. Prior to the collection of baseline data, the researchers reflected together and established a shared understanding of the goals and practices of the study, practised administering the RSPM and literacy instruments, and discussed effective classroom observations, data collection techniques and protocols.

Data were generated to determine the following: 1) to assess learners' problem solving and general literacy abilities, 2) to determine if any, and, if so, what type of scientific literacy strategies were occurring in grade 6 and 7 science classrooms in the experimental schools, and 3) to investigate teachers' ideas and perceptions about scientific literacy and the strategy being promoted. Prior to the intervention, the learners from both experimental (n=601) and comparison (n=122) groups were tested using the RSPM and standard literacy tests for reading, writing and speaking. As the principle focus of the study was to track the teachers' progression in the implementation process of the integrated teaching strategies approach, classroom observations and interviews were conducted exclusively with the experimental teachers (n=11).

6.1. Raven's Standard Progressive Matrices

The researcher and the research assistant administered the RSPM by projecting each item of the test on the classroom wall using a data projector. Additionally, poster-sized examples of each item of the test were provided in case of technical difficulties or possible power outages. The instructions for the test were communicated in English and in isiXhosa and, as per Raven's test instructions, the first item of the RSPM was used as a class example. The classrooms were arranged so that students were seated individually or in pairs (where only double desks were available), and the learners were reminded to work individually and how to make their selection of the correct answer using the answer sheet provided. The time allocated for each item was determined by when the majority of the learners had put down their pencils on completion of the particular question. On completion of the test, the RPSM answer sheets were collected (see Appendix A).

The data collection techniques employed during the baseline tests of the RSPM were replicated in the post-tests. Each answer sheet submitted by the learners in the post-test was cross-checked to verify that the learner had also participated in the baseline test. Data generated by learners who did not have corresponding pre-test and post-test data were not included in the statistical analysis. Additionally, any anomalies or changes to information, i.e. same student name and classroom, but different birth date listed on the pre- and post-tests, were clarified with the respective teacher. Responses for the RSPM tests were captured electronically and analysed statistically.

6.2. Literacy tests

As the tests were used to assess the learners' levels of reading, listening, writing and speaking in the language of learning and teaching (Appendices B and D) and in learners' home language (Appendices C and E), two literacy tests were administered to each learner.

Classrooms were randomly selected to start with either the English or the isiXhosa tests. As per instructions, while the learners were engaged with the isiXhosa tests, the research assistant (who is a first-language isiXhosa speaker) addressed the learners and communicated the instructions using only the learners' mother tongue. Conversely, when the English version of the test was administered, the instructions were provided in English. At the completion of each test, the learners' responses were collected for capturing and analysis. In addition to assessing learners' reading, listening and writing skills, a randomly selected group of six learners (per school) participated in a small focus group discussion to assess their ability to speak in English and isiXhosa (Appendix F). The same group of learners were used in the oral pre- and post-tests.

Similarly to the RSPM, the data collection procedures followed in the baseline literacy tests were repeated for the post-tests. The results of the literacy tests were also treated statistically. As the data generated from the literacy tests were used to measure any changes that may have occurred in terms of reading, listening, writing and speaking skills during the intervention, learners who did not have corresponding pre-test and post-test data were not included in the statistical analysis. The data were used to determine any statistically significant differences between the experimental and comparison groups, as well as any differences in performance between the rural and township learners.

6.3. Classroom observations

Prior to the professional development workshops, classroom observations were conducted to assess the experimental science teachers' classroom practices. The data generated from the baseline observation were used to measure any modifications to their teaching practices and their implementation of the integrated teaching strategies model. For the initial observation, teachers were informed in advance to conduct a 'normal' Grade 6

science lesson for the observation, i.e. to continue with the same topic and activities as per their year plan. The observations occurred in the natural setting of the classroom and the researcher conducted the observation using the *Scientific Literacy – Classroom Observation Schedule* (Appendix G).

Subsequent to the professional development workshops, three classroom observations were conducted with the experimental teachers. As the principal focus of the classroom observations was to track the teachers' progression in the implementation process of the integrated teaching strategies approach, the experimental teachers, who attended professional development workshops, were the only group observed. Each observation was conducted within the normal time frame of 45 minutes for the science class and, due to the limitations of time, the teachers were only assessed on their ability to implement certain aspects of the model, i.e. that which they deemed appropriate for their particular lesson for the day. The *Scientific Literacy - Classroom Observation Schedule* used during the baseline observations, was also used for the subsequent observations.

McMillan and Schumacher (1993) highlight the importance of post-observation discussion between the researcher and teacher in order to reach a mutual understanding of the meaning and context of the events that took place during the observation, and thus strengthen the validity of the observation. As such, reciprocal feedback and discussion by the teacher and researcher was conducted immediately after the classroom observation had been completed. This provided an opportunity for the researcher and participating teacher to discuss observations made during the lesson.

6.4. Teacher interviews

Prior to the instructional intervention, each experimental teacher participated in a semi-structured interview. The researcher used the *Scientific Literacy – Interview Questions* protocol (see Appendix I) to:

- Evaluate teachers' ideas and attitudes regarding scientific literacy; and
- Elicit the type of literacy, as well as inquiry activities which occurred in the classroom to support science learning.

The interviews generated qualitative data from the Tyumie Valley and Port Elizabeth teachers. Data were recorded and, when necessary, verified with the teacher to ensure that the participant's ideas were accurately noted.

Upon the completion of the project, a post-intervention interview was conducted with participating teachers to establish if and/or how the teachers' ideas and attitudes about scientific literacy changed throughout the course of the intervention. The concluding interview was also used to obtain the teachers' professional feedback regarding the implementation of the scientific literacy model.

6.5. Learners' science notebooks

Qualitative and quantitative data generated from the analysis of learner science notebooks were used to: 1) measure the level of learners' conceptual and procedural understanding when conducting scientific investigations, and 2) determine if and how teachers used the science notebook strategy in relation to the integrated teaching strategies approach. As the data generated from the science notebooks were used to supplement data

from the classroom observations, the sample was only collected from the learners in the experimental group.

As there was no evidence of learner writing during the baseline classroom observation, learners' science notebooks were only collected at the end of each study. A random sample of six learners' science notebooks were collected from each of the five Tyumie Valley schools (n=30) and the six Port Elizabeth schools (n=36) provided a total of 66 notebooks. All entries were analysed using the *Science Notebook Checklist* (see Appendix H) and an average score was used to describe the overall level of learners' science writings. Data gleaned from the science notebooks also provided valuable information regarding the level of learners' conceptual and procedural understanding when conducting scientific investigations.

7. DATA COLLECTION INSTRUMENTS

This section provides a description and rationale of the instruments used in this study. The following instruments were used in the data collection procedures to investigate learner performance in problem-solving, general literacy and their ability to use the science notebook approach. In addition, the measures that were used to investigate teacher practices, teachers' attitudes about scientific literacy, as well as the use of the integrated teaching strategies model, are described.

7.1. Raven's Standard Progressive Matrices

The Raven's Standard Progressive Matrices (RSPM) are multiple-choice tests used to measure what Raven, Court and Raven (1990) describe as factors which contribute to general intelligence in terms of deductive and reproductive abilities, or the capacity to deduce (eductive) and store and reproduce (reproductive) information. While a large body of

research suggests that the RSPM is one of the best measurements of general intelligence (Anastasi, 1988; Jensen, 1987), other researchers have used the test to measure other aspects of cognitive ability such as deductive reasoning (Colberg, Nestor, & Trattner, 1985), inductive ability (Rogers, Fisk, & Hertzog, 1994) and non-verbal intelligence (Bathurst & Kee, 1994; Jensen, 1983). As this study attempts to investigate the effects of the integrated teaching strategies approach on learners' problem solving abilities, the RSPM was chosen for this research as it is the test most widely used as a measure of individual difference in cognitive ability (DeShon, Chan, & Weissbein, 1995). Additionally, the test has been validated and deemed effective for cross-cultural studies (Abdel-Kalek & Raven, 2006; Skuy, Gewe, Osrin, Khunou, Fridjhon, & Rushton, 2002), as the use of pictures and visual patterns, as opposed to text, is purportedly unbiased with respect to non-verbal language.

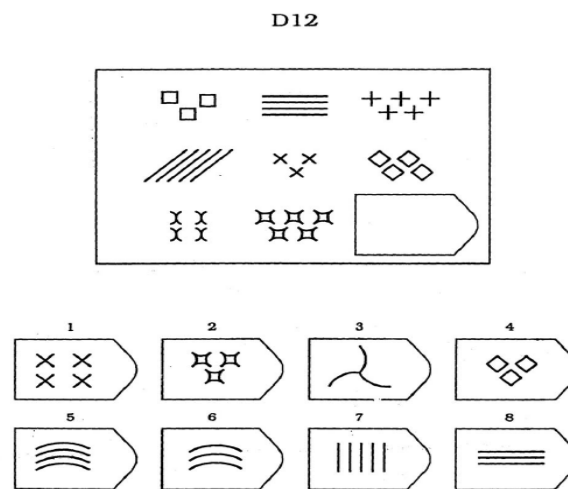


Figure 3.3 Example of Raven's Standard Progressive Matrix test item (from Raven, Court & Raven, 1995)

The RSPM consists of 60 test items and is divided into five different sets (A-E). Each item contains a particular design, which has a missing piece, and the participants are required to select the missing part of the design. Figure 3.3 illustrates one of the items from set D. As

the name of the test suggests, the complexity of the items increases from each set and requires higher levels of cognitive reasoning in the form of developing comparisons, reasoning by analogy, and organising spatial information into related wholes (Skuy, et.al, 2002).

7.2. Literacy tests

The literacy tests used in this study (Appendices B and C) were adapted from the tests used for the Mpumalanga Primary Schools Initiative (MPSI) in South Africa. The MPSI was spearheaded and funded by the Mpumalanga Department of Education and the British government's Department for International Development (DfID) in 1996 and sought to improve Intermediate Phase (Grades 4-6) learner achievement in the learning areas of English language, Science and Mathematics. As the MPSI study reflected similar areas of focus and an equivalent target group, the test was deemed appropriate for this study. The only modification was to translate the test into isiXhosa, as one of the objectives of this study was to assess learners' literacy levels in their home language (isiXhosa) as well as in the language of teaching and learning (English). Two mother tongue isiXhosa language lecturers in the Faculty of Education at the Nelson Mandela Metropolitan University translated the English tests into isiXhosa and validated one another's translation via back translation into English before reaching consensus on the final translation.

The language tests contain four sections to assess different literacy skills, namely reading, listening, writing and speaking. Section A assessed learners' reading comprehension skills. In this section, learners were asked to answer questions, make inferences, interpret a graph and map based on the corresponding text that they had read. The majority of questions were multiple choice. However, learners were also tasked with interpreting a diagram and completing a paragraph about the diagram using a using a set writing frame.

The listening section of the test, Section B, contained four subsections, which assessed learners' ability to answer questions, follow instructions, and complete a diagram and a table of information. In this section, the researcher read a story, provided information and dictated instructions for learners to follow (see Appendices D and E). Section C evaluated the learners' writing abilities. The learners were given six sequential pictures and asked to develop and write a story based on the pictures. In this way, learners were assessed on their ability to interpret and transfer visual information to written text. In addition, this section tested whether the learners were able to construct coherent and meaningful sentences, which were grammatically correct. The final section, Section D, tested learners' speaking skills. A random sample of five learners per school was asked to participate in discussion based on gravitational force. The researcher asked the learners to predict whether a feather or a chalkboard duster would reach the ground first, when dropped at the same height. The learners were encouraged to discuss the subject as a group and offer their individual or collective ideas. In this section, learners were assessed on their ability to reason and engage in exploratory talk in English and in isiXhosa.

7.3 Classroom observation schedule

Johnson and Christensen (2004) believe that observation is a valuable key in obtaining information about the behavioural patterns of people in certain situations and may prove to be useful in confirming practices against their stated beliefs. The observation schedule used in this study is a modified version of a validated classroom observation schedule used in a number of other studies (Webb, 2009). The *Classroom Observation Schedule* measured the degree to which the teachers incorporated the proposed scientific literacy strategies in their science lessons. This instrument, used in the diagnostic (baseline)

and the three additional observations, assessed twelve components in relation to the scientific literacy model as discussed in chapter 2, including:

1. The use of a stimulus;
2. Exploratory talk and classroom discussion;
3. Posing an investigable question;
4. Planning an investigation;
5. Conducting or 'doing' an investigation;
6. Learner writing with science notebooks;
7. Learner reading;
8. Teacher questioning skills;
9. Teacher feedback to learners;
10. Line of learning in relation to the teacher's subject knowledge;
11. Line of learning in relation to student generated ideas; and,
12. Learner subject knowledge assessed by means of class argumentation or presentations.

The data generated examined the level at which the teachers could apply the integrated teaching strategies approach in the classroom. In addition, the levels at which the learners responded to the strategy through classroom discussion (*Component 2*), writing with science notebooks (*Component 6*), reading (*Component 7*), generating ideas through the Line of Learning (*Component 11*), as well as learner subject knowledge through argumentation and/or presentation (*Component 12*) were also investigated.

7.4. Interview questions

McMillan and Schumacher (1993) note that interviews have the advantage of being flexible and, generally, have a very high response rate. Interviews allowed the researcher to

probe and clarify responses, which would have not been possible with written questionnaires. As such, a semi-structured interview, consisting of open-ended questions relating to criteria in the classroom observation instruments, as well as aspects addressed in the professional development workshops, was used. The interview provided teachers with opportunities to expand on issues raised and clarify their responses.

7.5. Science notebook checklist

The five-item science notebook checklist was used to assess learners' writing in science and to determine the degree to which their respective teachers guided and assisted them in using inquiry skills and developing their procedural and conceptual knowledge in science. The checklist also assessed various components of the scientific process, such as constructing a testable question, writing and implementing the procedures, collecting data, and using visual representations such as labelled drawings. The fifth component evaluated learners' ability to draw conclusions.

The five components were assessed on a rating scale of zero - 4. The rating scales illustrate increasing learner ownership and the level at which the learners actively participate in the learning process by constructing their own science knowledge (Nesbit, et al., 2004). A rating at Level 0 indicates that there was no evidence of the component present. Level 1 indicated that the learner copied the teacher's information. Level 2 suggests that the learner was able to generate his/her own information; however, some of the information may have been inaccurate. Level 3 indicates that the learner generated his/her own ideas, although some of the information may have been incomplete or missing details. Finally, a Level 4 rating suggests that the learner generated complete and accurate information.

8. DATA ANALYSIS

The data were analysed on completion of the intervention and triangulated with one another in an attempt to reach valid conclusions and appropriate recommendations. Qualitative responses were categorised and the frequency of responses were recorded according to each teacher and their respective classroom in order to obtain a personalised description and understanding of their abilities.

The quantitative data from this study provided descriptive statistics of all participating schools. Analysis of co-variance (ANCOVA) was applied as the pre-test scores were statistically significantly different in terms of the samples being compared. An analysis of covariance is a more sophisticated method of analysis of variance (ANOVA) as it allows for the inclusion of continuous variables (covariates) into the ANOVA model. As noted above, in this study, the covariates were the initial scores of the participants, and the use of ANCOVA eliminates the issue of unequal pre-test scores. In order to gauge the reliability of the RSPM data, Cronbach's coefficient alpha (α) was calculated to determine the internal consistency or average correlation for each section of the RSPM test and Cohen's *d* was calculated to determine the effect size (practical significance) of changes that were statistically significant.

9. ETHICAL CONSIDERATIONS

Scientists have a moral commitment to search for truth and knowledge, yet this quest should not be at the expense of the rights of individuals in society (Mouton, 2001). In keeping with the accepted professional ethics of research, the aims of the study, as well as the research design and methodologies, were communicated and discussed with the principals and teachers prior to any data collection taking place. The participants' right to anonymity,

including their right to refuse participation in the study, were conveyed. Individual learner consent was not elicited as the teachers and principals served *in loco parentis* for the learners at their school and gave consent on their behalf. All of the participants used in this study were informed volunteers and were aware that their responses would be used for this thesis. The right to seek full disclosure about the research topic and the results of the study were also guaranteed.

10. METHODOLOGICAL LIMITATIONS

The following methodological limitations are noted with respect to the research sample used and the classroom observations made in this study.

10.1. Sample size

The small sample of schools and teachers from the Nelson Mandela metropolitan area and the Tyumie Valley cannot be considered a reflection of classrooms in South Africa and, therefore, the results may not be generalised to the educational system as a whole. However, the rich information gleaned from the small sample of science teachers can be used to raise the issue and initiate debate on how an integrated teaching strategies approach can be used to improve scientific literacy especially amongst second-language English learners. Furthermore, the descriptive and statistical data may assist and influence the design of similar studies, as well as form more acute research questions, in the future.

10.2. Classroom observations

In the case of classroom observations, there is always a possibility that the lessons presented were not ‘authentic’ in the sense that the teacher may have prepared the lesson by rehearsing it with the learners prior to the formal observation. There is also a risk that learners were engaged in a previously delivered lesson. These limitations are noted, but it

must also be considered that even the contrived use of the teaching strategies contribute to an understanding of the feasibility of these approaches in the types of classrooms in which this research study took place.

10.3. Subjective nature of interpretation

In Thomas Kuhn's seminal work, the Structure of Scientific Revolutions (1962), he emphasised that observation is 'theory-laden' and shaped by the humanly constructed 'paradigms' that scientists invariably bring to observation. As such, there may be a possibility of misinterpretation of teachers' responses during the interviews or classroom observations. However, to minimise this limitation on validity, interview responses and explanation of teacher practice were probed as deeply as possible and discussed with the teachers for clarification.

11. CHAPTER SUMMARY

As the research design of this study is influenced by interpretivist and positivist perspectives, the study is grounded in the theoretical framework of pragmatism. In light of this, a mixed-method approach was used for the collection of data. As this study seeks to investigate factors which contribute to improving scientific literacy, e.g. through the professional development of science teachers, the implementation of a new model, as well as teacher performance and learner achievement, both qualitative and quantitative approaches possessed equally valuable and diverse perspectives to this study. The methods were conducted concurrently and the integration of the qualitative and quantitative methods occurred during the interpretation of the data. Additionally, the instruments used for the classroom observations and learners' science notebooks reflect Creswell and Plano Clark's (2007) notion of the embedded design's correlational model whereby qualitative data are rooted within a quantitative design to help explain the outcomes.

In this chapter, the sample type and size are discussed and justified. The assumptions made in selecting the particular research method used and the type of data collected through the RSPM, general literacy tests, professional development workshops, classroom observations, teacher interviews, and learners' science notebooks are also substantiated in this chapter. In addition, the ethical considerations in terms of the participants, such as the participant's right to privacy and full disclosure, as well as the methodological limitations of the study, are discussed.

CHAPTER FOUR

RESULTS

1. INTRODUCTION

This chapter reports on the data generated from two scientific literacy studies. These have been conducted in the rural community of Tyumie Valley near the Hogsback Mountains and four urban townships of Port Elizabeth, both milieus located in the Eastern Cape, South Africa. The findings of the Tyumie Valley and Port Elizabeth studies, as well as the comparative results of the experimental and comparison groups in both environments, are illustrated in an attempt to answer the central question in this study namely, *Can an integrated teaching strategies approach be used as a strategy to improve scientific literacy in Grade 6 classrooms in the Eastern Cape Province of South Africa?* The data have been triangulated and are discussed in the following chapter within the framework provided by the literature review. Qualitative data obtained from teacher interviews, classroom observations and learners' science notebooks will be presented and, in the cases of the classroom observations and science notebooks, will be supplemented with quantitative data acquired by the RSPM (RSPM) and isiXhosa and English literacy tests.

2. FIRST STUDY – TYUMIE VALLEY, HOGSBACK

The Tyumie Valley study was conducted between January 2007 and November 2007 and data have been generated throughout this academic year. Prior to the intervention, the learners from both experimental and comparison groups were tested using the RSPM (n=168) while the classroom observations were conducted exclusively with the experimental teachers (n = 5). The diagnostic data generated from the experimental teachers provided insight on

their current classroom practice in science. Additionally, the RSPM pre-test was conducted to determine the reasoning abilities of both the experimental and comparison group learners.

Professional development workshops on the integrated teaching strategies approach were conducted in February 2007. In an attempt to measure any changes which may have occurred subsequent to the workshops, data from the experimental teachers' pedagogic activities and their ability to apply the integrated teaching strategies approach were collected throughout the intervention, as were a random sample of their learners' science notebooks (n = 30).

The random sample of learners' notebooks was used to triangulate the data generated from the classroom observations and learners' RSPM scores. This also provided information regarding the level of learners' conceptual and procedural understanding when conducting scientific investigations. At the completion of the intervention, a post-test of the RSPM was conducted with learners from both experimental and comparison groups. The data obtained were treated statistically in order to measure any possible gains in learners' reasoning abilities, as well as to determine whether any statistically significant differences exist between the reasoning abilities of learners who were exposed to the intervention compared to those learners who were not.

The study was conducted with Grade 6 and 7 teachers and learners from seven primary schools in Tyumie Valley, of which five were experimental schools (n = 5) and two served as comparisons (n = 2). The ages of the learners in both the experimental (n = 122) and comparison groups (n = 46) ranged between 8 – 17 years and the median age for learners is that of a Grade 6 learner, which is twelve years old. The approximate size of the multi-Grade 6 and 7 classes were 20 to 40 learners per class and the average number of years

teaching experience for the participating teachers is twenty-one years; with experience ranging 29 years to 14 years.

The mother tongue language for both learners and teachers in the Tyumie Valley is isiXhosa, while a marginal group may possess communicative skills in other African languages. English, however, is the predominant additional language for the teachers and learners in this region and is also the official language of learning and teaching in the Intermediate Phase (IP) – Grades 4 – 7.

2.1 Raven’s Standard Progressive Matrices

The first-study data generated by the RSPM testing established a baseline of information on participating Grade 6 and 7, English second-language learners’ problem solving skills. The data were also used to measure any changes that may have occurred in terms of these skills over the integrated teaching strategies approach intervention. Pre- and post-test scores of pupils in the experimental and the comparison groups in Tyumie Valley were obtained and treated statistically in order to determine any statistically significant differences with the groups.

The following inferential statistics were obtained using the experimental group data and comparison group data for the RSPM over the duration of the first study. The results are summarised in Table 4.1. In Table 4.1, the F-ratio and the degrees of freedom (df) are presented. F is the sample statistic that is used to determine whether the variances in the two independent samples are equal. F is also used to calculate the probability value (p).

Table 4.1

Inferential statistics derived from RSPM test scores in Tyumie Valley (n = 168)

		F	p
A	Pre-Test	25.22	<.001
	ExpCon	0.33	.569
B	Pre-Test	11.28	.001
	ExpCon	3.01	.085
C	Pre-Test	29.64	<.001
	ExpCon	4.29	.040
D	Pre-Test	26.42	<.001
	ExpCon	0.23	.632
E	Pre-Test	7.39	.007
	ExpCon	1.09	.299
TOTAL	Pre-Test	33.95	<.001
	ExpCon	1.57	.211

F(df=1, 165)

The “Pre-test” rows indicate that all the tests were statistically significant with regard to the pre-tests. It was necessary to account for the fact that the experimental and comparison sample group could not initially be balanced with regard to the dependent variables, i.e. in this study not only the differences in the means between the experimental and comparison groups were considered, but also the initial positioning of the learners in terms of the RSPM test scores. For this reason, Analysis of Covariance (ANCOVA) techniques were applied. ANCOVA is a more sophisticated method of analysis of variance (ANOVA) as it allows for the inclusion of continuous variables (covariates) into the ANOVA model. In this study, the covariates were the initial scores of the participants. In other words, the result of the treatment alone could be statistically evaluated between the experimental and comparison groups by eliminating the possibility that one class was inherently more able than another. As previously noted, the data generated by the RSPM tests were treated statistically using ANCOVA and the results of various views of the data are reported in tables 4.2 and 4.3. The

“ExpCon” rows, however, show that there is not a significant difference between the mean scores of the experimental and comparison groups, except for section C.

Table 4.2 maps the significance of the experimental and comparison groups’ test results. The RSPM scores are sectioned into five categories of 12 reasoning problems in increasing levels of difficulty in each category i.e. total of 60; whereas the subsections are scored up to a maximum of 12.

Table 4.2

Mean pre- and post-test scores, gain scores ($\Delta \bar{x}$), the practical (d) significance of the statistical data and statistical probability (p)

(n=168; experimental, n = 122; comparison, n = 46; $\alpha=0.82$)

		Pre-	Post-	$\Delta \bar{x}$	d	p
A	Experimental	8.12	8.84	0.73	0.24	<.001
	Comparison	7.17	8.79	1.62	0.41	<.001
B	Experimental	5.58	7.38	1.80	0.47	<.001
	Comparison	5.63	6.42	0.78	0.18	<.001
C	Experimental	4.27	5.15	0.89	0.31	<.001
	Comparison	4.00	4.13	0.13	n.a.	.052
D	Experimental	4.69	5.37	0.68	0.20	<.001
	Comparison	4.36	5.00	0.63	0.14	<.001
E	Experimental	1.05	1.26	0.21	0.14	<.001
	Comparison	1.55	1.12	-0.42	0.21	<.001
Total	Experimental	23.70	28.08	4.32	0.40	<.001
	Comparison	22.73	25.42	2.69	0.19	<.001

Note: $\Delta \bar{x}$ denotes change in mean scores between pre-and post tests. A positive score implies that the post-test mean was higher than the pre-test mean.

d = Cohen’s d.

Table 4.2 shows that there was a statistical difference between the mean pre-post scores of both the experimental groups as well as the comparison groups. This indicates that learning did take place in most groups during the nine-month period of the intervention. Except for the comparison groups' scores for section E of the RSPM, the post-test mean scores are all higher than the pre-test mean scores for both experimental and comparison groups.

The unit for reliability is Cronbach's coefficient alpha (α) and overall values are given for combined experimental and comparison groups. The threshold value for accepted statistical reliability is that $\alpha > 0.70$. The reliability levels for the RSPM ($\alpha = 0.82$) may be considered as reliable. Cohen's d statistics were calculated to determine whether statistically significant ($p < 0.05$) pair-wise differences were practically significant. A small practical significance is noted where $0.2 < d < 0.5$; a moderate practical significance is noted if $0.5 < d < 0.8$ and a large practical difference is recorded if $d > 0.8$. Expressed differently, an effect size of less than 0.2 is considered to be insignificant, an effect size between 0.2 and 0.5 is considered to be of small significance; an effect size between 0.5 and 0.8 is considered as being moderately significant, while an effect size of 0.8 and greater is considered to be highly significant. Effect size as expressed by the Cohen's d statistics is defined as the difference in means divided by the pooled standard deviation and is a measure of magnitude (or significance) of the differences between the pre- and post-test scores (Gravetter & Walnau, 2008). As regards the total RSPM tests, the practical significance of the experimental groups is larger than the practical significance of the comparison groups.

Differences in mean score change between pre- and post-tests for experimental and comparison groups are reported in table 4.3.

Table 4.3

RSPM mean difference between experimental and comparison mean scores in Tyumie Valley (n = 168)

Section	$\Delta\bar{x}$ experimental	$\Delta\bar{x}$ comparison	Mean difference	p
A	0.73	1.62	-0.89	.005
B	1.80	0.78	1.02	.005
C	0.89	0.13	0.76	.005
D	0.68	0.63	0.05	.005
E	0.21	-0.42	0.63	.001
Total	4.32	2.69	1.63	.005

$\Delta\bar{x}$ denotes difference in means. A positive score implies that the post-test mean was higher than the pre-test mean. As noted earlier the differences in the change in mean scores between the experimental groups was slightly larger than the change in mean scores between the comparison groups' pre- and post-tests. As $p < .05$ in all cases Cohen's d was calculated in order to gauge the effect size of the practical significance of the differences, which is reported in table 4.4.

Table 4.4

Overall comparison of practical significance for RPSM changes in Tyumie Valley (n = 168)

	Experimental		Comparison	
	d	Effect	d	Effect
A	0.24	Small	0.41	Small
B	0.47	Small	0.18	Insignificant
C	0.31	Small	n.a.	Insignificant
D	0.20	Small	0.21	Small
E	0.14	Insignificant	0.21	Small
Total	0.40	Small	0.19	Insignificant

d = Cohen's d.

The mean differences for the RSPM tests in Tyumie Valley have been graphed below to visually illustrate the increases in reasoning skill that occurred in the overall study pre-post the intervention.

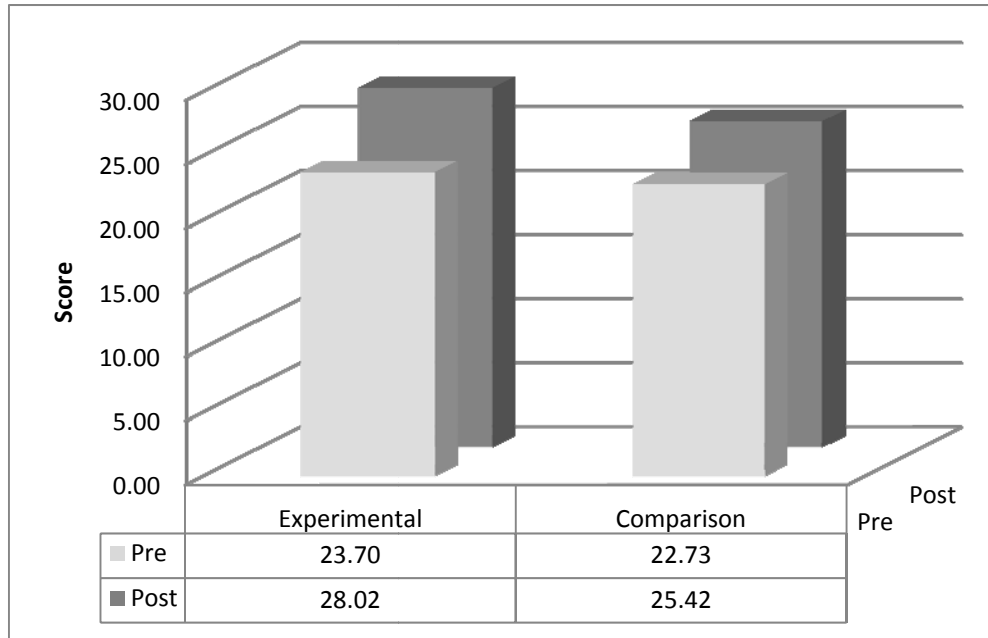


Figure 4.1 Comparison of the 50-percentile scores for the RSPM amongst the experimental and comparison groups in Tyumie Valley

The 50-percentile scores for the Tyumie Valley study groups depicted in Figure 4.1 illustrate any improvements made in the RSPM. In line with Raven’s procedures and to provide a comparison, the median score was used to provide a standard comparison of groups. The pre- and post-test scores for the experimental and comparison groups fell at 23.70 and 28.02, and 22.73 and 25.42, respectively. When compared to the 50-percentile norm for 12 year-old children in the United Kingdom (UK) of 38, both Tyumie Valley post-test figures are considerably lower and represent minimal improvement in scores.

2.2 Literacy tests

The pre- and post-tests for general literacy were conducted with the experimental and comparison learners (n=168) to examine the literacy levels in both their mother tongue, isiXhosa, and in English, the language of learning and teaching. Although administered in two languages, the tests were identical in content. Various reading skills such as comprehension, making inferences, interpreting diagrams and using relevant vocabulary to complete a writing frame were assessed. Learners' listening skills were also evaluated during these tests. Learners were given multiple-choice questions, which included stories, instructions or information which was presented to answer. Through small group discussions facilitated by the researcher, learners' speaking skills were assessed, while their writing skills were evaluated by requesting them to write a short paragraph based on several sequential pictures. Table 4.5 reports the mean scores and the standard deviation derived from each section of the English and isiXhosa literacy tests for the experimental and comparison groups in Tyumie Valley.

Table 4.5

Descriptive statistics derived from the literacy test scores in Tyumie Valley (n=168)

	Experimental				Comparison			
	Pre		Post		Pre		Post	
	$\Delta \bar{x}$	δ	$\Delta \bar{x}$	δ	$\Delta \bar{x}$	δ	$\Delta \bar{x}$	δ
English								
Reading	35.01	19.25	45.07	21.57	46.72	18.14	49.80	19.50
Listening	45.81	20.54	56.26	20.15	65.43	19.99	66.91	19.96
Writing	8.62	14.67	11.31	17.59	9.24	13.90	11.67	14.62
Speaking	33.48	19.88	34.68	23.41	30.10	16.34	39.30	23.25
isiXhosa								
Reading	48.33	18.39	55.56	18.91	50.50	19.43	59.38	17.74
Listening	57.87	18.27	63.07	17.72	67.09	22.54	60.69	18.31
Writing	16.90	19.02	24.96	19.66	21.41	16.28	16.67	16.65
Speaking	58.32	9.04	55.12	24.56	61.10	3.96	51.20	15.10

The differences between mean scores of the experimental and control groups for the reading, listening, writing and talking aspects of the literacy tests (English and isiXhosa) were computed and Analysis of Co-Variance (ANCOVA) techniques were applied. A positive score indicates a higher score for the experimental group than the control group, while a negative score indicates the opposite. An asterisk indicates that the difference is statistically significant, recorded as a 99% difference in confidence levels of learners (Table 4.6).

Table 4.6

Mean differences in the scores of the experimental and comparison groups (n=168) in Tyumie Valley for the pre- and post-tests in reading, listening, writing and talking in the English and isiXhosa tests (positive scores indicate a higher statistic for the experimental group than the control group)

	Differences in mean scores			
	English		isiXhosa	
	Pre-test	Post-Test	Pre-test	Post-test
Reading	-11.7*	-4.73	-2.17	-3.81
Listening	-19.62*	-10.65*	-9.21	2.38
Writing	0.62	0.36	-4.51	8.29*
Speaking	3.38	-4.62	-2.78	3.92

* = statistically significant at the 99% level of confidence.

These data indicate that the comparison group of learners statistically scored significantly higher than the experimental group in the English pre-test reading and listening categories, as well as in the post-test English listening category. Although there were differences between the mean scores in the other categories, none of these scores were statistically significant. These statistically significant negative differences in the experimental mean scores of the reading and listening categories were reduced considerably

in the English language test and were reversed in terms of writing in isiXhosa, where the writing in isiXhosa scores became statistically significantly better than those of the comparison group.

Comparisons were made of the changes in pre- and post-test scores in all the literacy categories for experimental and comparison groups: reading, listening, writing and talking. The experimental and control groups' scores changed drastically in the reading post-tests. The mean differences between the changes in the pre- and post-test scores of these groups are indicated in Table 4.7. Again, a positive figure indicates a higher score for the experimental group than for the comparison group.

Table 4.7

Difference in mean score changes between the experimental and comparison groups for reading ability (n = 168). A positive figure indicates that a bigger change in score was recorded for the experimental than the comparison group).

	Mean change	p	Cohen's d
English	7.65*	0.005	0.47
isiXhosa	-0.93	0.714	n.a

* = statistically significant at greater than the 99% level of confidence ($p \leq 0.01$); n.a = not applicable

The improvements in the mean scores of the experimental group compared to the comparison group in terms of English reading were statistically significant and the Cohen's d score suggests a medium effect size (0.2-0.5 = small effect; 0.5-0.8 = medium; ≥ 0.8 = large). This means that the workshops had a medium effect in practical terms on the experimental group as a whole. Although the scores of the comparison group improved marginally more than the experimental group when reading in Xhosa from the pre- to post-test, this result is not statistically significant.

After assessing learners' reading skills, the focus of this study moved to their listening skills. The mean differences between the pre-and post-test scores for the experimental and comparison groups in terms of listening are shown in Table 4.8. Again, positive figures indicate a bigger change in listening skills between the pre- and post-test scores for the experimental group than the comparison group.

Table 4.8

Difference in mean score changes between the experimental and control groups for listening ability (n=168)

	Mean change	p	Cohen's d
English	9.16*	0.01	0.60
isiXhosa	11.48*	0.005	0.62

*=statistically significant at greater than the 99% level of confidence ($p \leq 0.01$)

The improvement in the mean score of the experimental group in English and Xhosa was statistically significant and the Cohen's d score indicates that there was a medium effect in practical terms on the experimental group as a whole.

In addition to the testing the listening and reading capabilities of the learners, the learners' writing abilities were also assessed. The mean differences between the changes of the pre- and post-test scores for the experimental and comparison groups in terms of writing are shown in Table 4.9.

Table 4.9

Difference in mean score changes between the experimental and comparison groups for writing ability (n=168)

	Mean change	p	Cohen's d
English	0.56	0.810	n/a
isiXhosa	13.48*	>0.005	0.78

*=statistically significant at greater than the 99% level of confidence ($p \leq 0.01$); n/a= not applicable.

The data reveals that there was no statistically significant improvement in the English writing category for either the comparison or experimental group, whereas there was a significant improvement in the mean score of the experimental group's isiXhosa writing skills. The Cohen's D figure indicates that there was a medium effect (approaching large). In contrast to this, there were no statistically significant differences between the pre- and post-talking tests in either English or isiXhosa.

The differences in the learners' abilities to listen, read, write, and speak in English and isiXhosa, are shown in Table 4.10. A positive number indicates a higher score for the isiXhosa test than what was attained for the same activity in English.

Table 4.10

Mean differences in scores between learners' English and isiXhosa abilities in reading, listening, writing and speaking (n=168)

	Mean differences between Xhosa and English test scores							
	Pre-test				Post-test			
	Mean diff	n	p	d	Mean diff	n	p	d
Reading	9.53*	88	0.00	0.67	0.91	168	0.73	n/a
Listening	10.41*	88	0.00	0.57	13.03*	168	0.00	.70
Writing	-3.89	88	0.155	n/a	8.56*	168	0.00	.55
Speaking	-6.16	15	0.43	n/a	8.35	14	0.22	n/a

* = statistically significant difference at greater than the 99% level of confidence ($p \leq 0.01$); n/a = not applicable

The above data reveal that the pre-test reading scores were statistically significantly better in isiXhosa than in English. This was, however, not the case in the post-test, where the differences in achievement had been reduced ten-fold and the mean difference was no longer statistically significant. Conversely, in the case of listening, the highest mean score for isiXhosa increased in the post-test, with the difference between groups remaining statistically significant and revealing a greater effect size. The pre-test score for writing was better for English than in isiXhosa, but not statistically significant. This finding was, however, significantly reversed in the post-test, as learners then achieved higher scores for writing in isiXhosa. Because of the small size of the sample used for the speaking test, no statistically significant differences could be detected, but it appears that learners' speaking abilities changed from being better in English in the pre-test, to better in Xhosa in the post-test.

The language data presented were generated as an integral part of this study and, although used in Mayaba's (2009) Masters dissertation, play an important role in understanding the overall effects of the integrated learning strategies approach to teacher and learner development. This will be further discussed in Chapter 5.

2.3 Classroom observations

Four classroom observations were conducted over the duration of the study with the five teachers in the experimental group (n=5). As the principle focus of the classroom observations was to track the teachers' progression in the implementation process of the integrated teaching strategies approach, the experimental teachers, who attended professional development workshops, were the only group observed.

Prior to the workshops, classroom observations were conducted to assess the five experimental science teachers' classroom practice. This information was later used to detect any modifications to their teaching practice and implementation of the integrated teaching strategies model. Three additional classroom observations were conducted with the experimental schools throughout the duration of the study. These observations were scheduled in Terms 2, 3 and 4 of the school year.

The *Classroom Observation Schedule* measured the degree at which the teachers incorporated the proposed scientific literacy strategies in their science lessons. This instrument, used in diagnostic and the three additional observations, assessed twelve components in relation to the scientific literacy model, viz: the use of a stimulus; Exploratory talk and classroom discussion; Posing an investigable question; Planning an investigation; Conducting or "doing" an investigation; Learner writing with science notebooks; Learner reading; Teacher questioning skills; Teacher feedback to learners; Line of learning in relation

to the teacher's subject knowledge; Line of learning in relation to student generated ideas, and; Learner subject knowledge assessed by means of class argumentation or presentations.

The data generated examined the level at which of the teachers could apply the integrated teaching strategies approach in the classroom. In addition, the levels at which the learners responded to the strategy through: classroom discussion (*Component 2*), writing with science notebooks (*Component 6*), reading (*Component 7*), generating ideas through the Line of Learning (*Component 11*) and learner subject knowledge through argumentation and/or presentation (*Component 12*) were also analysed. The experimental teachers are denoted as A_{tv} , B_{tv} , C_{tv} , D_{tv} and E_{tv} in the data that follows.

Component 1: Use of a stimulus

The teachers' use of a stimulus levels over four classroom observation sessions in the experimental schools in the Tyumie Valley are illustrated in Figure 4.2.

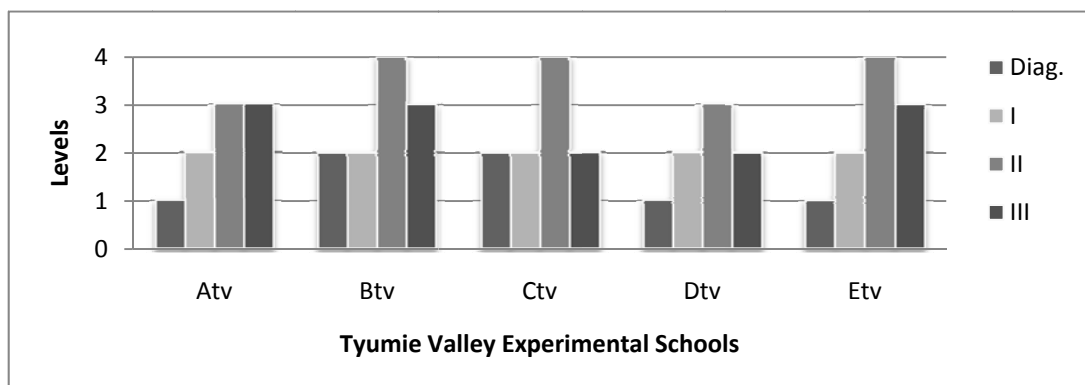


Figure 4.2 Teachers' use of a stimulus levels over four classroom observation sessions in the experimental schools in Tyumie Valley

Results of the diagnostic observation indicate that three of the five teachers from schools Atv, Dtv, and Etv did not use an introduction to stimulate learners' thoughts about

the science topic presented in class (Level 1; n=3). However, two of the teachers from schools Btv and Ctv, briefly introduced the lesson and elicited learners' ideas by asking closed-ended questions (Level 2; n=2). The teacher from school Dtv did not use a formal introduction at the start of the lesson. She addressed the learners by saying, "Today we will be discussing..." and then promptly began the lesson by teaching content from his/her notes. This method was mirrored by teachers from schools Atv and Etv who were also at Level 1 of the Classroom Observation Schedule. None of the teachers began their lesson by asking higher order thinking questions related to the science topic (Level 3; n=0), nor did any teachers use a stimulus such as a reading or discrepant event as an introduction to their lesson (Level 4; n=0).

Subsequent to the training session, teachers from schools Atv, Dtv, and Etv, along with counterparts from schools Btv and Ctv, began their lesson with a brief introduction and closed-ended questions. The brief introductions were characterised by the teacher eliciting learners' prior knowledge about the given topic by asking questions such as, "Can you tell me what you know about...?" By the observation II, two teachers from schools Atv and Dtv moved to a higher level of introductory teaching by asking higher-order questions, for example, they posed questions such as "How did you know that?" and linked the questions to the science topic (Level 3; n=2). Three teachers from schools Btv, Ctv, and Etv progressed to the next level using a stimulus such as reading or using a discrepant event as an introduction to a science topic (Level 4; n=3). During the final observation, none of the teachers used a reading or a discrepant event to begin their lesson (Level 4; n=0). However, three of the teachers from schools Atv, Btv, and Etv asked their learners higher-order questions regarding the topic at hand (Level 3; n=3). The teachers from schools Ctv, and Dtv, reverted to asking closed-ended questions and a short introduction to commence the lesson (Level 2; n=2). The

discussion of these observations, as well as those in the other components, will be discussed in the following chapter.

Component 2: Exploratory talk and classroom discussion

The experimental teachers' use of exploratory talk and classroom discussion was observed over four classroom observation sessions in Tyumie Valley. This is illustrated in Figure 4.3.

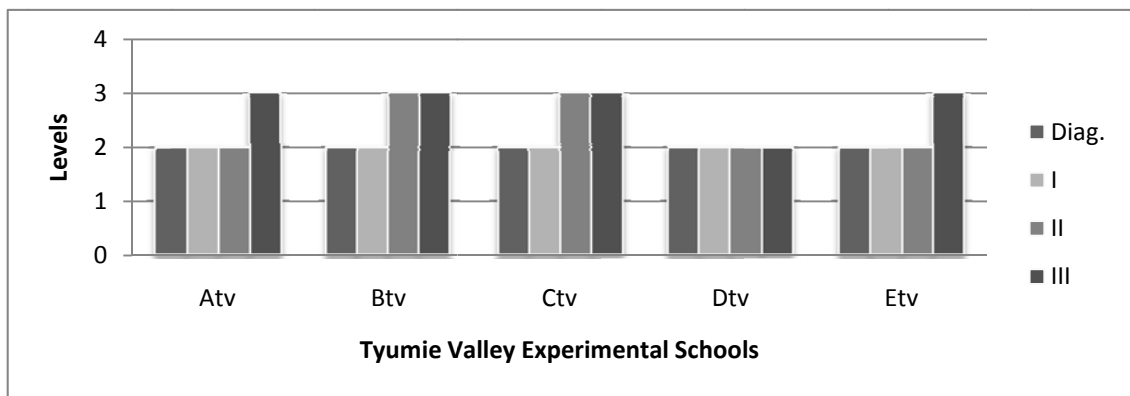


Figure 4.3 Teachers' use of exploratory talk and classroom discussion over four classroom observation sessions in the experimental schools in the Tyumie Valley

The lowest level of Component 2 indicates that no discussions took place in the classroom and this level of teaching is characterised by the teacher lecturing and the learners listening to the teacher (Level 1; n=0). Results of the diagnostic observation, however, suggest that there was some level of discussion happening in all five experimental classrooms. Learners in these classrooms answered questions posed by the teacher, but the learners provided little else in terms of classroom discussion (Level 2; n=5). There was no evidence of teachers facilitating exploratory talk (Level 4; n=0), nor were there evidence of learners participating in cumulative or disputation discussion (Level 3; n=0).

The pattern of minimal discussion continued throughout all five (n=5) schools following the professional development workshops (Level 2; n=5) and persisted in three of the schools, A_{tv}, D_{tv} and E_{tv}, during observation II (Level 2; n=3). In each school, several learners regularly answered the teacher's question. However, the other learners were often reluctant to answer any questions or offer ideas. Results from observation II also indicate that teachers from schools B_{tv} and C_{tv} facilitated classroom dialogue, during which learners were engaged in cumulative or disputational discussions (Level 3; n=2). The teachers supported this type of talk by asking the learners questions such as, "Do you agree or disagree with her statement...? Tell us why?"

During observation III, there was no evidence of any of the teachers facilitating the ideal practice of exploratory talk, e.g. engaging critically but constructively with each other's ideas (Level 4; n=0); however, four out of the five teachers from schools A_{tv}, B_{tv}, C_{tv} and E_{tv} promoted cumulative or disputational discussions in their classroom (Level 3; n=4). Only one teacher from school D_{tv}, did not exhibit any improvements in exploratory talk and classroom discussion throughout the observations.

Component 3: Investigable questions

The teachers' use of investigable questions, which formed Component 3 of this study, was observed over four sessions in the experimental schools in Tyumie Valley. The results are illustrated in Figure 4.4.

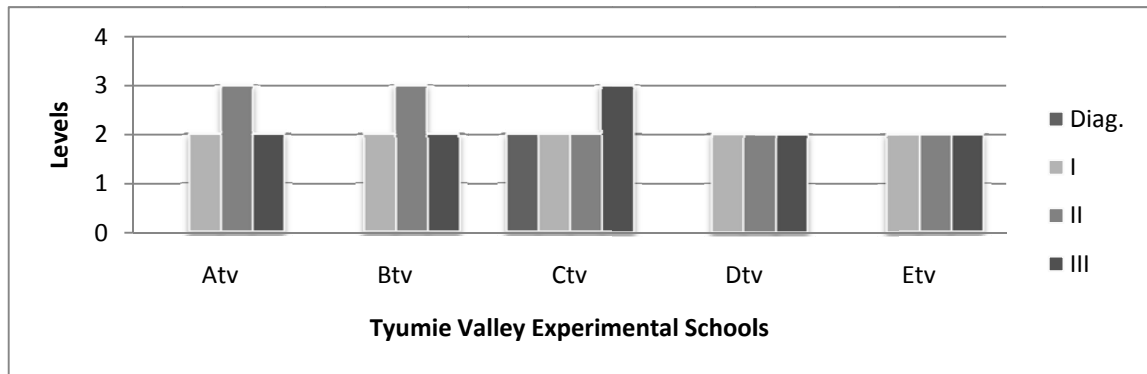


Figure 4.4 Teachers' use of an investigable question over four classroom observation sessions in the experimental schools in Tyumie Valley

Results of the diagnostic observation indicate that four out of the five experimental teachers from schools Atv, Btv, Dtv and Etv did not supply or facilitate questions for learners to investigate in class (Level 1; n=4). Teachers at this level may have facilitated practical work, but did not have questions for learners to test. The practical work may have been, as in the case of school Atv, more demonstrative in nature; for example, learners from school Atv were asked to count the number of petals on a dichotyledon flower. The teacher Ctv, however, provided an investigable question in his/her classroom (Level 2; n=1) by asking the learners, "How can we make this water hot?" During the diagnostic observation, there was no evidence of the other teachers guiding their learners by asking investigable questions (Level 3; n=0), nor was there evidence of learners posing their own questions to test in class (Level 4; n=0).

In the observation following the professional development workshops, all five teachers provided questions for learners to investigate (Level 2; n=5). During this observation, all teachers employed the water drop investigation which was facilitated in workshops. Another investigation discussed and practiced at the workshops was that of the

magnet and washers¹. Again, all of the teachers facilitated the magnetism investigation for observation II. Two teachers from schools A_{tv} and B_{tv}, guided learners in asking an investigable question regarding the strength of the magnets (Level 3; n=2), while teachers from schools C_{tv}, D_{tv} and E_{tv} remained at Level 2 (n=3). By the final observation, teacher from school C_{tv} also progressed to guiding his/her learners in asking an investigable question (Level 3; n=1), but the other four teachers from schools A_{tv}, B_{tv}, D_{tv} and E_{tv}, continued to supply the questions for learners to investigate (Level 2; n=4). Throughout the observations, the dominant practice appeared to be that teachers provided the investigable questions.

Component 4: Planning an investigation

Component 4 deals with the learners’ ability to plan an investigation over four classroom observation sessions. The levels at which learners performed in the experimental schools in the Tyumie Valley are illustrated in Figure 4.5.

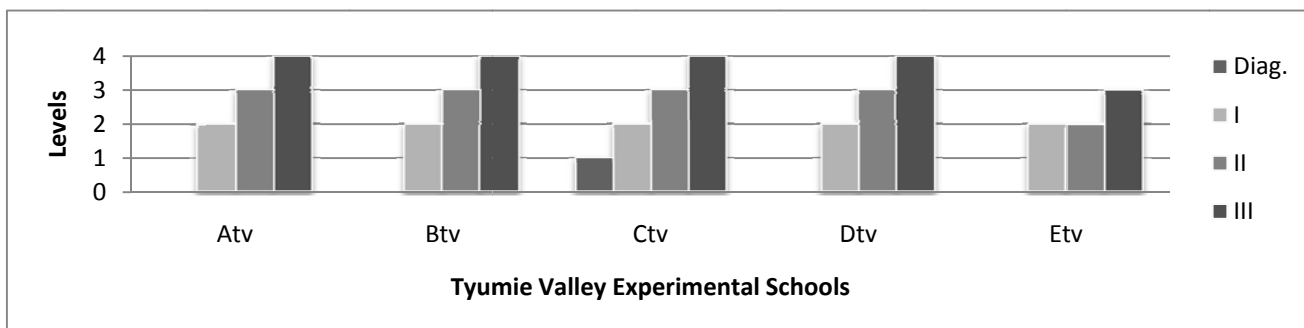


Figure 4.5 Learners’ ability to plan an investigation over four classroom observation sessions in the experimental schools in the Tyumie Valley

¹ As discussed in Chapter 3, two investigations were modeled in the professional development workshops for the experimental teachers. The first investigation, ‘water drops’, dealt with properties of water and surface tension, while the ‘magnets and washers investigation’ focused on magnetism.

As there was no question to investigate during the diagnostic observation, a naught response was captured for schools A_{tv}, B_{tv}, D_{tv} and E_{tv} for planning an investigation (n=4). Although teacher from school C_{tv} provided the investigable question, “How can we make this water hot?” learners in this his/her class were still unable to formulate ways in which to answer the question (Level 1; n=1). One learner suggested that the water could be boiled using a paraffin stove. This was the accepted answer by the learners in the class and there were no other ideas, which were explored or offered for discussion. During the diagnostic observation, there was no evidence that several learners interacted within a large group and offered ideas in which to answer the investigable question (Level 3; n=0). There was also no evidence of learners independently discussing problems, questions or ways in which to answer the investigable question (Level 4; n=0).

During observation I, all five groups of learners progressed by following their teachers’ step-by-step instructions to answer the investigable question (Level 2; n=5). The learners continued to improve in both observations II and III. Excluding teacher from school E_{tv} who stayed at Level 2 (n=1), while the remaining four groups of teachers from schools A_{tv}, B_{tv}, C_{tv}, and D_{tv} provided evidence of at least two or three learners in a large group interacting and offering ideas and ways to answer the investigable question (Level 3; n=4).

During the final observation, these four groups of learners were able to incorporate with the rest of the members in their group to discuss problems or question and their ability to reason independently of their teacher progressed (Level 4; n=4). Learners from school E_{tv} also showed improvement by advancing to Level 3 (n=1). Learners’ ability in planning an investigation increased as teachers facilitated more purposeful group work, e.g. establishing roles and responsibilities to each learner and as teachers provided more guidance in terms of

the investigation; or when the learners' were encouraged to "be creative" and use their imaginations when trying to plan the investigation.

Component 5: Conducting investigations

The level at which learners were able to conduct investigations over four classroom observation sessions in the experimental schools in the Tyumie Valley are illustrated in Figure 4.6.

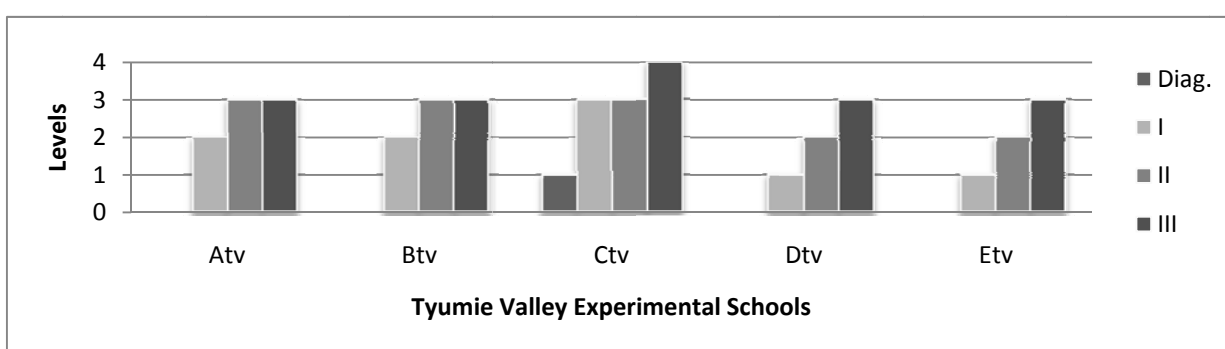


Figure 4.6 Learners' ability to conduct an investigation over four classroom observation sessions in the experimental schools in the Tyumie Valley

As depicted in the figure above, a naught response was captured for schools A_{TV} , B_{TV} , D_{TV} and E_{TV} for conducting a scientific investigation during the diagnostic observation. Learners from school C_{TV} were unable use their apparatus, collect data and draw conclusions during the investigation (Level 1; $n=1$). For example, when conducting her investigation on boiling water², the teacher from school C_{TV} adapted the learners' suggestion to use a paraffin stove and, instead, used an electrical stove to heat the water. At various intervals, she called

² It is important to note that teacher C_{TV} initially posed the question, "How can we make this water hot?" As learners only offered one solution, i.e. boiling a pot of water by using a paraffin stove, the teacher shifted her focus from testing different independent variables such as heat from stoves, coals, sunlight, etc. to measuring temperature.

on four learners to read the thermometer in the pot of water. Each learner had difficulty reading the thermometer as this was his or her first time using such an instrument. The teacher from school C_{TV} attempted to instruct each of the four learners on how to read the thermometer during this lesson. The learners participating in the exercise and those who were observing did not and were not encouraged to collect data or draw conclusions from this investigation. During the diagnostic observation, there was no evidence from any of the schools that several learners interacted within a large group nor offered ideas in which to answer the investigable question (Level 3; n=0). There was also no evidence that learners discussed problems, questions or attempted to answer the investigable question independently (Level 4; n=0).

Learners from schools D_{TV} and E_{TV} progressed to Level 1 (n=2) during observation I. However, learners from schools A_{TV} and B_{TV} progressed to Level 2 (n=2) as they were able to conduct the investigation as their teacher demonstrated how to use the apparatus (i.e. medicine dropper), collect data and draw conclusions. With the guidance of their teacher, learners from school C_{TV} were able develop ways to use their apparatus, collect data and draw conclusions (Level 3; n=1). In the final observation, all schools advanced to a higher level of conducting a scientific investigation. Learners from schools A_{TV}, B_{TV}, D_{TV} and E_{TV} progressed to Level 3 (n=4) and groups of learners from C_{TV} were able to conduct an authentic investigation appropriately and independently of their teacher (Level 4; n=1).

Component 6: Learner writing with science notebooks

The learners' ability to write for science using science notebooks comprised Component 6 of this study. This ability was tested over four classroom observation sessions in the experimental schools in the Tyumie Valley and the results are demonstrated in Figure 4.7.

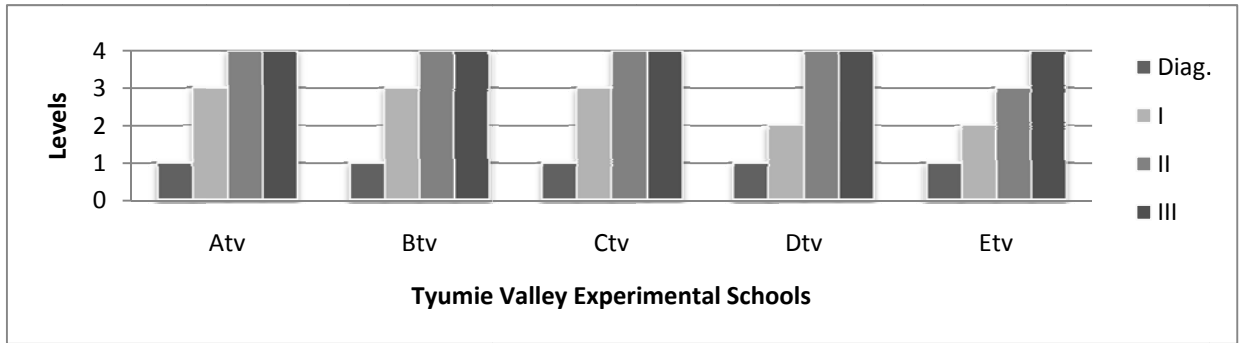


Figure 4.7 Learners' ability to write for science using their science notebooks over four classroom observation sessions in the experimental schools in the Tyumie Valley

Results from the diagnostic observations indicate that learners from the experimental schools did not engage in any writing activities during their science lesson (Level 1; n=5). There was no evidence that learners engaged in effective writing (Level 2; n=0), as they did not record their findings nor write in a manner that enhanced learning (Level 4; n=0) nor did they record their findings in a simplistic manner (Level 3; n=0).

However, subsequent to the professional development workshops, learners engaged in a variety of writing activities. Although learners showed progression by advancing from no writing to some writing, the writing activities of learners from schools D_{tv} and E_{tv} were categorised as ineffective and their findings incoherent (Level 2; n=2). Learners from schools A_{tv} , B_{tv} and C_{tv} wrote to record their findings, but their text was simplistic and did not enhance their learning (Level 3; n=3). These levels (2 and 3) of writing can be described as writing which is characterised by incomplete sentences, misspelt words and an illogical sequence of ideas.

Even though the learners from E_{tv} displayed simplified text within their writing (Level 2) in observation II, the learners from school E_{tv} , as with the other schools, demonstrated

consistent development throughout the observations. With the exception of learners from school E_{tv} in observation II, observations II and III revealed that learning in each school was enhanced by the effective recording of results (Level 4; n=5).

Component 7: Learner reading

The next part of this study deals with the learners’ ability to read for science over four classroom observation sessions in the experimental schools in the Tyumie Valley. This is Component 7, and is illustrated in Figure 4.8 below.

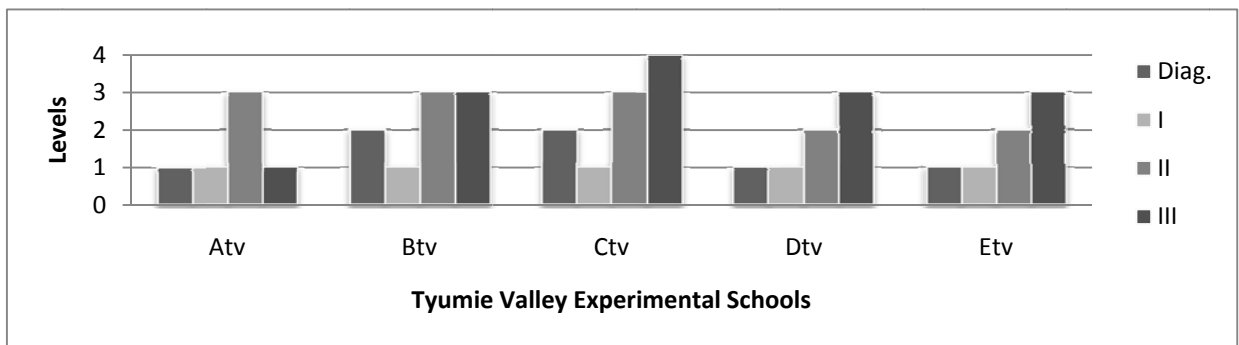


Figure 4.8 Learners’ ability to read for science over four classroom observation sessions in the experimental schools in Tyumie Valley

Analysed data from the diagnostic observations indicates that learners from schools B_{tv} and C_{tv} engaged in reading, but struggled to do so. Learners were generally asked to read vocabulary word(s) pertaining to the lesson or a sentence written by the teacher on the chalkboard. Reading in class was often done in chorus, i.e. aloud and together as a class. This type of reading had a limited to no effect on their learning (Level 2; n=2). The remaining teachers from schools A_{tv}, D_{tv} and E_{tv} did not engage learners in any readings relevant to the lesson (Level 1; n=3). There was also no evidence learners read effectively to

enhance their learning (Level 4; n=0), nor was there evidence that learners read simplified or ineffective text (Level 3; n=0).

During observation I, learners did not read for the lesson. However, by observation II, learners from schools D_{tv} and E_{tv} displayed evidence of Level 2 reading (n=2), while learners from schools A_{tv}, B_{tv} and C_{tv} read during the lesson, but their reading had limited effect on their learning (Level 3; n=3). Learners from the experimental schools were provided with books to supplement their investigation on magnetism and they subsequently displayed the ability to read the text. However, the learners' ideas and understanding about magnetism did not necessarily improve after reading (See Components 11 and 12). Some learners, such as learners from school C_{tv}, were only able to progress to reading effectively (Level 4; n=1) during the last observation and learners from schools B_{tv}, D_{tv} and E_{tv} read science text, but this displayed limited effect on their learning (Level 3; n=3). During the final observation, learners from school A_{tv} did not read for science regressing to Level 1.

Component 8: Teachers' questioning skills

The teachers' use of questioning over four classroom observation sessions in the experimental schools in the Tyumie Valley is illustrated in the figure below.

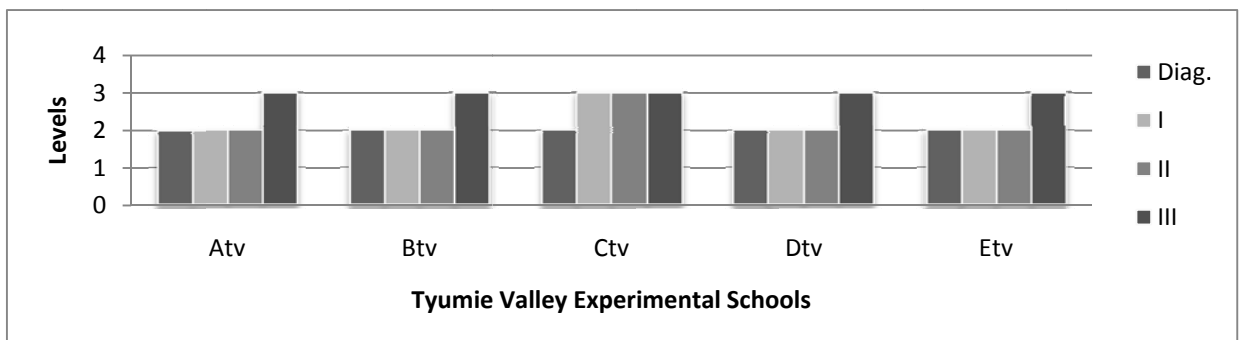


Figure 4.9 Teachers' use of questioning over four classroom observation sessions in the experimental schools in Tyumie Valley

Figure 4.9 suggests that during the five classes observed during the diagnostic interview, none of the teachers asked a variety of open and close-ended questions which probed for learners' understanding (Level 4; n=0), nor did any of the teachers ask mostly close-ended questions with one or two open-ended questions (Level 3; n=0). Teachers commonly asked simple-recall or close-ended questions (Level 2; n=5) therefore excluding Level 1 which indicates that teachers do not ask any questions.

Simple-recall and/or close-ended questioning continued in observations I and II for schools A_{tv}, B_{tv}, D_{tv} and E_{tv} (Level 2; n=4). The teacher from school C_{tv} was the only teacher whose questioning skills advanced to asking a few open-ended questions, but she mostly asked closed-ended questions in observation II (Level 3; n=1). By observation III, all teachers progressed to this level (Level 3; n=5). Teachers posed more questions beginning with words, such as "Why" and "How", but often reverted back to asking lower-order questions when learners were hesitant to respond. There was no evidence that any of the teachers asked a variety of questions, including as open- and close-ended questions, which explored learners' understanding of the science topic presented (Level 4; n=0) throughout the observations.

Component 9: Teachers' feedback to learners

The teachers' use of feedback to learners over four classroom observation sessions in the experimental schools in the Tyumie Valley is illustrated in Figure 4.10.

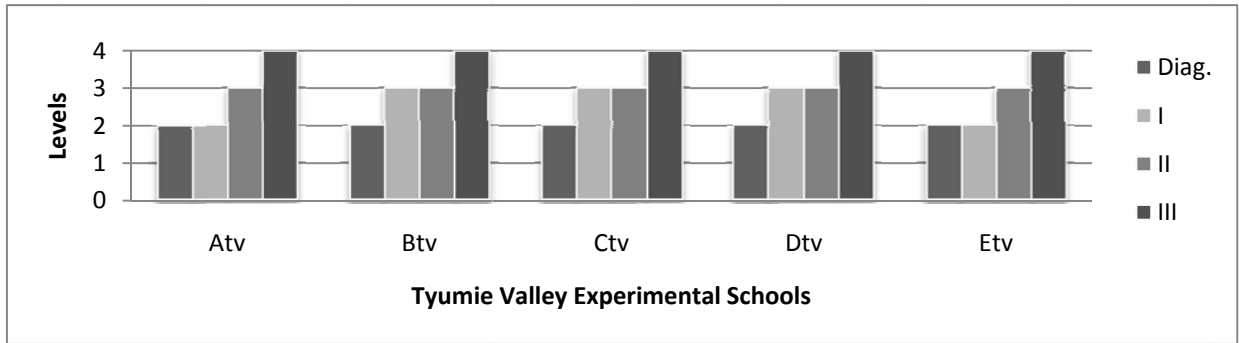


Figure 4.10 Teachers' use of feedback over four classroom observation sessions in the experimental schools in Tyumie Valley

As indicated in Figure 4.10, the results from the diagnostic information indicate that teachers only provided feedback to incorrect responses in a manner that discouraged further effort (Level 2; $n=5$). There was no evidence that teachers provided feedback to learners about incorrect answers (Level 3; $n=0$), or correct and incorrect answers (Level 4; $n=0$) in a manner that encouraged further effort.

Discouraging feedback persisted during classes taught by those who attended the professional development workshops (Level 2; $n=5$). However, teachers from schools B_{TV}, C_{TV} and D_{TV} progressed from responding to incorrect answers in an inhibitive manner to responding in a way that encouraged the continued engagement from the learners (Level 3; $n=3$). By observation II, all teachers were at Level 3 ($n=5$) in their facilitation of feedback and, by observation III, all teachers advanced to providing feedback about both correct and incorrect answers in a manner that encouraged further effort (Level 4; $n=5$). In many cases, the teachers' positive response to the learners answers, albeit correct or incorrect, improved learners' willingness to participate during the lesson.

Component 10: Line of learning – Teacher subject knowledge

The teachers' subject knowledge was measured over four classroom observation sessions in the experimental schools. The levels in which the Tyumie Valley teachers performed are illustrated in Figure 4.11.

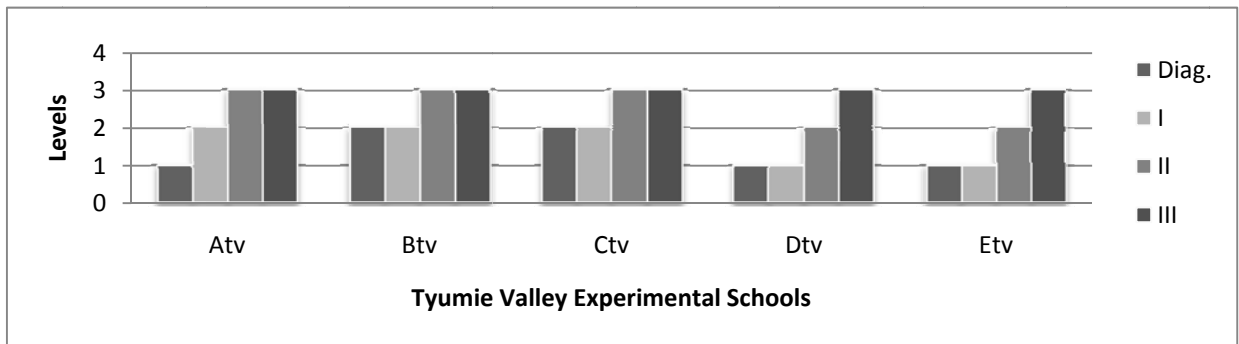


Figure 4.11 Teachers' subject knowledge over four classroom observation sessions in the experimental schools in Tyumie Valley

Figure 4.11 suggests that, during the initial observation, none of the teachers demonstrated a clear (Level 4; $n=0$) or adequate (Level 3; $n=0$) understanding of the concepts being taught. In the classroom, teachers from schools Btv and Ctv demonstrated partial understanding of the lesson (Level 2; $n=2$) and the remaining teachers from schools Atv, Dtv and Etv, demonstrated an inadequate understanding of the concepts being taught (Level 1; $n=3$). The teachers' insufficient subject knowledge was evident not only in their explanations, but also in the manner in which they taught certain concepts. For example, during a lesson on pollution, littering was the only idea discussed throughout the lesson. The teacher from school Etv spent a considerable amount of class time touting the negative aesthetic value of pollution and then briefly remarked the potential hazards that littering has on "animals which drink from the river."

While most teachers displayed an inadequate understanding of the concepts (Atv, Dtv and Etv), only teacher from school Atv progressed to having a partial understanding in the first observation (Level 2; n=1); teachers from schools Dtv and Etv remained at Level 1. The observation II showed improvements from all teachers. Teachers from schools Dtv and Etv demonstrated a partial understanding (Level 1; n=2) of the concepts taught, while their counterparts from schools Atv, Btv and Ctv continued to show an adequate understanding about the content taught in class (Level 3; n=3). During observation II, teachers appeared more comfortable when discussing magnetism in their classroom. They were able to describe concepts such as magnetic poles and teacher from school Ctv took the time to clarify terminology such as, attract and repel. Although no teachers demonstrated a clear conceptual understanding (Level 4; n=0) during observations I and II, by the final observation, all of the teachers provided evidence that their understanding of the concepts being taught was adequate (Level 3; n=5).

Component 11: Line of learning – Student generated ideas

Another aspect of this study is Component 11. This deals with the ideas generated by the learners over four classroom observation sessions in the experimental schools in the Tyumie Valley and is illustrated in Figure 4.12.

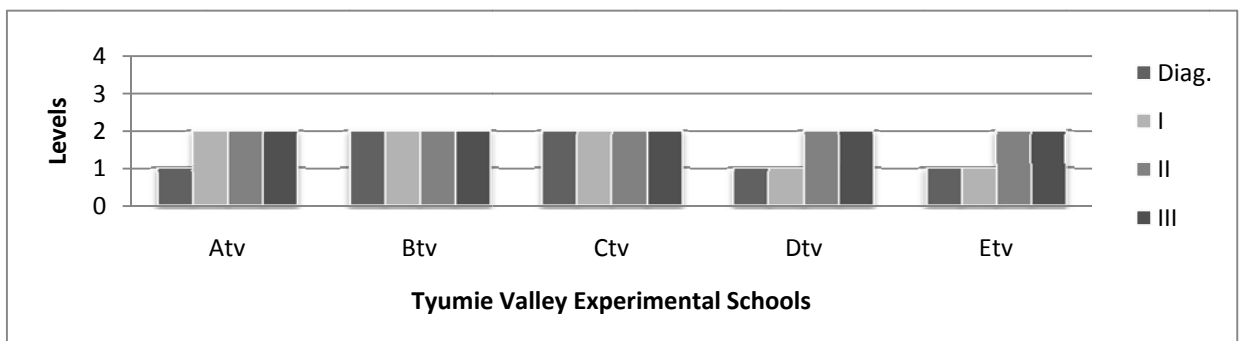


Figure 4.12 Learners' generated ideas over four classroom observation sessions in the experimental schools in the Tyumie Valley

Figure 4.12 indicates that, of the five classes observed, there was no evidence that the learners, through their own efforts, were able to clearly or adequately expand (Levels 4 and 3; n=0) their scientific understanding during the Line of Learning discussions. The learners from schools B_{tv} and C_{tv} were able to partially expand (Level 2; n=2) their scientific understanding, but, learners from schools A_{tv}, D_{tv} and E_{tv} were unable to expand (Level 1; n=3) their scientific understanding during the Line of Learning.

During observation I, learners from schools D_{tv} and E_{tv} remained at Level 1 (n=2). However, by observations II and III, learners from schools D_{tv} and E_{tv}, as well as of the learners from schools A_{tv}, B_{tv}, C_{tv}, consistently remained at Level 2 in partially expanding their scientific understanding. When teachers posed questions during the lesson, learners were reluctant to offer their ideas. In an attempt to make sure that the learners understood the questions, all of the teachers utilised code-switching strategies, e.g. English to isiXhosa and vice versa. In addition, the teacher from school D_{tv} encouraged learners to answer in isiXhosa if they were uncertain about the English translation. In spite of the language support, learners' correct responses as well as their overall participation was limited. Throughout the observations, learners were unable to adequately (Level 3; n=0) or clearly (Level 4; n=0) expand their scientific understanding.

Component 12: Argumentation and presentation – Learner subject knowledge

Learners' subject knowledge was also assessed through argumentation and presentations over four classroom observation sessions. The performance levels of the experimental school learners in the Tyumie Valley are illustrated in Figure 4.13.

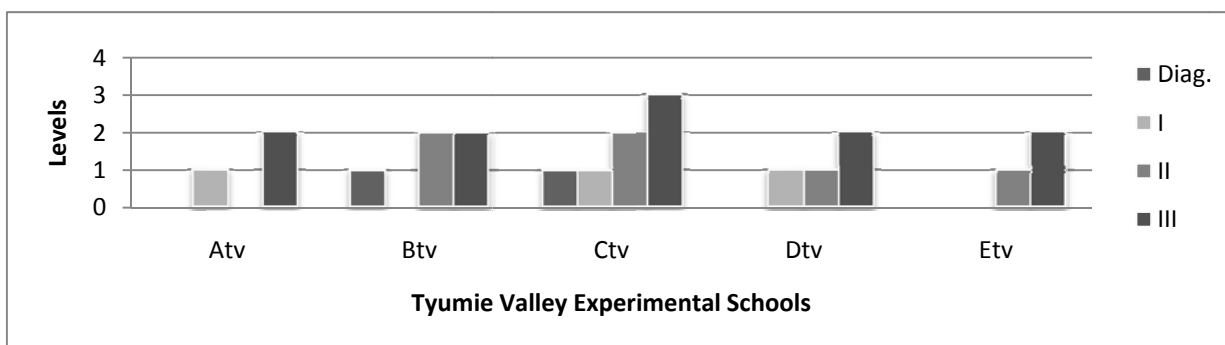


Figure 4.13 Learners' subject knowledge demonstrated through argumentation and presentations over four classroom observation sessions in the experimental schools in the Tyumie Valley

As Figure 4.13 suggests, there were no presentations in three of the five the classrooms during the initial classroom observation. Hence, a naught response was recorded for schools Atv, Dtv and Etv (Level 0; n=3). Learners from schools, Btv and Ctv, presented their ideas and demonstrated a very limited understanding of the concepts under discussion (Level 1; n=2). None of the learners presented or argued their ideas in a manner which demonstrated a partial, adequate or clear (Levels 2, 3 and 4, respectively; n=0) understanding of the concepts or procedures taught in the lesson.

During observation I, learners from schools Atv, Ctv and Dtv presented their ideas or argued their point of view regarding the concepts, but their presentations suggested that their understanding of the concepts was minimal (Level 1; n=3). There were no presentations recorded for schools Btv and Etv during observation I (Level 0; n=2).

Observation II showed some improvements in schools Btv, Ctv, Dtv and Etv. Learners from schools Btv and Ctv demonstrated partial understanding of the scientific concepts taught in class (Level 2; n=2). The learners at Level 2 were able to discuss procedural aspects of the investigation, but had difficulty discussing their knowledge about

the given topic. Learners from schools Dtv and Etv displayed limited conceptual and procedural understanding during their presentations and learners from school Atv did not present or argue at this time.

By the final observation, learners from schools Atv, Btv, Dtv and Etv exhibited partial understanding of the scientific concepts presented through their presentations or argumentation (Level 2; n=4), while learners from Ctv showed an adequate conceptual understanding through their presentations or argumentation (Level 3; n=1). None of the learners presented or argued in a manner which demonstrated that they had a clear understanding of the concepts taught during their science lesson (Level 4; n=0).

2.4 Learners' science notebooks

Qualitative and quantitative data generated from the analysis of learner science notebooks were used to: 1) measure the level of learners' conceptual and procedural understanding when conducting scientific investigations; and 2) determine if and how teachers used the science notebook strategy in relation to the integrated teaching strategies approach. As the data generated from the science notebooks were used to supplement data from the classroom observations, the sample was only collected from the learners in the experimental group. A random sample of thirty (n=30) learners' science notebooks were collected across the five schools (six notebooks per school). The collection of entries were analysed using the *Science Notebook Checklist* and an average score was used to describe the overall level of learners' science writings.

The five-item *Science Notebook Checklist* assessed learners' writing in science and determined the degree to which their respective teachers guided and assisted learners to use inquiry skills and develop their procedural and conceptual knowledge in science.

The checklist assessed the following five components on a rating scale of zero - 4:

- i. Constructing an Investigable Question
- ii. Designing an Investigation
- iii. Collecting and Recording Data
- iv. Scientific Drawings
- v. Drawing Conclusions

The rating scales illustrated increased learner ownership of the respective component and the level at which the learners actively participated in the learning process by constructing their own science knowledge (Nesbit, et. al, 2004). Rating Level 0 indicated that there was no evidence of the component present. Level 1 indicated that the learner copied the teacher's information. Level 2 suggests that the learner was able to generate his/her own information, but that some of the information may have been inaccurate. Level three indicated that the learner generated his/her own ideas, yet some of the information may have been incomplete or incomplete details. Finally, Level 4 suggests that the learner generated complete and accurate information.

Data generated from the learners' science notebooks (n = 30) have been analysed and yielded the following information regarding the construction of an investigable question, designing an investigation, collecting and recording data, the use of scientific drawings and drawing conclusions.

Constructing an investigable question

The analysis of learners' science notebooks indicate that, during classroom investigations, the majority of the learners either copied their teacher's question (Level 1;

n=25) or simply did not have evidence of a question in their notebooks (Level 0; n=5). Although some of the students included questions in their notebooks, the questions were not always inquiry-based, nor were they testable questions from which learners could manipulate variables and construct fair tests. The activities and the corresponding questions could be characterised as traditional experiments with questions posed such as, “Which liquid is an acid or base?” or “Which phase of water do you see?” The investigable questions, which were observed in the learners’ notebooks, resulted from the investigations which were trained at the professional development workshops. Of the 30 science notebooks that were analysed, there were none with evidence that learners attempted to construct, on varying levels, investigable questions using their own words as suggested in Levels 2 – 4.

Designing an investigation

All learners from Tyumie Valley demonstrated evidence of an experimental procedure in their science notebooks. Most of the learners copied their teachers’ sequential procedure (Level 1; n=14), while thirteen learners out of the 30 learners constructed and wrote plans for answering the question. Some learners’ plans, however, were incorrect (Level 2; n=13) and generally consisted of three or four incomplete sentences which were in some cases not written chronologically. Learners also displayed evidence of constructing an investigative plan, yet the investigation could not be replicated as details were missing from the text (Level 3; n=3). Throughout the intervention, no learners showed evidence of being capable of writing a procedure which was complete and could be replicated (Level 4; n=0).

Collecting and recording data

Data from learners’ science notebooks in Tyumie Valley indicate that all learners collected and recorded data throughout the intervention. Some learners copied their teachers’ data (Level 1; n=4) or recorded their own data inaccurately (Level 2; n=14). Other learners

recorded accurate, yet incomplete data (Level 3; n=8), while four learners provided complete and accurate data in their science notebooks (Level 4; n=4). The majority of learners recorded inaccurate data, and therefore scored at a Level 2. Examples of inaccurate data include utilising the incorrect units of measurements, omitting key measurements or miscalculating averages or differences between several figures.

Scientific drawings

The majority of learners provided evidence of original scientific drawings to support their observations. Eight learners produced drawings which were either not labelled correctly, or omitted relevant details (Level 2; n=8) whilst seven learners provided labelled drawings which included limited relevant details (Level 3; n=7). Four learners were able to produce an original drawing which was correctly labelled and detail about what was observed (Level 4; n=4). The Level 4 drawings and many of those who scored at Levels 2 and 3 in this component appear to have been drawn thoroughly. Many learners dedicated half or three-quarters of the page to their scientific drawings. There was evidence that some learners replicated their teachers' drawings (Level 1; n=4), while seven learners displayed no evidence of scientific drawings in their science notebooks (Level 0; n=7).

Drawing conclusions

A moderate number of learners from Tyumie Valley were able to explain scientific concepts in their own words. Despite their efforts to use their own words, thirteen (n=13) of the learners' conclusions were incorrect (Level 2). The learners' conclusions were simply a reiteration of their results written in sentence form. Six learners (n=6) constructed conclusions which were generally correct, while their conclusions missed some relevant detail(s) (Level 3). Eight learners (n=8) copied their teachers' explanation (Level 1) and

three (n=3) of the thirty learners displayed no evidence of drawing conclusions from the investigations (Level 0).

2.5 Teacher interviews

During the course of the intervention, teachers from the experimental group (n=5) participated in semi-structured interviews. The initial interview fulfilled several objectives: 1) to evaluate teachers' ideas and attitudes regarding scientific literacy; 2) to elicit the type of literacy, as well as inquiry activities which occurred in the classroom to support science learning, and; 3) to investigate teachers' perceptions regarding their classroom environment for teaching science. Upon completion of the intervention, an additional interview was conducted with participating teachers, to establish if and/or how the teachers' ideas and attitudes about scientific literacy changed throughout the course of the intervention. The concluding interview was also used to obtain the teachers' professional feedback regarding the implementation of the scientific literacy model.

The interviews generated qualitative data from the Tyumie Valley teachers. Data were recorded and, when necessary, verified with the teacher to ensure that the participant's ideas were noted accurately. Although some of the teacher's answers were brief (especially when answering questions regarding classroom environment or current teaching practice), other questions elicited in-depth responses that required further analysis. Data have been analysed and categorised into broad themes according to the teachers' responses. For the purposes of reporting, these themes and the frequency of the themes are presented in this section.

Diagnostic interviews

During the diagnostic interviews, participating teachers were asked a number of questions, including their interpretation of the term scientific literacy. Four out of the five teachers stated that they were unfamiliar with the term, but offered answers such as, “The way of teaching science in a modern way”, “Knowledge about science”, and “Students’ questions and observations”. The one teacher who was familiar with the term said that scientific literacy, “deals with science and language. It is also a way of teaching science.”

The second question of the interview focused on reading in science. Teachers were asked if and what their learners read to supplement the science lessons. All five teachers affirmed that their learners read for science. The reading material that teachers mentioned were notes on the blackboard, notes from the teacher, textbooks and homework to answer questions. One teacher explained that some of the learners in his/her class came from a different primary school which is why their reading skills were poor and undeveloped.

Writing in science constituted the basis of the third question of the interview. Similar to the previous question, teachers were asked if they facilitated writing in science and, if so, were asked to describe the writing activities. One teacher explained that his/her learners did not write in science and that they only listened in class. This teacher stated that, “No writing is done in science because that is the duty of the English teacher.” The remaining four teachers maintained that learners are engaged in writing activities such as “writing” tests, class work and notes from the teacher.

The fourth question of the interview was intended to examine the teachers’ classroom practice regarding scientific investigations. All five of the teachers stated that their learners conducted investigations. Four of the five teachers asserted that investigations take place every fortnight, while the remaining teacher stated that his/her learners engaged in

investigations once a week. Teachers' examples of their classroom investigations included: experiments on electricity (no specifics mentioned) and examining the three phases of water.

The final question of the investigation focused on the teachers' best practices in science. However, all the responses shifted towards the negative aspects of teaching and learning science. All five teachers echoed the need for more material and apparatus to engage in experiments and scientific practicals. Three of the five teachers mentioned the disparity of teacher qualifications and the subjects they are expected to teach. One teacher mentioned that high school science was not one of his/her subjects, that he/she was forced to teach science due to a shortage of staff. Teachers also cited other challenges to teaching science, such as uneducated parents, dusty classrooms and failed experiments.

Concluding interviews

At the conclusion of the intervention, another interview was conducted to establish if and/or how the teachers' ideas and attitudes of scientific literacy changed throughout the course of the intervention. During the diagnostic interview, four of the five teachers stated that they were unfamiliar with the term scientific literacy, but at the concluding interviews expressed that they understood the term to refer to, "Reading and writing in science", "dealing with science and including home languages, such as home language and English" and "language and science". One teacher commented that, "Science literacy is a great influence to the children. By doing practical work, it is easier for them to understand the information."

The concluding interview was also used to obtain the teachers' professional feedback regarding the implementation of the scientific literacy model. All of the teachers believed that the model was beneficial and they cited various aspects for the model's usefulness in the classroom. One teacher commented that it was a useful teaching guide and the model

reminded her to incorporate more reading or writing in her classes. Another teacher suggested that, “the learners enjoyed doing the investigation and at the same time they were developing their thinking skills and other skills for science.” Teachers cited additional reasons for the model’s usefulness. They confirmed that it assisted learners in understanding scientific terminology and that the model facilitated collaboration and interaction between learners, as well as between learners and teachers. One teacher stated, “When educators use this model, they no longer are absently feeding learners’ information.”

In addition to the positive responses, teachers also offered constructive feedback about the challenging aspects of the model. The majority of the teachers agreed that certain aspects of the investigative process were particularly difficult to implement. Aspects such as, the lack of resources for conducting investigations, the learners’ ability to draw conclusions, time constraints for facilitating the investigations, as well as “learners conducting the experiments incorrectly”, proved to be problematic for some teachers. One teacher also commented that, “[learners’] results are not the same as in the textbook”, which left her confused as how to explain the unexpected results. Another challenging issue which teachers conveyed centred on the issues of language. One teacher explained that she found the terms difficult to explain, as she had to interpret and explain everything in English and isiXhosa. Another teacher commented that her learners’ English skills were very poor and that the learners found it challenging to communicate in English. One teacher offered the final criticism of the model suggested that the model was difficult because, “other learners don’t want to think, so I have to give them the chance to think critical.”

3. SECOND STUDY – PORT ELIZABETH

In addition to the Tyumie Valley study, data from the Port Elizabeth schools were generated throughout the integrated teaching strategies approach intervention. In order to

gather comparative data, the methodology and use of instruments were replicated in the second study. Data were generated by means of classroom observations, RSPM test scores, literacy tests, learners' science notebooks and teacher interviews.

The second study was conducted with Grade 6 learners from eight primary schools in Port Elizabeth, six of which were experimental schools (n=6), and while the other two served as comparisons (n=2). The ages of the learners in the experimental (n=479) and comparison groups (n=196) ranged between nine – 17 years, and 11 years was the median age for this group. The approximate sizes of the Grade 6 classes were 30 to 40 learners per class. The average number of years teaching experience of teachers in both groups was 22 years. The teacher with the most years teaching experience has taught for 27 years, and, the least experienced, for 14 years. The mother tongue language for both learners and teachers was isiXhosa and while a small group may possess communicative skills in other African languages, English was the predominant second language for the teachers and the learners. The study took place between the academic year of February 2008 – November 2008.

3.1 Raven's Standard Progressive Matrices

The second-study data generated by the RSPM testing established a baseline of information on participating Grade 6, second-language learners' problem solving skills. The data were also used to measure any changes that may have occurred in terms of these skills over the integrated teaching strategies approach intervention. Pre- and post-test scores of pupils in the experimental and the comparison groups in Port Elizabeth were obtained and treated statistically in order to determine any statistically significant differences with the groups.

The following inferential statistics were obtained using the experimental group data and comparison group data for the RSPM over the duration of the first study. The results are summarised in Table 4.11. In Table 4.11, the F-ratio and the degrees of freedom (df) are presented. F is the sample statistic that is used to determine whether the variances in the two independent samples are equal. F is also used to calculate the probability value (p).

Table 4.11

Inferential statistics derived from RSPM test scores in Port Elizabeth (n = 675)

		F	p
A	Pre-Test	135.50	<.001
	ExpCon	9.41	.002
B	Pre-Test	219.48	<.001
	ExpCon	24.68	<.001
C	Pre-Test	91.47	<.001
	ExpCon	25.33	<.001
D	Pre-Test	116.12	<.001
	ExpCon	34.01	<.001
E	Pre-Test	19.97	<.001
	ExpCon	1.96	.162
TOTAL	Pre-Test	283.93	<.001
	ExpCon	57.40	<.001

F(df=1, 674)

The “Pre-test” rows indicate that all the tests were statistically significant with regard to the pre-tests. The “ExpCon” rows show that that there is also a significant difference between the mean scores of the experimental and comparison groups, except for section E. It was necessary to account for the fact that the experimental and comparison sample group could not initially be balanced with regard to the dependent variables, i.e. in this study not only the differences in the means between the experimental and comparison groups were considered, but also the initial positioning of the learners in terms of the RSPM test scores.

For this reason, Analysis of Covariance (ANCOVA) techniques had to be applied. Analysis of covariance is a more sophisticated method of analysis of variance (ANOVA) as it allows for the inclusion of continuous variables (covariates) into the ANOVA model. In this study, the covariates were the initial scores of the participants. In other words, the result of the treatment alone could be statistically evaluated between the experimental and comparison groups by eliminating the possibility that one class was inherently more able than another. As previously noted, the data generated by the RSPM tests were treated statistically using ANCOVA and the results of various views of the data are reported in tables 4.12 and 4.13.

Table 4.12 maps the significance of the experimental and comparison groups' test results. The RSPM scores are sectioned into five categories of 12 reasoning problems in increasing levels of difficulty in each category i.e. total of 60; whereas the subsections are scored up to a maximum of 12.

Table 4.12

Mean pre- and post-test scores, gain scores ($\Delta \bar{x}$), the practical (d) significance of the statistical data and statistical probability (p); (n=675; experimental, n = 479; comparison, n = 196; $\alpha=0.82$)

		Pre-	Post-	$\Delta \bar{x}$	d	p
A	Experimental	6.19	8.35	2.16	0.66	<.001
	Comparison	8.10	8.36	0.26	0.09	<.001
B	Experimental	4.13	6.14	2.01	0.63	<.001
	Comparison	6.00	5.93	-0.07	-0.02	<.001
C	Experimental	2.65	4.20	1.55	0.53	<.001
	Comparison	4.24	3.75	-0.49	-0.20	<.001
D	Experimental	2.55	4.24	1.69	0.57	<.001
	Comparison	3.99	3.54	-0.45	-0.16	<.001
E	Experimental	0.91	1.26	0.35	0.25	<.001
	Comparison	1.27	1.19	-0.08	-0.05	<.001
Total	Experimental	16.44	24.19	7.75	0.83	<.001
	Comparison	23.59	22.78	-0.81	-0.10	<.001

Note: ΔX denotes change in mean scores between pre-and post tests. A positive score implies that the post-test mean was higher than the pre-test mean.
d = Cohen's d.

Table 4.12 shows that there was a statistical difference between the mean pre-post scores of both the experimental groups as well as the comparison groups. The post-test mean scores are all higher than the pre-test mean scores for the experimental groups. This indicates that learning did take place in most groups during the nine-month period of the intervention. However, the comparison group demonstrated negative gains, or scored lower in their post-test, overall and in sections B, C, D and E.

The unit for reliability is Cronbach's coefficient alpha (α) and overall values are given for combined experimental and comparison groups. The threshold value for accepted

statistical reliability is that $\alpha > 0.70$. The reliability levels for the RSPM ($\alpha = 0.82$) may be considered as reliable. Cohen's d statistics were calculated to determine whether statistically significant ($p < 0.05$) pair-wise differences were practically significant. A small practical significance is noted where $0.2 < d < 0.5$; a moderate practical significance is noted if $0.5 < d < 0.8$ and a large practical difference is recorded if $d > 0.8$. Expressed differently, an effect size of less than 0.2 is considered to be insignificant, an effect size between 0.2 and 0.5 is considered to be of small significance; an effect size between 0.5 and 0.8 is considered as being moderately significant, while an effect size of 0.8 and greater is considered to be highly significant. Effect size as expressed by the Cohen's d statistics is defined as the difference in means divided by the pooled standard deviation and is a measure of magnitude (or significance) of the differences between the pre- and post-test scores (Gravetter & Walnau, 2008). As regards the total RSPM tests, the practical significance of the experimental groups is larger than the practical significance of the comparison groups.

Differences in mean score change between pre- and post-tests for experimental and comparison groups are reported in table 4.13.

Table 4.13

RSPM mean difference between experimental and comparison mean scores in Port Elizabeth (n = 675)

Section	$\Delta\bar{x}$ experimental	$\Delta\bar{x}$ comparison	Mean difference	p
A	2.16	0.26	1.90	<.005
B	2.01	-0.07	1.94	<.005
C	1.55	-0.49	1.06	<.005
D	1.69	-0.45	1.24	<.005
E	0.35	-0.08	0.27	<.005
Total	7.75	-0.81	6.94	<.005

$\Delta\bar{x}$ denotes difference in means. A positive score implies that the post-test mean was higher than the pre-test mean. As previously noted, the differences in the change in mean scores between the experimental groups was slightly larger than the change in mean scores between the comparison groups' pre- and post-tests. As $p < .05$ in all cases Cohen's d was calculated in order to gauge the effect size of the practical significance of the differences, which is reported in table 4.14.

Table 4.14

Overall comparison of practical significance for RPSM changes in Port Elizabeth (n = 675)

	Experimental		Comparison	
	d	Effect	d	Effect
A	0.66	Moderate	0.09	Insignificant
B	0.63	Moderate	0.02	Insignificant
C	0.53	Moderate	0.20	Small
D	0.57	Moderate	0.16	Insignificant
E	0.25	Small	0.05	Insignificant
Total	0.83	Large	0.10	Insignificant

d = Cohen's d .

The mean differences for the RSPM tests in Tyumie Valley have been graphed below to visually illustrate the increases in reasoning skill that occurred in the overall study pre-post the intervention.

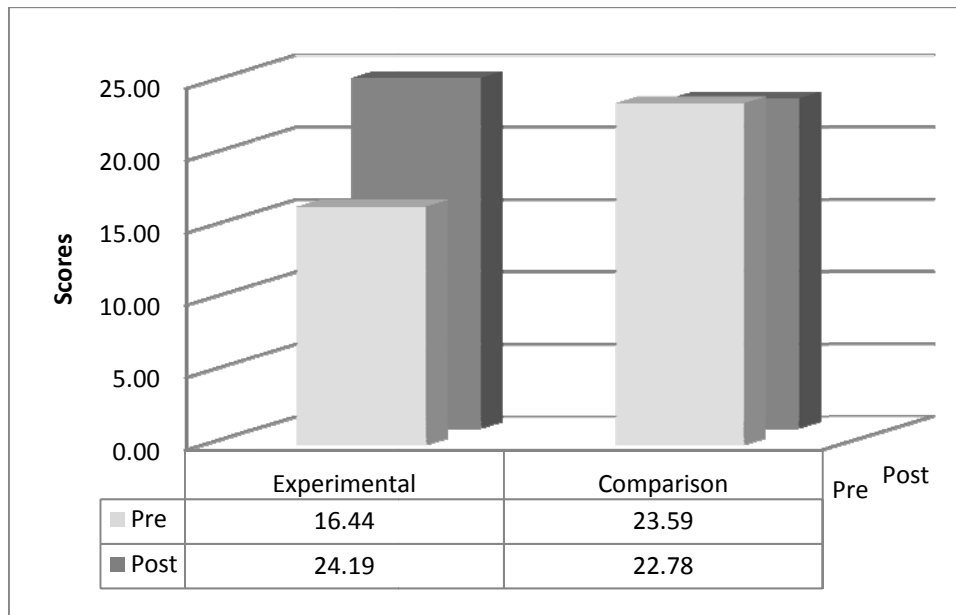


Figure 4.14 Comparison of the 50-percentile scores for the RSPM amongst the experimental and comparison groups in Port Elizabeth

The 50-percentile scores for the Port Elizabeth study groups depicted in Figure 4.14 illustrate any improvements made in the RSPM. In line with Raven’s procedures, the median score was used to provide a standard comparison of groups. The median pre- and post-test scores for the experimental and comparison groups fell at 16.44 and 24.29, and 23.59 and 22.78, respectively. The 50-percentile scores are notably lower than the United Kingdom (UK) 50-percentile norm of 38 for 12-year-old children.

3.2 Literacy tests

The literacy tests and the analysis of data for the Tyumie Valley group were replicated in Port Elizabeth. Table 4.15 reports the mean scores and the standard deviation derived from each section of the English and isiXhosa literacy tests for the experimental and comparison groups in Port Elizabeth.

Table 4.15

Descriptive statistics derived from the literacy test scores in Port Elizabeth (n=675)

	Experimental				Comparison			
	Pre		Post		Pre		Post	
	$\Delta \bar{x}$	δ	$\Delta \bar{x}$	δ	$\Delta \bar{x}$	δ	$\Delta \bar{x}$	δ
English								
Reading	38.16	13.16	38.78	15.39	26.95	13.03	28.79	12.49
Listening	57.26	15.33	63.11	16.83	54.53	18.23	56.57	17.66
Writing	26.38	16.87	34.36	17.84	23.33	9.80	24.25	10.28
Speaking	31.64	27.70	41.70	33.03	27.09	29.00	30.18	32.66
isiXhosa								
Reading	41.54	14.44	43.81	17.45	31.49	14.29	33.33	15.77
Listening	58.08	14.79	67.64	15.84	54.28	16.33	56.63	18.03
Writing	35.33	16.47	49.28	20.66	31.17	13.90	30.91	12.26
Speaking	36.00	26.17	72.73	7.50	40.73	25.46	56.36	10.39

The differences between mean scores of the experimental and comparison groups for the reading, listening, writing, talking aspects of the literacy tests (English and isiXhosa) were computed, and Analysis of Variance (ANOVA) techniques were applied. A positive score indicates a higher score for the experimental group than the comparison group, while a negative score indicates the opposite. An asterisk indicates that the difference is statistically significant, recorded as a 99% difference in confidence levels of learners (Table 4.16).

Table 4.16

Mean differences in the scores of the experimental and comparison groups in Port Elizabeth (n=675) for the pre- and post-tests in reading, listening, writing and talking in the English and isiXhosa tests (positive scores indicate a higher statistic for the experimental group than the comparison group).

	Differences in mean scores			
	English		isiXhosa	
	Pre-test	Post-test	isiXhosa	isiXhosa
Reading	11.21*	10.00*	10.05*	10.47*
Listening	2.72	6.54*	3.80	11.01*
Writing	3.05	9.90*	4.16	18.37*
Speaking	4.55	11.52	-4.73	16.36*

* = statistically significant at the 99% level of confidence

These data indicated that the experimental group of learners scored statistically significantly higher than the comparison group in the English and isiXhosa pre-test reading category. Although there were differences between the mean scores in the other categories, none of these scores were statistically significant. The post-test speaking section indicates that the comparison groups mean difference was higher than that of the experimental group, yet this difference was insignificant statistically. The post-test results in English and isiXhosa indicate that positive scores indicate a higher statistically significant score for the experimental group than the comparison group for reading, listening and writing. While the difference in mean score was higher in the English post-test speaking section, the differences did not reflect statistically significant changes. However, the isiXhosa post-test in the speaking section generated a change in mean difference that was statistically significant.

Comparisons were made of the changes in pre- and post-test scores in all the literacy categories for the experimental and comparison groups: reading, listening, writing and talking. There were minimal changes in the mean score for reading, as indicated in Table

4.17. The negative figure indicates that a bigger change in score was recorded for the comparison group than the experimental group.

Table 4.17

Difference in mean score changes between the experimental and comparison groups for reading ability (n=675). A negative figure indicates that a bigger change in score was recorded for the comparison group than the experimental group in Port Elizabeth.

	Mean change	p	Cohen's d
English	-1.22	0.465	n/a
isiXhosa	0.42	0.811	n/a

n/a = not applicable

The improvement in the mean scores of the comparison group in terms of English reading was higher than that of the experimental group. However, this trend was reversed in the isiXhosa reading. The marginal improvements in both languages were not statistically significant.

The next section of the literacy tests focused on learners' listening skills. The mean differences between the pre- and the post-test scores for the experimental and comparison groups in terms of listening are shown in Table 4.18. Positive figures indicate a bigger change in listening skills between the pre- and post-test scores for the experimental group than the comparison group.

Table 4.18

Difference in mean score changes between the experimental and comparison groups for listening ability (n=675) in Port Elizabeth

	Mean change	p	Cohen's d
English	3.82	0.066	n/a
isiXhosa	7.21*	0.0005	0.38

* = statistically significant at greater than the 99.9% level of confidence ($p \leq 0.005$)

The improvement in the mean score of the experimental group in English, yet it was not statistically significant. In contrast to this, improvement in the mean score for the experimental group in isiXhosa was statistically significant and the Cohen's d score suggests a small effect size (0.2-0.5 = small effect; 0.5-0.8 = medium; ≥ 0.8 = large). This means that the workshops had a slight effect in practical terms on the experimental group as a whole.

In addition to testing the listening and reading capabilities of the learners, their writing abilities were also assessed. The mean differences between the changes of the pre- and post-test scores for the experimental and comparison groups in terms of writing are depicted in Table 4.13.

Table 4.19

Difference in mean score changes between the experimental and comparison groups for writing ability (n=675) in Port Elizabeth

	Mean change	p	Cohen's d
English	6.85*	0.0005	0.39
isiXhosa	14.21*	0.0005	0.63

* = statistically significant at greater than the 99.9% level of confidence ($p \leq 0.0005$)

The improvements of the mean scores of the experimental groups in English and isiXhosa writing was statistically significant and the Cohen’s d score indicates that there was a small effect in English and in isiXhosa, there was a medium effect in practical terms on the experimental group as a whole.

The final section of the literacy test focused on learners speaking abilities. The mean differences between the changes of the pre- and post-test scores for the experimental and comparison groups in terms of speaking are shown in Table 4.20.

Table 4.20

Difference in mean score changes between the experimental and comparison groups for speaking ability (n=22) in Port Elizabeth

	Mean change	p	Cohen's d
English	6.97*	0.010	0.94
isiXhosa	21.09*	0.006	1.01

* = statistically significant difference at greater than the 99% level of confidence ($p \leq 0.01$)

The improvements for both English and isiXhosa speaking for the experimental group were statistically significant and the Cohen’s d figures indicate that there was a large effect size for the results in both languages.

The differences in the learners’ abilities to listen, read, write and speak in English and isiXhosa are shown in Table 4.21. This analysis combines the experimental and comparison groups. A positive number indicates a higher score for the isiXhosa test than what was attained for the same activity in English.

Table 4.21

Mean differences in scores between learners' English and isiXhosa abilities in reading, listening, writing and speaking (n=675) in Port Elizabeth

	Mean differences between English and isiXhosa test scores							
	Pre-test				Post-test			
	Mean diff	n	p	d	Mean diff	n	p	d
Reading	1.16	298	0.469	n/a	-0.48	298	0.766	n/a
Listening	-1.07	298	0.548	n/a	-4.46	298	0.008	0.25
Writing	-1.11	298	0.477	n/a	-8.47*	298	0.0005	0.4
Speaking	9.27	22	0.406	n/a	-0.485	22	0.657	n/a

* = statistically significant difference at greater than the 99.9% level of confidence ($p \leq 0.005$); n/a= not applicable

The data above reveals that the pre-test learners' reading scores were better in isiXhosa than in English. However, learners reading abilities in English improved in the post- test. In the listening and writing pre-tests, the mean differences favoured the English tests. Learners' English skills improved in post-test, with writing showing statistically significant mean difference. The Cohen's d scores for the listening and writing post-tests suggests that the workshops had a slight effect in practical terms for English usage. While the learners' mean difference was quite high for isiXhosa in the pre-test, the post-test score suggests learners English-speaking abilities improved in the post-test.

3.3 Classroom observations

As with the Tyumie Valley study, classroom observations formed a part of the Port Elizabeth study. A total of four classroom observations were conducted with the six (n=6) teachers of the experimental group and, as with the Tyumie Valley study, the primary focus

of the classroom observations were to track the experimental teachers' progression in the implementation process of the integrated teaching strategies approach; therefore, the two (n=2) comparison group teachers were not formally observed. The classroom observation schedule was used to assess the diagnostic and the three subsequent observations. Information from the preliminary observation was later used to measure any modifications to the teachers' classroom practice throughout the study.

Component 1: Use of stimulus

In the study, the teachers' use of a stimulus over four classroom observation sessions in the experimental schools in Port Elizabeth is illustrated in Figure 4.15.

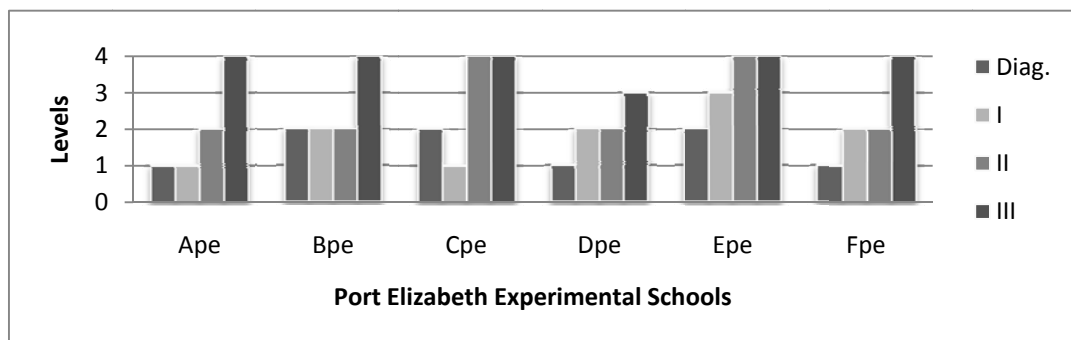


Figure 4.15 Teachers' use of a stimulus over four classroom observation sessions in the experimental schools in Port Elizabeth

Results of the diagnostic observation indicate that teachers from schools A_{pe}, D_{pe} and F_{pe} did not use an introduction to stimulate learners' thoughts about the science topic (Level 1; n=3). However, the remaining teachers from schools B_{pe}, C_{pe} and E_{pe}, provided a brief introduction to the lesson and elicited learners' ideas by asking closed-ended questions (Level 2; n=3). None of the teachers began their lesson by asking higher-order thinking questions or questions prompted by the use of 'why' or 'how' related to the science topic (Level 3; n=0), nor did any teachers use a stimulus such as a reading or discrepant event as an introduction to their lesson (Level 4; n=0).

Subsequent to the training sessions, the teacher from school A_{pe} remained at Level 1 (n=1) whilst the counterparts, teachers from schools B_{pe}, D_{pe}, and F_{pe}, began their lesson with a brief introduction and closed-ended questions (Level 2; n=3). Teacher from school E_{pe} progressed to Level 3 (n=1) by asking his/her learners higher-order thinking questions at the onset of the science lesson. Teacher from school C_{pe} regressed to Level 1 (n=1). By observation II, however, teacher from school C_{pe}, along with E_{pe}, made considerable gains in using a stimulus (Level 4; n=2). Teacher from school E_{pe} read a short story titled “A Trip to the Recycling Factory” to the learners. This particular read-aloud story encouraged learners to think about how certain metals are sorted in the factory by the use of a strong magnet. Teachers B_{pe}, D_{pe} and F_{pe}, consistently remained at Level 2 (n=3). Teacher A_{pe} also displayed progress in this level. The final observation marked sizeable gains for all teachers (Level 4; n=5), excluding D_{pe} whose brief introduction consisted of closed-ended questions (Level 3; n=1).

Component 2: Exploratory talk and classroom discussion

The next component of the study, the teachers’ use of exploratory talk and classroom discussion over four classroom observation sessions in the experimental schools in Port Elizabeth, is Component 2, which is illustrated in Figure 4.16.

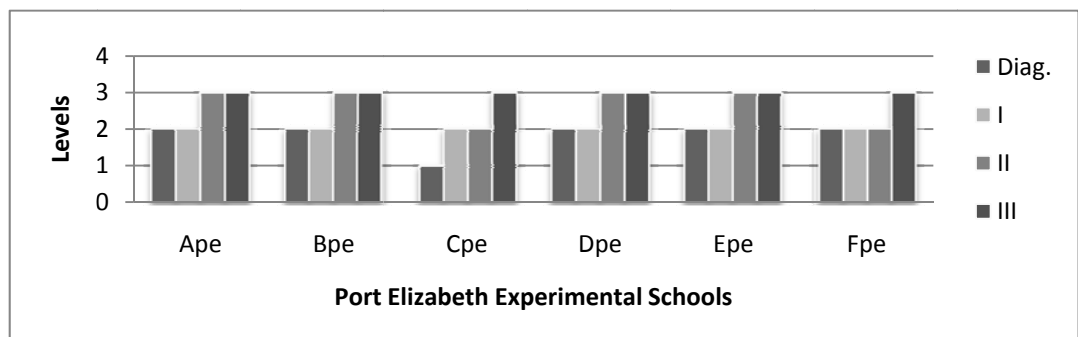


Figure 4.16 Teachers’ use of exploratory talk and classroom discussion over four classroom observation sessions in the experimental schools in Port Elizabeth

Prior to the professional development workshops, the dialogue present in all classrooms consisted of teachers' use of questions to elicit responses and the answers given by the learners. There was little else in terms of classroom discussion (Level 2; n=5). Teacher from school C_{pe}'s classroom lacked any discussion activities whatsoever (Level 1; n=1). During this observation, teacher from school C_{pe} dominated the verbal communication in the classroom, but by observation I, he/she progressed to the same level of his/her colleagues.

Teachers from schools A_{pe}, B_{pe}, D_{pe}, E_{pe} and F_{pe} remained at Level 2 (n=5) of Component 2 during observation I. During observation II, teachers from schools C_{pe} and F_{pe} continued in the pattern of minimal discussion and closed-ended questions (Level 2; n=2). However, there was evidence of learners engaging in cumulative or disputation discussion (Level 3; n=4) in classrooms from schools A_{pe}, B_{pe}, D_{pe} and E_{pe}. Learners' retorts or affirmations were generally offered at the teacher's request. By the final observation, all of the classrooms engaged in Level 3 (n=6) discussion. There was, however, as no evidence of teachers facilitating exploratory talk (Level 4; n=0).

Component 3: Investigable questions

Component 3, the teachers' use of an investigable question over four classroom observation sessions in the experimental schools in Port Elizabeth, is illustrated in Figure 4.17.

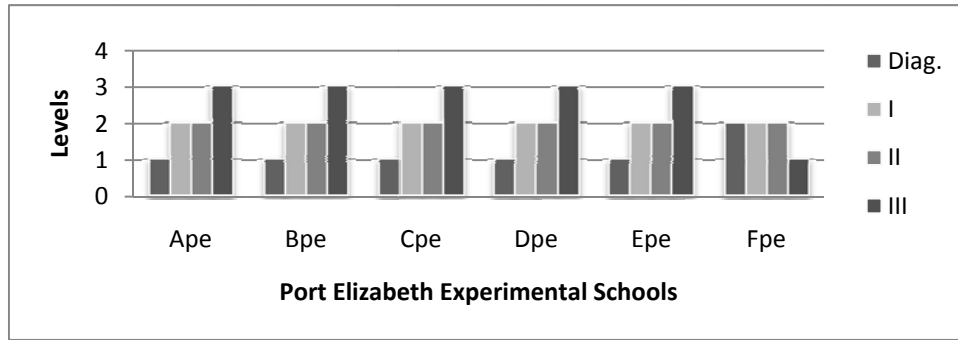


Figure 4.17 Teachers' use of an investigable question over four classroom observation sessions in the experimental schools in Port Elizabeth

Results of the diagnostic observation indicate that teachers from schools A_{pe} , B_{pe} , C_{pe} , D_{pe} , E_{pe} did not have a (supplied or facilitated) question for learners to investigate in class (Level 1; $n=5$). Teacher from school F_{pe} , however, provided an investigable question in his/her classroom (Level 2; $n=1$). There was no evidence that teachers guided their learners by asking an investigable question (Level 3; $n=0$), nor was there evidence of learners posing their own questions to test in class (Level 4; $n=0$).

Following the professional development workshops, all of the teachers provided questions for learners to investigate during observations I and II (Level 2; $n=6$). During these observations, the teachers facilitated either the water drop or the magnet and washer investigation. By the final observations, five of the six teachers guided learners in asking an investigable question (Level 3; $n=5$). Teacher from school C_{pe} asked learners what questions they had about magnets, gathered their responses on the blackboard and then prompted learners to ask various questions about how to determine the strength or weakness of the round magnet. During observation III, teacher from school F_{pe} dropped to Level 1 ($n=1$) by not supplying or facilitating a question for learners to investigate.

Component 4: Planning an investigation

The next component, Component 4, deals with the learners' ability to plan an investigation over four classroom observation sessions in the experimental schools in Port Elizabeth. This is shown in Figure 4.18.

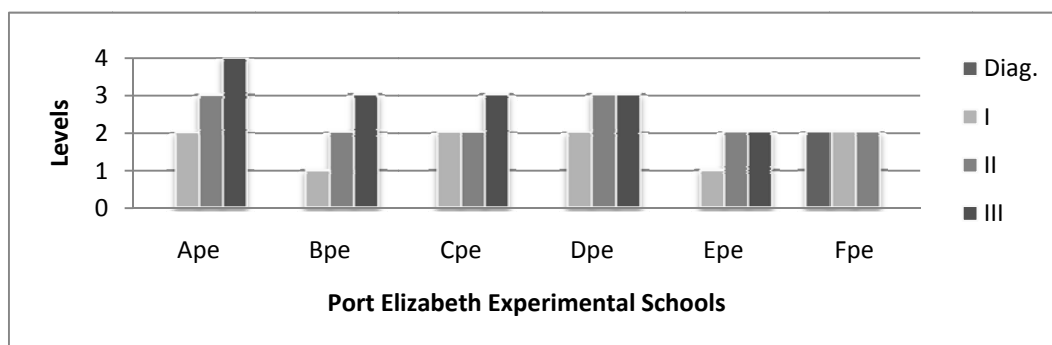


Figure 4.18 Learners' ability to plan an investigation over four classroom observation sessions in the experimental schools in Port Elizabeth

As there was no question to investigate in Component 3, a nought response was captured for schools A_{pe}, B_{pe}, C_{pe}, D_{pe}, E_{pe}, for Component 4. Although teacher from school F_{pe} provided an investigable question, learners in this his/her class were still unable to formulate ways in which to answer the question (Level 1; n=1). During the initial observation, there was no evidence that several learners interacted within a large group and offered ideas in which to answer the investigable question (Level 3; n=0). There was also no evidence that learners discussed, questions or ways in which to answer the investigable question independently (Level 4; n=0).

However, during observation I, learners from all of the schools displayed progression in planning an investigation. Four schools followed their teacher's step-by-step instructions to answer the investigable question (Level 2; n=4) whilst schools B_{pe} and E_{pe} advanced to

Level 1 (n=2). Teachers assisted learners by prescribing the instructions, which appeared to be an effective strategy as most learners were unfamiliar with the processes of an investigation. This introduction to plan an investigation afforded the learners from schools A_{pe} and D_{pe} the opportunity to work with 2 or 3 of their peers in suggesting ways to answer the investigable questions during observation I (Level 3; n=2). Learners from schools B_{pe}, C_{pe}, E_{pe} and F_{pe} continued to rely on their teacher for assistance with the investigative plan (Level 2; n=4). While learners from schools B_{pe}, C_{pe} and D_{pe} exhibited Level 3 (n=3) planning in the final observation, learners from school E_{pe} continued to follow the teacher's step-by-step plan. Learners from school A_{pe} were able to, independently from their teacher, collaborate and discuss ways in which to answer the investigable question (Level 4; n=1). As learners from school F_{pe} did not have a question to investigate (Component 3), a naught response was also captured for the observation III.

Component 5: Conducting an investigation

Component 5, the learners' ability to conduct an investigation over four classroom observation sessions in the experimental schools in Port Elizabeth, is illustrated in Figure 4.19.

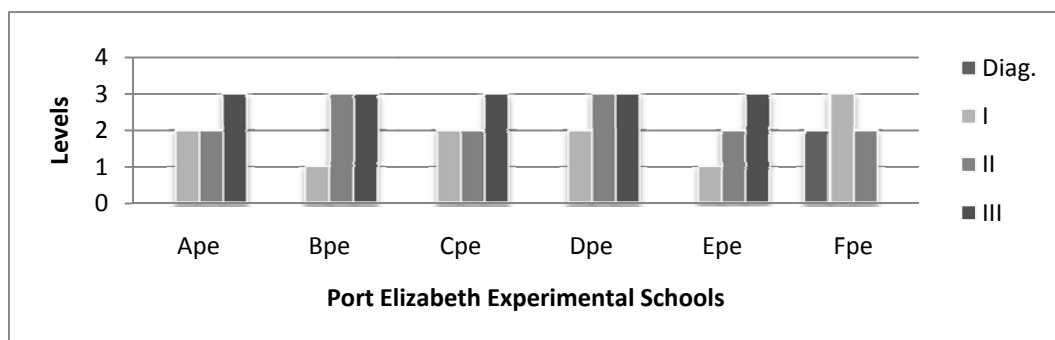


Figure 4.19 Learners' ability to conduct an investigation over four classroom observation sessions in the experimental schools in Port Elizabeth

As with Components 3 and 4, a naught response was captured for schools A_{pe}, B_{pe}, C_{pe}, D_{pe}, and E_{pe} for conducting an investigation during the diagnostic observation. Learners in school F_{pe} were able to conduct the investigation as their teacher demonstrated how to use the apparatus, collect data and draw conclusions (Level 2; n=1). There was no evidence that learners were able to use their apparatus, collect data and draw conclusions (Level 1; n=0), nor was there evidence that learners used their apparatus, collected data or came to conclusions independently (Level 4; n=0) or with teacher guidance (Level 3; n=0).

Subsequent to the Scientific Literacy Strategy workshops, learners from schools A_{pe}, C_{pe}, and D_{pe} were able to use their apparatus, collect data and draw conclusions as modelled by their teacher (Level 2; n=3), while learners from school F_{pe} were able to conduct these aspects of an investigation only with the guidance from their teacher (Level 3; n=1). Conversely, learners from school E_{pe} were unable to perform any aspects of the investigation during observation I (Level 1; n=1).

By observation II, however, learners from school E_{pe}, along with A_{pe}, C_{pe}, and F_{pe}, also progressed to Level 2 (n=4). Learners from schools B_{pe} and D_{pe} reached Level 3, conducting the investigation with the guidance of their teacher, in observation II, as well as in the final observation. Once again, a naught response was captured for observation III as learners from school F_{pe} did not have a question to investigate. Throughout the observations, there was no evidence that learners proceeded to Level 4 (n=0).

Component 6: Learners' writing with science notebooks

In addition to their ability conduct an investigation, learners' ability to write for science using science notebooks was also analysed. The learners were assessed on this component, Component 5, during four classroom observation sessions in the experimental schools in Port Elizabeth. This is illustrated in Figure 4.20.

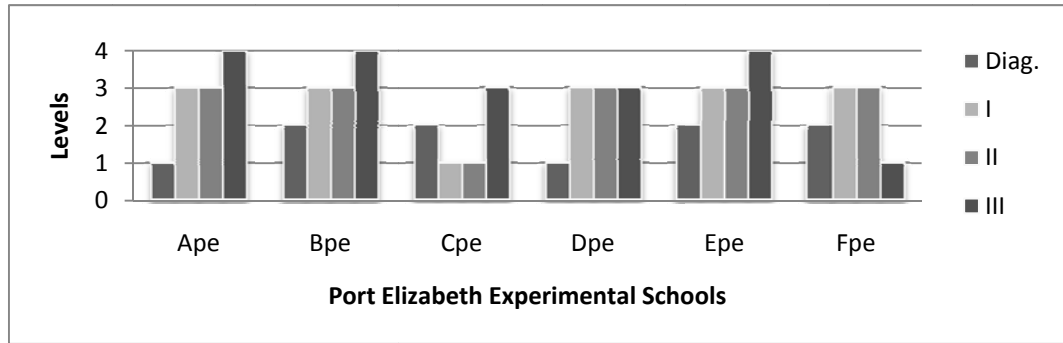


Figure 4.20 Learners' ability to write for science using their science notebooks over four classroom observation sessions in the experimental schools in Port Elizabeth

Results from the diagnostic observations indicate that learners from schools A_{pe} and D_{pe} did not engage in any writing activities (Level 1; $n=2$). Although the remaining learners engaged in writing, analysis of the science notebooks suggest that that the content of the writing was incoherent and did not enhance learning (Level 2; $n=4$). There was no evidence of simplistic writing (Level 3; $n=0$) or effective writing to record findings and enhance learning (Level 4; $n=0$).

Observation I displayed considerable gains in all learners' abilities, except those of learners from school C_{pe} . The learners from schools A_{pe} , B_{pe} , D_{pe} , E_{pe} , F_{pe} exhibited simplistic writing in their science notebooks and continued in this manner during observation II (Level 3; $n=5$). Learners from school C_{pe} did not engage in writing during observations I and II (Level 1; $n=1$), but, in the final observation, showed evidence of basic written text in their science notebooks (Level 3; $n=1$). Learners from school D_{pe} consistently remained at Level 3, simplistic writing, in terms of their writing in observations I, II and III. While learners from school F_{pe} did not write for science in the final observation (Level 1; $n=1$), learners from schools A_{pe} , B_{pe} , and E_{pe} advanced to the highest level of writing by writing effectively to record findings and enhance learning (Level 4; $n=3$). Teachers from these schools

continually guided learners and reinforced various writing skills, for example by using words such as *first*, *next* and *last* when writing down their procedure or suggesting that learners utilise phrases such as, “I think... because...”.

Component 7: Learner reading

The next component, Component 6, deals with learners’ ability to read for science over four classroom observation sessions in the experimental schools in Port Elizabeth. This is shown in Figure 4.21.

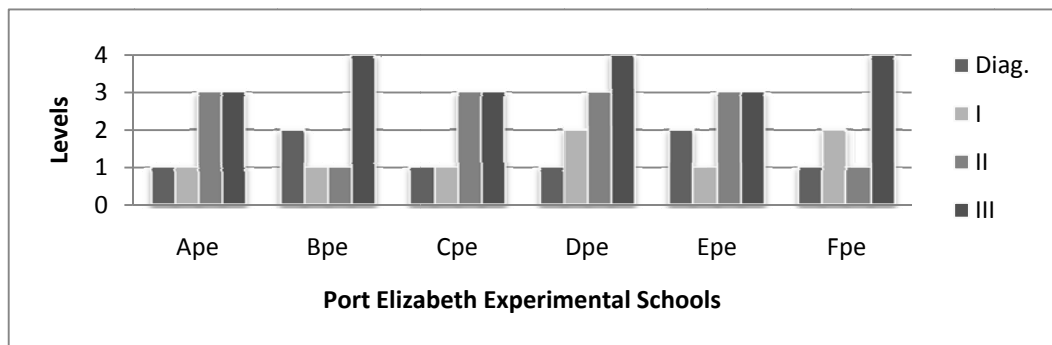


Figure 4.21 Learners’ ability to read for science over four classroom observation sessions in the experimental schools in Port Elizabeth

Data from the diagnostic observations indicate that learners from schools B_{pe}, and E_{pe} engaged in reading, but struggled to read from written text. The reading that the learners engaged in had limited to no effect on their learning (Level 2; n=2). The remaining four schools did not provide evidence that any reading took place (Level 1; n=4). During the initial observation, there also was no evidence that the learners read effectively from various forms of literature to enhance their learning (Level 4; n=0), nor was there evidence that the learners read simplified or ineffective text (Level 3; n=0).

During observation I, learners from schools D_{pe}, and F_{pe} progressed to Level 2 (n=2) reading. The learners from schools A_{pe} and C_{pe} remained at Level 1, while learners from schools B_{pe} and E_{pe}, regressed to this level of reading (n=4). Although learners from schools B_{pe} and F_{pe} did not yet read for science during observation II (Level 1; n=2), the remaining learners were reading simplified text, such as reading vocabulary on the blackboard, to support the lesson. By the final observation, at least half of the learners were reading at Level 3 (n=3) and learners from schools B_{pe}, D_{pe} and E_{pe}, could read effectively to enhance their learning (Level 4; n=3). The teacher from school B_{pe} assigned various readings in the textbook for learners to read and to supplement his/her lesson on vertebrates and invertebrates. Prior to the reading, the teacher reminded her learners to stop after the section and consider whether they: 1) understood the reading, 2) needed to ask someone about the section, 3) could skim the section to find the focus words, and 4) could compile information to answer questions from the section.

Component 8: Teachers' questioning skills

The teachers' questioning skills were the eighth aspect of the classroom observation analysed in this study. Component 8 was observed during four classroom observation sessions in the experimental schools in Port Elizabeth and is illustrated in Figure 4.22.

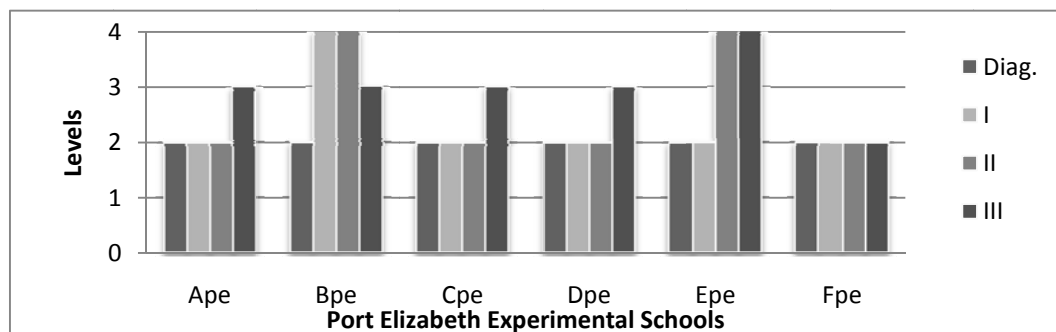


Figure 4.22 Teachers' questioning skills over four classroom observation sessions in the experimental schools in Port Elizabeth

Of the six classes observed, none of the teachers asked a variety of open and close-ended questions which probed for learners' understanding (Level 4; n=0), nor did any of the teachers ask mostly close-ended questions with one or two open-ended questions (Level 3; n=0) during the diagnostic observation. There was, however, evidence that all teachers asked simple-recall or close-ended questions (Level 2; n=6).

Level 2 questioning continued in observations I and II for schools A_{pe}, C_{pe}, D_{pe}, E_{pe} and F_{pe} (n=5). The teacher A_{pe} regularly posed questions, but only three to four learners participated by answering the questions. When the teacher asked learners to share their predictions during observation II, three learners raised their hand to contribute. Learners were not required or guided to include the reasons for their prediction. Only two teachers from schools B_{pe} and E_{pe}, were able to advance to a more sophisticated form of questioning, which incorporated both open and close-ended questions, in observations I and II and observations II and III respectively (Level 4; n=2). During observation III, the teachers from schools A_{pe}, B_{pe}, C_{pe}, D_{pe} progressed to Level 3 (n=4) and the teacher from school F_{pe} continued to ask simple-recall or close-ended questions throughout the study (Level 2; n=1).

Component 9: Teachers' feedback

The teachers' use of feedback is the ninth component of this study. This component was analysed over four classroom observation sessions in the experimental schools in Port Elizabeth, as is illustrated in Figure 4.23.

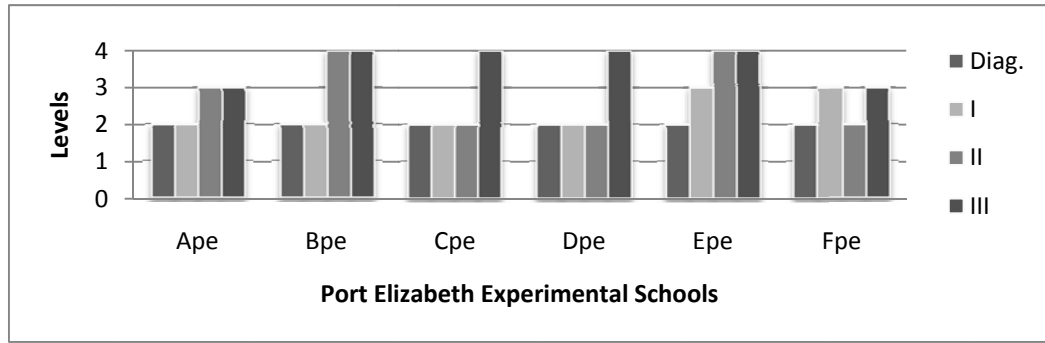


Figure 4.23 Teachers' use of feedback over four classroom observation sessions in the experimental schools in Port Elizabeth

Results from the diagnostic information indicate that all teachers provided feedback to incorrect responses in a manner that discouraged further effort (Level 2; n=6). During the observation, it was common practice for teachers to ignore learners' incorrect responses and continue to ask the question until one of the learners provided the correct response. If the learners did not offer sufficient answers, then the teacher would provide the answer. There was no evidence that teachers provided feedback about in situations where learners provided either only incorrect answers (Level 3; n=0) or where learners provided a combination of correct and incorrect answers (Level 4; n=0) in a manner that encouraged further effort.

Level 2 feedback persisted for teachers from schools A_{pe}, B_{pe}, C_{pe}, and D_{pe} during observation I (n=4). However, teachers E_{pe} and F_{pe} advanced from responding in a discouraging manner to one that encouraged the continued engagement from the learners (Level 3; n=2). By observation II, several teachers moved beyond Level 2 feedback skills. The teacher from school A_{pe}'s feedback encouraged learners who answered incorrectly (Level 3; n=1), while teachers B_{pe} and E_{pe} provided encouraging remarks or kept positive demeanours for all learner responses (Level 4; n=2). The remaining teachers continued to respond at Level 2. During the final observations, four out of the six teachers achieved Level 4 scores

(n=4) for this component of the study. The teachers from schools A_{pe} and F_{pe} produced Level 3 (n=2) feedback.

Component 10: Line of learning – Teachers’ subject knowledge

The next component of the study, Component 10, deals with the teachers’ subject knowledge. This was observed during four classroom observation sessions in the experimental schools in Port Elizabeth and is illustrated in Figure 4.24.

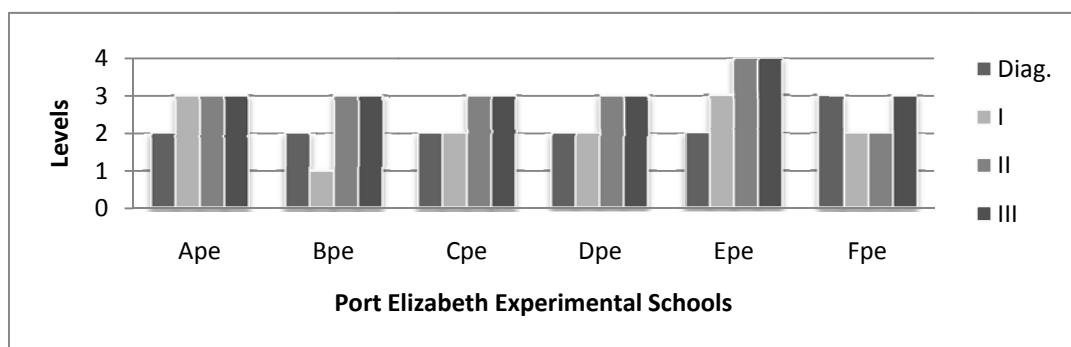


Figure 4.24 Teachers’ subject knowledge over four classroom observation sessions in the experimental schools in Port Elizabeth

Results from the initial observation indicate that none of the teachers demonstrated a clear understanding of the concepts being taught (Level 4; n=0) except for the teacher from school F_{pe} who displayed an adequate understanding (Level 3; n=1). The remaining five teachers exhibited a partial understanding of the concepts that they taught (Level 2; n=5). There were no teachers in the initial observation whose understanding would be classified as inadequate (Level 1; n=0).

During observation I, teachers from schools C_{pe}, D_{pe}, and F_{pe} continued to demonstrate partial understanding of the concepts (Level 2; n=3), while teacher from school B_{pe}’s content knowledge of the given lesson was insufficient (Level 1; n=1). Teachers from

schools A_{pe} and E_{pe} showed adequate subject knowledge, during their lessons in observation I (Level 3; n=2). Observation II yielded Level 3 (n=4) results for schools A_{pe}, B_{pe}, C_{pe}, and D_{pe}, and Level 2 (n=1) for F_{pe}. During observation II, teachers often used various examples to illustrate ideas. For example, teacher from school D_{pe} explained series and parallel circuits in relation to the lights in the classroom. She even posed the question, “If all the lights in the classroom were connected in series and one light went out, what would happen to the other light bulbs?” During the final observation, the teacher from school E_{pe} continued to excel in her content knowledge (Level 4; n=1) whilst her colleagues provided evidence that their understanding of the concepts which they taught was adequate (Level 3; n=5).

Component 11: Line of learning – Student generated ideas

Over four classroom observation sessions, learners from the experimental schools in Port Elizabeth were assessed on their ability to generate ideas regarding the lesson presented. Their demonstrated levels are illustrated in Figure 4.25.

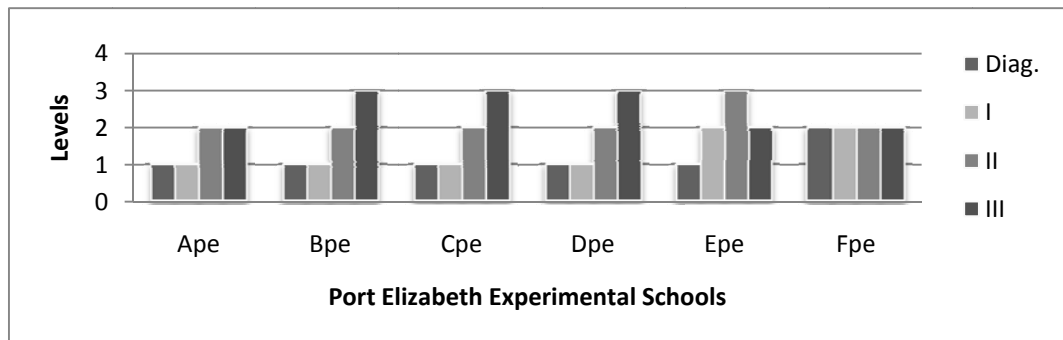


Figure 4.25 Learners’ ability to generate ideas over four classroom observation sessions in the experimental schools in Port Elizabeth

There was no evidence in the five classes observed that learners were able to clearly (Level 4; n=0) or adequately (Level 3; n=0) expand their scientific understanding through

their own efforts. The learners from school F_{pe} were able to partially expand (Level 2; n=1) their scientific understanding during the discussion of the Line of Learning. However, learners from the remaining schools were unable to expand (Level 1; n=4) their scientific understanding during this discussion.

During observation I, learners from schools A_{pe}, B_{pe}, C_{pe}, and D_{pe} remained at Level 1 (n=4), but by the observation II they, along with learners from school F_{pe} were able to expand their ideas partially (Level 2; n=5). Learners from school E_{pe} demonstrated the ability to adequately expand on their ideas (Level 3; n=1). By the final observation, half of the learners (B_{pe}, C_{pe}, D_{pe}) advanced to Level 3 (n=3) whilst the remaining learners stayed at Level 2 (n=3). Throughout the observations, learners were unable to clearly (Level 4; n=0) expand their scientific understanding through their own efforts.

Component 12: Argumentation and presentation – learners’ subject knowledge

The learners’ subject knowledge demonstrated through argumentation and presentations over four classroom observation sessions in the experimental schools in Port Elizabeth is illustrated in Figure 4.26.

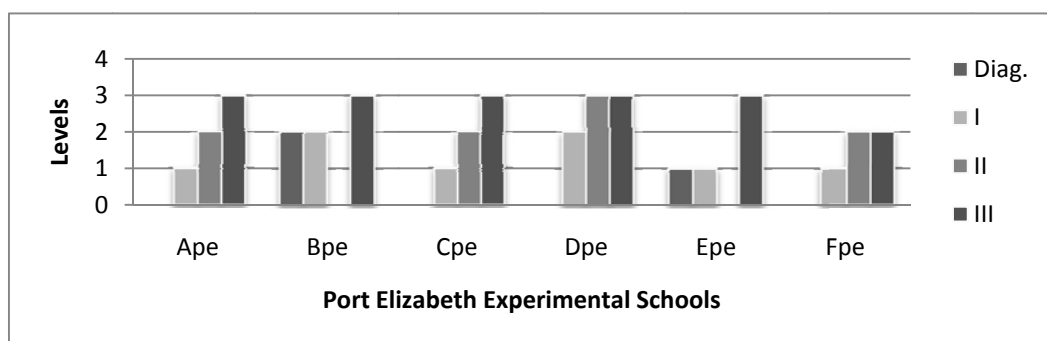


Figure 4.26 Learners’ subject knowledge demonstrated through argumentation and presentations over four classroom observation sessions in the experimental schools in Port Elizabeth

Results from the diagnostic observation indicate that there were no presentations in four of the six the classrooms, hence, a naught response was recorded for schools A_{pe}, C_{pe}, D_{pe}, and F_{pe} (n=4). Learners from school E_{pe} presented their ideas and demonstrated very limited conceptual understanding (Level 1; n=1) and learners from school B_{pe} presented their ideas in a manner which demonstrated a partial (Level 2; n=1) understanding. There were no learners who displayed an adequate (Level 3; n=0) or clear (Level 4; n=0) understanding of the concepts or procedures taught during the initial observation.

During observation I, the majority of learners (A_{pe}, C_{pe}, E_{pe}, F_{pe}) presented their ideas, but also displayed very limited understanding of the concepts taught in class (Level 1; n=4). Learners from schools B_{pe} and E_{pe} exhibited partial understanding of scientific conenpts (Level 2; n=2), as did learners from schools A_{pe}, C_{pe}, and F_{pe} during observation II (Level 2; n=3). Learners from schools B_{pe} and E_{pe} did not present at this time. The final observation yielded Level 3 (n=5) results for all schools other than F_{pe} whose learners remained at Level 2 (n=1). The majority of presentations simply reflected what was done during the investigation. The presentations, however, became much more effective when the teachers instructed the learners to use Toulmin's model to offer the reasons, evidence and possible rebuttals to their claims. None of the learners presented their ideas or argued their point of view regarding scientific concepts in a manner which demonstrated that they had a clear understanding of the concepts taught during their science lesson (Level 4; n=0).

3.4 Learners' science notebooks

As in the case of the Tyumie Valley study, the analysis of learners' science notebooks were used to measure the level of learners' conceptual and procedural understanding when conducting scientific investigations. It was also used to determine if and how teachers used the science notebook strategy in relation to the integrated teaching strategies approach. A

random sample of thirty-six (n=36) learners' science notebooks were collected across the six schools (six notebooks per school). As the data generated from the science notebooks were used to supplement data from the classroom observations, the sample was only collected from the learners in the experimental group. The collection of learners' entries were analysed using the Science Notebook Checklist and an average score was used to describe the overall level of their science writings. Data generated from the learners' science notebooks (n = 36) have been analysed and yielded the following information regarding the construction of an investigable question, designing an investigation, collecting and recording data, the use of scientific drawings and drawing conclusions.

Constructing an investigable question

The analysis of learners' science notebooks indicate that the majority of the learners copied their teacher's question (Level 1; n=19) during scientific investigations conducted in the classrooms. The investigable questions that were analysed in the learners' notebooks, especially for observations I and II, resulted from the investigations which were used during the training at the professional development workshops. While there was evidence that the teachers posed other questions as well, these questions could be classified as experimental, demonstrational or researchable questions. One example of a researchable question, which was posed, was, "Is [the animal] a vertebrate or an invertebrate?"

Nearly one-third of the learners wrote questions in his or her own words. These questions were, however, not investigable questions (Level 2; n=11). During a lesson on magnetism, the teacher asked, "Is the material magnetic or non-magnetic?" Some learners rewrote the question as, "Will the object stick to the magnet?" Six learners were able to construct an investigable, but did not include all the relevant details in their questions. For example, learners asked, "How can we make it bright?" as opposed to, "How can we make

the bulb shine or glow brighter?” There was no evidence that learners constructed clear and/or accurate Level 4 investigable questions.

Designing an investigation

Of the thirty-six notebooks analysed, all of the learners demonstrated evidence of an experimental procedure in their science notebooks. Most of the learners were able to design and write a plan in answering the question. Some of the learners’ plans were, however, incorrect (Level 2; n=14), while others’ investigations could not be replicated as there were details missing from the text (Level 3; n=19). The most common mistakes that learners made in Level 2 and 3 entries, were that they omitted important steps of the plan, that they did not always consider the fairness of the test, and that the designs were incongruous with the investigable question. A small group of learners demonstrated that they were able to create and write down a complete and replicable procedure (Level 4; n=3).

Collecting and recording data

Data from learners’ science notebooks in Port Elizabeth indicate that all learners collected and recorded data throughout the intervention. The majority of learners were able to record accurate, albeit incomplete data (Level 3; n=17) and ten learners provided complete and accurate data in their science notebooks (Level 4; n=10). Nine learners produced Level 2 (n=9) entries, which contained inaccurate data. Examples of inaccurate data include utilising the incorrect units of measurement, omitting key measurements or miscalculating averages or differences between several figures.

Scientific drawings

Results from the analysis of the scientific drawings illustrate a wide range of data. This included: learners who had no drawings in their notebooks (Level 0; n=3); learners who

copied teacher's drawings (Level 1; n=3); learners creating drawings which were labelled incorrectly or omitted relevant detail (Level 2; n=7); labelled drawings which included only limited relevant detail (Level 3; n=18), as well as original drawings by learners which were correctly labeled and provided details regarding their observations (Level 4; n=5). Over half of the learners produced Level 3 drawings, which, with more attention to labelling or the materials used, could advance to Level 4.

Drawing conclusions

Analysis of the science notebooks indicates that all learners wrote a conclusion about their investigation. A small number of learners were able to correctly write a complete explanation about the investigation using his/her own words (Level 4; n=3) and ten learners' conclusions were also correct, although missing some relevant detail (Level 3; n=10). The other half of the learners either copied their teachers' explanation (Level 1, n=12) or were unable to construct a correct conclusion (Level 2; n=11). Learners often reiterated the result of the investigation with no explanation as to why they believed they achieved those results.

3.5 Teacher interviews

During the second study, semi-structured interviews were conducted with the Port Elizabeth experimental teachers (n=6). As with the Tyumie Valley study, the initial interview was conducted to evaluate teachers' ideas and attitudes regarding scientific literacy, to elicit what type of literacy and inquiry activities occurred in the classroom that supported science learning, and to investigate teachers' perceptions regarding whether their classroom environment was conducive to teach science. Upon completion of the intervention, an additional interview was conducted to establish if and/or how the teachers' ideas about and attitudes towards scientific literacy changed throughout the course of the intervention. The

concluding interview was also used to obtain the teachers' professional view regarding the implementation of the integrated teaching strategies approach model.

The questions and interview methodology for the second study group was replicated from the Tyumie Valley study. As with that study, data have been analysed and categorised into broad themes according to the teacher's responses. For the purposes of reporting, the themes and the frequency of the themes are presented in this section.

Diagnostic interview

During the diagnostic interview, teachers were asked about 'scientific literacy' and were asked to describe their interpretation of this term. The most frequent response to this question was associated to "understanding" or having "knowledge about science". It should be noted, however, that the teachers' use of the phrase knowledge about science is not associated to the knowledge about the development or nature of science as conventionally understood in science education discourse. Responses such as, "Scientific literacy, I think it's about the knowledge about science, like knowing concepts and vocabulary" more closely reflect knowledge in science. One teacher alluded to scientific literacy in relation to the nature of science by saying, "Seeing just a product does not satisfy me. I become curious to know how it was before, i.e. the process it undergone to be what it is. At time I have imaginations of what had happen & began to explore."

The next most common themes of scientific literacy centred on notions of general literacy, such as reading and writing, the interpretation of science, and "thinking scientifically". One of the teachers stated that, "Scientific literacy means to be able to think scientifically and understand science in our daily life." The use or understanding of science as it applies to everyday life was not a common response. Other infrequent responses dealt with the application of science, methods of learning science and the acquisition of

knowledge. One teacher provided a negative response, e.g. “It means not understand about science concepts, vocabulary and not be able to interpret them in easier language.”

The second question of the interview focused on reading in science. Teachers were asked if and what their learners read to supplement the science lessons. Of the six teachers interviewed, only one teacher reported that his/her learners did not read for science. The reason offered for not reading during class centred on the absence of textbooks at the school. The lack of textbooks was also echoed in two other responses, but one teacher stated that she utilised articles from newspapers and developed handwritten posters for learners to read. The other reading resources included reading notes or worksheets from teachers, books or “other sources” from the library and textbooks. Two teachers stated that their learners read for procedural aspects in science such as, “...a method of doing an experiment” and “...instructions given to do experiment...”

Writing in science was the centre of the third question of the interview. Similar to the previous question, teachers were asked whether they facilitated writing in science and, if so, were asked to describe the writing activities. All the teachers reported that the learners were engaged in writing for science. The level of writing activities ranged from blackboard writing, “writing” tests, class notes and assignments to more advanced forms writing, such as written summaries of the day’s lesson. One teacher reported that she required that the learners write about the topics that they research and commented that research was done “...at a low level.”

The fourth question of the interview investigated teachers’ classroom practice regarding scientific investigations. Two teachers cited the lack of resources, such as laboratory equipment, as reasons why they do not conduct investigations in class. Another teacher stated that investigations are facilitated when teachers can improvise with household

items, for example, by using a kettle and a dish to demonstrate evaporation and condensation. The remaining three teachers affirmed that their learners conducted investigations and provided examples of classroom investigations. Their examples included testing acids and bases, observing phases of water, hunting for locusts, discussing energy transfers, examining food nutrients and going on nature observations. The teachers did not comment on how frequently the investigations take place and only one teacher commented that learners performed investigations “... *with limited success.*”

The final question of the investigation focused on the teachers’ best practices in science. However, all the responses focused on the negative aspects of teaching and learning science. Teachers stated that teaching science was difficult and/or unsuccessful due to the lack of resources to conduct investigations, coupled with the large number of learners in their classroom. One teacher suggested that the lack of time allocated to teaching science also contributed to the challenges. Poor learner performance, i.e. learners’ inability to “*express themselves*”, as well as the lack of motivation and interest in science, were recurring themes. According to the teachers interviewed, language barriers, substandard reasoning, and cognitive skills were other reasons for weak learner performance.

Concluding interview

At the conclusion of the intervention, another interview was conducted to establish if and/or how the teachers’ ideas and attitudes of scientific literacy changed throughout the course of the intervention. When interviewed, all six teachers focused more on changes in the classroom practice of teaching science than on transformations that may have occurred in their attitudes about scientific literacy. Four out of the six experimental group teachers expressed that, since the intervention, they incorporated more language and literacy strategies to assist learners to understand the topics presented in the lesson. These teachers suggested

that their “new way of teaching” helped learners better understand the scientific language in English. Teachers strongly promoted reading and writing in English and when asked whether they allow learners to write in isiXhosa, two of the teachers stated that they prefer not to “give the learners a gap” to write in isiXhosa. The teachers offered several reasons for forcing learners to write in English. Firstly, teachers stated that their learners understand spoken English, therefore, they can and should practice writing in English. Teachers’ second reason for promoting writing in English is due to the fact that the medium of instruction and testing is in English; hence, learners must become accustomed to the English language. Furthermore, teachers affirmed that bilingual teaching, teaching in English and then repeating the same information in isiXhosa, is simply too time consuming.

In addition to the issues and the use of language in scientific literacy, one teacher shared that her understanding of scientific literacy has changed. Prior to the workshops, she would teach the content at the onset of the lesson and, perhaps, afterwards conduct an experiment to “prove to the learners that the content is true”. This teacher commented that she found it much more useful to begin the lesson with a short reading or the investigation, so that the learners could develop questions about “...collecting the data or coming up with a conclusion.”

The concluding interview was also used to obtain the teachers’ professional feedback regarding the implementation of the scientific literacy model. All of the teachers stated that the model was beneficial as it assisted them in varying their teaching strategies. One teacher commented that, “I see that my teaching was more teacher-centred before. Now learners are forced to be involved.” Another teacher noted, “[The model] has made my work easier. Instead of doing straight teaching, which is strenuous, we are doing the work together. No one is left behind. If I am only talking then maybe a student doesn’t hear something, but

when we are working together, everyone is participating. Even the little bit that you do is better than the learners sitting there listening the whole day.”

Another positive comment about the model included the use of the stimulus to introduce the topic. One teacher shared the following information, “This model helps us to trigger learners’ thinking and to ask why they think that. Learners all have their hands raised. They even offered answers that you didn’t expect. We often underestimate them, but if you give them triggers, they often give wonderful ideas.”

Teachers also offered constructive feedback about the challenging aspects of the model. The most common response from all of the teachers related to issues of time. Half of the teachers stated that, due to poor literacy skills, learners spent a considerable amount of time writing in their science notebooks. One teacher simply said that, “The investigation, plus writing it up in the science notebook, takes up too much time.” Another teacher also referred to the time constraints, and commented on the difficulty of following all the steps of the model as, “there is a lot [teachers] have to cover.” Learner presentations were also cited as an aspect of the model that is time consuming. One teacher, however, shared that after observing lengthy presentations, she realised that she “...needed to teach my learners about picking out the most important part and sharing that information instead of telling us everything step-by-step.”

Teachers expressed other challenges in implementing the model, such as difficulty in fully engaging learners in exploratory talk and argumentation; handling a variety of learners’ results and conclusions during an investigation; and managing the Department of Education’s learner portfolio requirements and assessment practices. The interviews provided constructive feedback and criticism regarding the model and will be further discussed in the following chapter.

4. CHAPTER SUMMARY

This chapter reported on the data generated from the two Scientific Literacy studies, which were conducted in Tyumie Valley and Port Elizabeth. Qualitative data obtained from teacher interviews, classroom observations and learners' science notebooks were presented and, in the cases of the classroom observations and science notebooks, were supplemented with quantitative data acquired by means of the RSPM (RSPM). In addition, quantitative data generated by literacy tests in Tyumie Valley and Port Elizabeth were presented in this chapter as it assists in understanding the effects of the integrated teaching strategies approach on literacy and language development.

The findings of the individual studies, as well as the combined results of experimental and comparison groups in both milieus, attempted to answer the central question in this study, namely '*Can the integrated teaching strategies approach be used as a strategy to improve scientific literacy in Grade 6 classrooms in the Eastern Cape Province of South Africa?*' The data presented were triangulated and are discussed in the Chapter 5 within the framework provided by the literature review.

CHAPTER FIVE

DISCUSSION OF RESULTS

1. INTRODUCTION

This chapter focuses on the analysis of the results of the study in terms of the principle research question: *Can the integrated teaching strategies approach be used as a strategy to improve scientific literacy in Grade 6 classrooms?*

The analysis of the quantitative and qualitative data in chapter four are compared and contrasted to the theoretical underpinnings noted in chapter two in an attempt to provide answers to the research sub-questions, viz.:

- *Can teachers be developed professionally to use the strategy successfully in their science classrooms?*
- *What effect does the use of the strategy have on the way children engage in the processes and procedures required for scientific investigations?*
- *What effect does the use of the strategy have on the learners' problem solving and general language and literacy abilities?*

As the validity and reliability of the findings, as well as the patterns and themes that emerge from this study, are important, a number of different methods were used to obtain data (McMillan & Schumacher, 1993). Methods, such as classroom observations and interviews, provided cross-validation among the data sources. As such, the combination of learner testing, classroom observations, science notebook analysis, and teacher interviews, provide corroborative and complementary pictures of the respondents' teaching and learning practices, as well as their use of the integrated teaching strategies approach.

2. DISCUSSION OF DATA

Although the data from Tyumie Valley and Port Elizabeth were collected and presented as two separate studies in the previous chapters, the discussion of the results are combined in this chapter. The combination of the studies aims to illustrate any common themes or possible disparities between the experimental and the comparison groups as a whole and may provide some insight about rural and township education in the Eastern Cape. The collective discussion also assists in examining how specific aspects of the intervention contribute to the successful implementation of the proposed integrated teaching strategies approach for improving scientific literacy.

2.1 Raven's Standard Progressive Matrices

The Raven's Standard Progressive Matrices (RSPM) was used in this study to assess learners' problem solving abilities before and after being exposed to a variety of pedagogical strategies aimed at improving the cognitive abilities of the learners. The quantitative data generated by experimental groups in Tyumie Valley and Port Elizabeth offered positive results which suggest that, overall, there was an improvement in the mean scores of learners who were exposed the integrated teaching strategies approach in comparison to those of who did not receive such treatment.

The overall results suggest that the Tyumie Valley experimental group made greater gains than that of the comparison schools, but because of the small size of the sample used, no statistically significant differences could be detected. While the experimental group in Tyumie Valley demonstrated greater improvement between their mean pre- and post-test scores across sets B through D, the comparison group demonstrated greater improvement only in set A, the least challenging of the items. In comparison, the Port Elizabeth experimental scores reflected consistent and statistically significant improvements in all sets.

Researchers, e.g. Klein (2006), acknowledge that teacher-centred, direct instruction is a useful component for developing concepts and word meanings, but emphasise that the relationship between language, the construction of meaning, and cognition is important for understanding and problem solving. The Raven's tests are measures of problem solving abilities, and it is possible that the gains made by the experimental groups in this test might be attributable to the learners' engagement in cognitively challenging scientific literacy tasks which offered opportunities to develop understandings through social interactions (Mortimer & Scott, 2003; Mercer, et al., 1995; Lemke, 1990).

While the gains in Raven's post-test scores were statistically significant, observable and considerable in Port Elizabeth, the overall median score of 24.19 was substantially lower than those scored by 11-12 year olds worldwide (AbdelKhalick & Raven, 2006) as depicted in Table 5.1. Table 5.1 reveals that South African learners' RSPM scores are disappointingly matched against the 5th percentile scores from countries such as the UK, US, India and Kuwait.

Table 5.1

The RSPM mean scores of learners aged 11-14 from the United Kingdom (UK), United States (US), Kuwait (KW), Qatar (QA), Pune & Mumbai (P&M) indicating cross-cultural stability; selection of cross-cultural and birth cohort norms. (from Abdel Khalick & Raven, 2006)

		Age in Years (Months)													
		11	11½	11½	11½	11	12	12½	12½	12½	12	13	13½	13½	14
		10(9)	11(3)	11(3)	11(0)		11(9)	12(3)	12(0)	12(3)		12(9)	13(3)	13(0)	13(9)
		To	to	to	to		to	to	to	to		to	to	to	to
		11(2)	11(8)	11(8)	11(11)		12(2)	12(8)	12(11)	12(8)		13(2)	13(8)	13(11)	14(2)
Perc		UK	UK	QA	KW	P&M	UK	UK	KW	US	P&M	UK	UK	KW	UK
95		50	51	48	48	49	52	53	50	51	52	54	54	52	55
50		40	41	38	37	33	41	42	40	40	39	43	44	42	45
5		24	25	19	15	12	26	27	19	22	14	28	29	23	30

Nevertheless, what is of importance is the fact that the experimental groups' demonstrated statistically significant gains over the comparison group. These improvements could be attributed to or what Raven, et al (1995) allude to as 'environmental influences and cultural opportunities', in this case probably the effect of the scientific literacy model used in the study. What is interesting is that while AbdelKhalick and Raven (2006) use the international data set as a baseline comparison for learners of the same age, they suggests that one should reserve judgement for including groups, such as black South Africans, who lack a tradition of written literacy. In this study literacy, in both the learners' home language and in English, was emphasised which, in the light of AbdelKhalick and Raven's (2006) statement, appears to warrant special attention.

In the case of the experimental groups, the qualitative and quantitative data generated from the classroom observations, learners' science notebooks and teacher interviews reflected progressive changes in learners' cognitive activities, as well as teachers' improved practice and positive self-reflection throughout the intervention. While there is no single explanation

for the gains made by the experimental learners, it is probable that the modifications to the overall classroom environment expanded learning opportunities and had a positive effect on learners' thinking and problem-solving skills.

2.2 Literacy tests

Central to the idea of improving scientific literacy in the classroom is the notion that learners must possess and develop reading, listening, writing and speaking abilities in science (Halliday & Martin, 1993; Norris & Phillips, 2003; Yore, et al., 2003; Yore, et al., 2007; Webb, 2009). In South Africa this is particularly true and there is an additional need to address learners' basic literacy and language skills. The results from assessments such as TIMSS (2003) and PIRLS (2006) suggest that there is an observable relationship between learners' low achievement at school and the fact that they do not speak the language of the test items at home (Reddy, 2006). In light of this, the literacy tests in this study were administered in English and isiXhosa to observe any possible changes or improvements to learners' language capabilities as a result of exposure to the integrated teaching strategies model.

Reading

The literacy tests suggests that the learners from both experimental groups improved slightly in their ability to read in isiXhosa, yet only the Tyumie Valley group demonstrated statistically significant gains in their reading ability in English. While the Tyumie Valley learners' improvement in reading may possibly be attributed to exposure to English books and other reading activities that supported the science lessons, the lack of results in Port Elizabeth require further explanation.

At the onset of the study, the Tyumie Valley and Port Elizabeth classrooms reflected Malatje's (2005) South African research findings which suggests that the use of textbooks in science lessons appear to be limited and reading as a classroom activity remains rare (Malatjie, 2005). Later into the study, however, the majority of the experimental teachers utilised the provided books to introduce the investigation on magnetism. It is interesting to note that, while the Tyumie Valley learners generated statistically significant gains in English reading, their teachers did not utilise books or other reading material unless they were supplied as part of the study. Despite having old textbooks and small school and/or classroom libraries, the Tyumie Valley teachers stated that they lacked reading material to use for their lessons. By comparison, the teachers from Port Elizabeth used more readings during their lessons and took the initiative to develop and/or retrieve teaching materials. Yet, in spite of more resourceful and provided more reading opportunities, their actions did not equate to better English reading results on the literacy test. A possible explanation for the Port Elizabeth groups' lack of improvement in English may be that learners' inadequate foundational reading skills hindered their ability to use reading as a tool for learning (Zimmerman, et al., 2008). In other words, learners' abilities were focused on learning-to-read rather than reading-to-learn science (England et al., 2007).

With regards to the Tyumie Valley results, one would not expect statistically significant gains made in English considering that they read less than their Port Elizabeth counterparts. However, it is probable that the introduction to reading in English allowed the learners to acquire and practice their low-level reading abilities through increased exposure to written language (Matjila & Pretorius, 2004). The reading strategies which teachers employed, such as reading aloud and shared reading, may have provided opportunities for learners to hear and see English text. Furthermore, reading and hearing the text may have

had a positive and reciprocal effect on how the learners were able to listen, interpret and understand the teachers' use of English in class (Mayaba & Webb, 2008).

Reading opportunities and language exposure are apparent explanations to the improvements made in the reading section. However, it should be noted that overall, the reading results were quite low. The scores on the reading section of the literacy test produced comparable outcomes to the PIRLS (2006), suggesting that reading skills are still unsatisfactory for “constructing meaning relative to a variety of text” (Sadler, 2008:86). Evidence from the classroom observations suggest some learners did not read at all or could not keep up with the class as they read various passages during shared reading sessions. During the class discussion of the text, some learners' responses (or lack thereof) indicated that they were able to decode the reading phonologically and could apply words to lower-order questions, yet they may not have fully comprehended the meaning of the text. Researchers such as Matjila and Pretorius (2004) contend that the reason so many learners do not understand what they are reading in school is that they are not adequately proficient in the language of learning and teaching, which is the language of their textbooks.

Listening

As mentioned in chapter four, the statistical results revealed overall improvements in the listening category for both experimental groups (Tyumie Valley and Port Elizabeth). Although the improvements for English listening in Port Elizabeth were not statistically significant, there were observable gains. The improvements in isiXhosa and English listening skills may possibly be attributed to the frequent use of code switching in the classrooms. However, code switching occurred differently in each milieu. The use of mother-tongue instruction with occasional code switching in English was the dominant practice in the Tyumie Valley, while the teachers in Port Elizabeth favoured English instruction with

isiXhosa code switching. Many researchers believe that employing mother-tongue instruction concurrently with code switching in a linguistically homogenous class will result in better learning and understanding (Probyn, et al., 2002; Setati, et al., 2002). This may be particularly true for learners in rural areas such as the Tyumie Valley and other areas of the Eastern Cape where there is little chance of hearing English outside of the school premises. Under these circumstances, English may be considered a foreign language (England, et al., 2007). Researchers such as Burkett, Clegg, Landon, Reilly and Verster (2001) indicate that learners who learn through a second language may experience difficulties as they have little exposure to English in their daily lives, and therefore have the widest gap to make up as they learn through the medium of English. As a result, the primary purpose of moving between dual languages in the classroom is to ensure that the use of instructional language, i.e. English, increases and that there is a transfer of understanding concepts from the one language to the other (England, et al., 2007; Setati & Adler, 2001).

Evidence from the classroom observations indicated that the experimental learners in this study were exposed to a significant amount of isiXhosa and English in their science classes. In this language-rich context, learners were engaged in academic and scientific language in both languages while making sense of the investigations and other classroom activities. In addition, concepts, explanations and vocabulary were reinforced and negotiated in their home language. It is plausible that the learners' listening abilities in both languages improved because they were engaged in an academic context that was negotiated, directed and meaningful (Met, 1994) and that these meanings were reinforced in English and the learners' home language.

Writing

The ability to effectively communicate scientific ideas and information through writing is a critical aspect of developing and improving scientific literacy (Hand, et al., 2004; Hand, et al., 2001; Hand, et al., 2004; Prain, 2006) and is an essential component of this study. Overall, the experimental learners from Tyumie Valley progressed marginally in English writing, but improved considerably in isiXhosa. The improvements in isiXhosa writing were also evident in Port Elizabeth, as was the learners' English writing ability. To support these claims, the learners' writings activities, which were noted during the classroom observations, will be addressed in this section and will be elaborated on further in the analysis of learners' science notebooks.

Researchers such as Berninger, Fuller and Whitaker (1996) posit that writing is dependent on the evolution of academic knowledge structures, processes and experiences and this progression was evident in the classroom observations. Following the professional development workshops teachers implemented the proposed strategy and learners had the opportunity to become immersed not only in English and isiXhosa, but also in the language of science. It is important to note that prior to the intervention the learners were rarely, if ever, encouraged to communicate their thoughts in writing. Learners were not engaged in meaningful writing activities, nor did they record data from their observations or experiments. Consequently, the development of learners' writing skills appeared to be a difficult task for teachers when writing strategies were initiated. Before any writing could take place, teachers had to provide guidance and instruction on the literacy aspects of the science notebook approach, for example defining and clarifying scientific terminology such as 'procedure' and 'conclusion' in English and in isiXhosa. In addition, further instruction was required for understanding the scientific methodology and processes for each component.

These observations of emerging writing and language skills are supported by Klein (2007, p. 164) who suggests that, “the quality and quantity of students’ writing is affected by their oral language abilities and by their facility with the mechanics of writing.” While some learners’ writings reflected structural errors such as incomplete sentences, misspelt words or a lack of sequence of ideas, there was evidence that learners enhanced their learning by recording some of their findings effectively. For the most part, the information in learners’ notebooks displayed writings that were organised, could be used to make connections with prior experiences, and could be used as reference tool which learners could use to find evidence and support their thinking (Hand, et al., 2004).

In addition to the inclusion of writing opportunities and practice in writing, another explanation for the learners’ gradual improvements in writing could be credited to the method of writing that was promoted. With the introduction of science notebooks, learners were exposed to a structured form of writing and a systematic way of thinking. The science notebook framework assisted learners in developing a comprehensive understanding of process skills, as well as developing science concepts within the line of learning (Fulton & Campbell, 2003; Miller & Calfee, 2004; Mintz & Calhoun, 2004). This process also allowed learners to emulate and communicate scientific understandings based on their investigations (Ruiz-Primo, et al., 2002) as each entry began with an investigable question and ended with scientifically accepted ideas about the content (Baxter, et al., 2000).

Speaking

Learners from the Tyumie Valley and Port Elizabeth experimental groups also demonstrated progression in their speaking abilities. However, statistically significant improvements in English and isiXhosa were only observable in Port Elizabeth. The type of talk and the discussion practices gleaned from the classroom observations are consistent and

confirm the results from the speaking section of the literacy test. As discussed in chapter 4, very little classroom discussion took place during the initial observations and the Initiation-Response-Feedback (IRE) questioning cycle (Edwards & Mercer, 1987; Mehan, 1979; Mortimer & Scott, 2003; Sinclair & Coulthard, 1975)) was the dominant classroom practice. Yet, subsequent to the professional development workshops, teachers began to employ more speaking opportunities for learners by asking more questions that were open-ended and by providing constructive feedback. As a result of this change, the learners progressively engaged in talk that could be characterised as cumulative and disputational talk during later observations. At a later stage, many of the teachers succeeded in facilitating certain communicative practices for exploratory talk to emerge. While Mercer (1996) suggests that cumulative and disputational talk are uncritical or less engaging than talk that requires constructive analyses, what is significant is that teachers created the platform whereby learners could openly express their ideas. Initially, it was not commonplace that learners engaged in classroom discussion, as many teachers in the study were initially reluctant to expose learners to this practice. The teachers attempted to remain in control of the discussion by employing IRE practices in the classroom (Dillon, 1994; Edwards & Mercer, 1987). The shift in teachers' attitudes and practices are discussed further in later sections of this chapter, yet the fact that teachers facilitated exploratory talk in the classroom is a probable explanation for the improvements learners' made on the speaking section of the literacy test. A number of teachers from both studies encouraged learners to participate in discussion and provided learners with rules about classroom dialogue such as, "It is okay to challenge someone's ideas, but you must be respectful and you must have a reason why you disagree."

2.3 Classroom observations

The results from the RSPM and the literacy tests appear to substantiate that ‘what teachers do’ serves as a key component to raising learner outcomes (Douglas, 2009). Literature on classroom observations and teacher professional development suggest that teachers’ instructional practices and behavioural interactions with students predict learning and change (improvement) as a function of specific and aligned support (i.e. the scientific literacy model) for teachers (Pianta & Hamre, 2009). As such, the classroom observations in this study were used to provide insight to, and explanations of, learners’ performance on the RSPM and the literacy tests and to supplement information with respect to the teacher interviews and learners’ science notebooks. The classroom observations were used to track the experimental teachers’ progress and judge their ability to implement the integrated teaching strategies approach. Overall, the classroom observations suggest three important findings:

- 1) The experimental teachers were able to implement various aspects of the integrated teaching strategies approach in their science classrooms and that their pedagogic skills improved over time. The greatest improvements were made in terms of teacher questioning and feedback skills;
- 2) While the classroom observations illustrate gradual improvements of overall teaching and learning, teachers did not exhibit high levels in the practices of developing an investigable question, facilitating exploratory talk and drawing conclusions, and;
- 3) Learners were provided with opportunities to improve their fundamental sense of science through reading, writing, discussing and inquiry-based activities. While the learners appeared more interested and engaged in their science lessons, they displayed low-to-mid levels of proficiency in activities such as writing and argumentation.

The following sections reflect the components assessed using the *Classroom Observation Schedule* and offer possible explanations to teachers' practices and effects of the scientific literacy model.

Use of a stimulus

Meiring, et al. (2002) suggest that learner interest and attention is readily obtained when an investigation or a lesson is introduced with a counter-intuitive observation or 'discrepant event'. Similarly, readings may be used to spark interest and provide basic information (England, et al., 2007). As such, the use of stimuli, for example discrepant events or stories, were promoted in this study to initiate learners' prior knowledge, possible misconceptions and interests of the science topic presented (Sackes, et al., 2009). The baseline observations suggest that discrepant events or other forms of stimuli were rarely used by the teachers in this study. Their lessons generally started with statements such as, "In today's class we will be learning about photosynthesis. Have you heard the word photosynthesis before?" While the teachers introduced the lesson with a question, the question itself appeared to be rhetorical. Irrespective of the learners' comments or familiarity with the term 'photosynthesis', teachers continued with the lesson without feedback or other questions to engage learners in the topic. This type of introduction, characterised by stating the topic of the lesson and posing a closed-ended question, was customary for the majority of the lessons observed, but occurred less frequently over time. One teacher in the Tyumie Valley commented that prior to the workshops she was unaware that there were other ways to commence her lesson. As teachers focused on using a stimulus, they increasingly employed higher-order questions and/or reading material when introducing the unit topics or lesson themes.

Although the use of discrepant events was advocated to create cognitive dissonance at the start of the lessons (Meiring, et al., 2002), this practice was not observed throughout the studies. The teachers from Port Elizabeth commented that they preferred to use literature to stimulate learners' thoughts, as books, newspapers or magazines were more accessible and much easier to implement than discrepant events. While discrepant events are touted as effective instructional tools in science, there appears to be very little research situated in science classroom practice. It is probable that the use of discrepant events may be challenging to teachers who do not have a strong background in science. Teachers, in general, find science a challenging subject to teach (Appleton & Kindt, 2000) and, therefore, would often rather employ familiar instructional tools such as reading to teach the subject (Sackes, et al., 2009). Nevertheless, stories have similar benefits as the use of discrepant events in challenging learners' existing mental constructs and misconceptions (Edwards, 1997; Elstgeest, 1985; Martin, 2000; Liem, 1987; Chiappetta, 1997). The use of the narrative books provided by the study served as an effective stimulus as it provided learners with ideas about the topic, encouraged learners to tackle unfamiliar content, and urged them to discuss the topic and ask questions (England, et al., 2007).

Exploratory talk

As discussed in the literacy sections, learners' verbal communication increased as teachers employed more strategies to support learner talk in science. Although learners demonstrated improvements in their speaking abilities, the examination of teachers' facilitation of exploratory talk is critical to understanding the effectiveness of the scientific literacy model. While teachers were aware of their responsibilities for facilitating talk, such as establishing a discussion goal, conveying high expectations, and reinforcing discussion with subject-matter tasks (Standford, 1996), the teachers did not make this explicit to their

learners and did not enforce certain aspects of exploratory talk such as reaching consensus within the group. Therefore, the majority of learners generally accepted the ideas of their group members who were academically or verbally proficient. Although the teachers communicated the ground rules for exploratory talk, their learners required constant reminders of these guidelines, which suggest that the explicit teaching of exploratory talk should be a customary part of the science lesson.

There was no evidence that learners ever fully participated in exploratory talk, the increased use of cumulative and disputational talk suggests that learners were engaged in preliminary thinking that may lead to exploratory talk. Wegerif, et al. (1999) suggest that these forms of talk are unconstructive in developing meanings and arguments, but one may argue that, in the context of this study, the learners at least participated and took a stance on their ideas, which possibly opened the window towards improved classroom discussion in the future.

Reading

During informal discussions and interviews with the teachers, many teachers addressed the reading challenges in their classrooms. They reported that a number of their learners were in an adverse position for learning as they entered Grade 6 without having basic emergent literacy skills, such as print or phonological awareness (Justice & Kaderavek, 2002). While most schools could not afford a remedial literacy tutor, some schools took measures to respond to the high levels of illiteracy. One experimental school in Port Elizabeth instituted a weekly period dedicated to reading in an attempt to develop their grade R through grade seven learners' fundamental literacy skills through. Teachers in the study are aware that children who gain reading and writing skills in earlier years generally develop into better readers and writers than learners who have inadequate knowledge in literacy

(Justice & Kaderavek, 2002; Stuart, 1995). Many of the teachers in the study cited the low literacy rates of learners' parents as an additional obstacle to their learners' success.

Despite the challenges to learners' reading abilities, several teachers continued to incorporate more reading activities during their science lessons. One teacher in Port Elizabeth progressed in offering her learners quality-reading opportunities. For example, during the initial observation for this Port Elizabeth teacher, reading vocabulary words on the blackboard was the only literacy activity in which the learners were engaged. At the following observation, the teacher included two to three sentences and vocabulary words to support the lesson on acids and bases and then, by the final observation, this teacher advanced to implementing several literacy approaches, including reading posters and other self-developed materials during the lesson introduction, and using reading aloud and guided reading with textbooks during the line of learning. Researchers such as Sadler (2007) may criticise these activities as exhibiting a 'simple' view of the fundamental sense of scientific literacy. However, given the teaching and learning context of the schools, the act of reading and text decoding is an essential literacy practice that needs to be honed by the learners. The teachers' instructional practice demonstrates that, when provided with the opportunity, learners are able to strengthen their basic literacy skills and demonstrate satisfactory reading skills. Moreover, when teachers incorporate activities which assist learners in constructing meaning (Macaro, 2003), learners are in a better position to expand their view of scientific literacy in the fundamental sense.

Investigable questions

Science, by its very nature, starts with trying to understand and explain a problem or phenomenon (Baxter, et al., 2000; DoE, 2002). As such, in order to understand the scientific process, it is essential that learners are able to pose an investigable problem. The process of

developing investigable questions in the Tyumie Valley and Port Elizabeth generated mixed results. While a small number of observations yielded instances where teachers attempted to guide learners in this process, evidence from the observations and learners' science notebooks highlight two critical occurrences. Firstly, some teachers were unable to formulate testable questions, as they were unsuccessful at facilitating discussion or mediating learners' questions. Secondly, some teachers simply provided the investigable questions. In over half of the classroom observations, teachers simply provided learners with the investigable questions and this practice was confirmed in learners' science notebooks. This was probably a result of teachers' previous experiences and lack of confidence when working with their learners to develop the question.

Harlen (1996) suggests that handling learners' questions is a skill, which can easily be developed through the identification of the type of question that is being asked, and knowledge of how to turn a question into one that can be investigated. This task, however, has proved to be quite challenging for teachers (Meiring, et al., 2002). In this study it is plausible that teachers' prior experiences, practices and meanings of 'investigations' affected the way in which they approached the concepts. For example, prior to the professional development workshops, the type of 'investigations' that were conducted were more illustrative or observational forms of practical work, as opposed to an inquiry-based investigations. Learners were often given questions such as, "How many petals are there on a dicotyledon flower?" and "Which animal is a vertebrate?" Teachers considered these questions 'investigable' as learners' needed to examine the flower's petals or consider which animal had possessed a backbone, yet the meaning of the word investigation did not include a thorough and systematic approach (Gott & Mashiter, 1991). Correspondingly, if learners were accustomed to traditional methods of practical work using illustrative, observational or researchable questions, then it is understandable that learners would initially rely on their

teacher for the ‘investigable’ question. Research suggests that educators can support learners by turning their statements into questions or by modelling questions with open-ended questions such as, “What happened?”, “What is your prediction?”, “What should we try next?”, “What will happen if...?”, and “How is this the same as... or different from...?” (Heil, et al., 1999). While this approach is welcomed, there appears to be very little research in the area of what teachers do to encourage their learners to ask and then investigate science.

One of the intended outcomes of the intervention was to shift teachers’ perceptions and practices in facilitating investigable questions or questions that learners can perceive, describe and used to test relationships between variables (DoE, 2002). In some cases, this shift appeared to be successful. Some teachers posed questions that were suitable for inquiry, or at least a starting point for developing investigable questions. For example, one teacher in the Tyumie Valley asked her learners, “How can we make this water hot?” This question prompted learners to think of a variety of ways in which to increase the temperature of the water, to evaluate methods in an attempt to make the water the hottest, and to integrate skills such as measuring the temperature of water by using a thermometer to evaluate the effectiveness of their ideas.

Another important aspect about the teachers’ use of investigable questions rests on the sustainability of this practice. During the final observation, the teacher from school F_{pe} regressed to facilitating an illustrative question; she explained, “I didn’t know what to do for investigation on electricity, so I thought we would just do a normal experiment today.” This teacher expressed difficulty in anticipating what type of questions learners would ask. In addition, her lack of confidence and inexperience with identifying the variables for an investigation on electricity compounded her fears and challenges. Teachers from both studies, however, expressed similar concerns as teacher from school F_{pe} about facilitating

future investigations. The teachers' apprehension is a cause for concern as research suggests that they will resort to methods of expository teaching and rote learning when they lack experience, confidence or general pedagogic content knowledge (Taylor & Vinjevold, 1999).

Planning and conducting investigations

The original work of Gott and Mashiter (1991) and later Gott and Duggan (2002) and Roberts and Gott (2006) suggest that practical problem solving in science requires both substantive (conceptual) understanding and procedural understanding. The procedural understanding required in planning and conducting investigations requires more than just a series of skills and procedures to be practiced (Roberts & Gott, 2006). It also requires the ability to interpret and recognise how these skills can be used to support the evidence for claims. Data from the observations indicate that, prior to the professional development workshops, learners in the participating teachers' classrooms had minimal opportunities to develop even the basic skills and procedures of an authentic investigation. However, as teachers in this study incorporated authentic scientific investigations during their lessons, their learners demonstrated increased abilities to plan and conduct scientific investigations. These enhanced abilities can be ascribed to teachers' modifications to their instructional practices (Crawford, 2000; Grossman & McDonald, 2008).

Teachers modelled the procedural aspects of the investigations, often providing prescriptive, step-by-step instructions to assist learners in answering the investigable questions. The teachers' explicit and systematic instruction of procedural methods allowed learners to gain knowledge and confidence in a variety of process skills, such as measuring, comparing and recording information. For many classrooms in the study (more so in the Tyumie Valley schools), this was the first time that there were sufficient apparatus for small groups of learner to carry out investigations. As a result, teachers had the additional task of

explaining how to use apparatus, such as thermometers and medicine droppers. Although the additional time spent on the explanations may have distracted attention from the investigations, the comprehensive explanations that were made provided the necessary platform for facilitating future inquiry-based activities that require similar procedural skills. By creating classroom environments which are consistent, predictable and supported by the teacher, learners become more self-reliant and are inclined to take more risks when they explore the world (Birch & Ladd, 1998; Hamre & Pianta, 2001; Howes, Hamilton, & Matheson, 1994).

Teachers' procedural demonstrations and learner support also assisted learners to work with their groups in order to find ways in which to answer their questions and conduct the investigation. The learners from the Tyumie Valley appeared able to work collectively, share ideas and allow all group members to handle the apparatus. In Port Elizabeth, however, small groups of learners (2-3 per group) tended to dominate the group work. In response to this, several teachers modified their instructions for group work by giving each learner specific roles or multiple opportunities to handle apparatus. In one classroom, the rotation of learners who were designated to handle apparatus prompted a valuable discussion about conducting fair tests and the reliability of data. One learner shared his group experience demonstrating critical "thinking behind the doing" (Roberts & Gott, 2006, p. 3) by stating, "Thandiswa, Nomda and I each tested the water drops three times because Thandiswa's drops were too big and we wanted to see if we would get the same [number of] drops."

The teachers' procedural instruction was not limited to the development of manipulative skills of handling apparatus. The teachers' practice also exemplified the Department of Education's perspective of developing cognitive and process skills, "by creating meaning and structure from new information and experiences" (DoE, 2002, p. 13).

Learners' competencies in process skills extended to the cognitively more challenging (and sometimes less successful) aspects of interpreting information and drawing conclusions.

Teachers' questioning skills and feedback to learners

In Mortimer and Scott's (2003, p. 16) work on "meaning making" in science classrooms, they address the issue of encouragement and the connection between emotion and learning by recognising that:

the fundamental importance of the affective and emotional aspects of teacher-student and student-student relationships in the process of teaching and learning science [and how] emotions can, and do, have a part to play in meaning making interactions specifically, and in cognitive orientation more generally.

Mortimer & Scott (2003, p. 16)

As such, the teachers' feedback and questioning practices were analysed to examine the extent to which talk and interaction effected learners' conceptual and emotional development in the classroom. The integrated teaching strategies approach, which is rooted in constructivist perspectives, requires a positive learning environment in which learners feel confident and comfortable to express their ideas, as well as knowing that their thoughts are acknowledged and valued as a part of the learning process (Mortimer & Scott, 2003). Researchers contend that children who are motivated and connected to others such as their peers or teachers are much more likely to establish positive development in both social and academic domains (Hamre & Pianta, 2001; Roeser, Eccles, & Sameroff, 2000; Silver, Measelle, Essex, & Armstrong, 2005).

Throughout all the observations, teachers displayed varying levels of questioning and feedback skills. Initially, teachers from both studies asked simple-recall or close-ended questions and their responses to learners were generally negative if the contributions were

incorrect. Correct answers were afforded limited praise while, overall, learners' responses received minimal encouragement or were treated with indifference. This is illustrated in the following example from a classroom in Port Elizabeth:

Teacher: In science, what is a 'force'?

Learner A: Something you do to move something

Teacher: What?

Learner A: (repeats answer) Something you do to move something

Teacher: I don't understand what you are saying. (Points to another learner)

Learner B: Something that is strong

Teacher: In science, 'force' is a push or a pull

The above example characterises Scott's (1998) belief that the combination of the power relationship between the teacher and learner and the role of the science teacher to establish the agreed scientific world-view with the learner often minimises opportunities for effective discourse. The teacher in this example did not notice the nature or substance of the learners' participation, nor did she recognise opportunities to probe their conceptual understanding. Consequently, teachers' general use of closed-ended questions and their dominance of the talk in class lead to missed opportunities in the development of learners' critical reasoning (Hanley, et al., 2007). In the example above, Learner A's understanding of *force* could have been elicited by asking the learner to explain her response or to provide an example. Instead, the ambiguous retort, "*What?*" suggested either that the teacher did not hear Learner A or that the teacher required further elaboration. Hence, the unconstructive feedback to the Learner A's repeated response and the action of calling on another learner implied that the answer was incorrect. Similarly, with Learner B, the teacher provided no feedback to the contribution and proceeded to define force. The learners' descriptions of

forces were, in fact, correct, but the learners were not able to ‘guess’ the teacher’s expectation of the definition. In this situation, the teacher regarded the learners’ ideas as obstacles to learning rather than starting points or ideas to work with in furthering scientific understandings (Duit & Treagust, 2003).

Subsequent to the professional development workshops, the teachers gradually began to employ other forms of questioning, for example by incorporating some open-ended questions amongst their lower-order questions, as well as asking a variety of questions to elicit learners’ understanding. Moreover, teachers improved their feedback strategy by replying positively to incorrect answers and by providing feedback to all learners irrespective of correct or incorrect contributions. The teachers’ newfound approach of combining effective questioning and constructive feedback encouraged further effort by the learners. As a result, this particular component displayed the most consistent growth at high levels.

Line of learning

Duit, Gropengießer and Kattmann (2005) posit that successful teaching and learning settings are only effective if the design of content structure for instruction is also given serious attention. The line of learning, which follows the learners’ conclusions in the science notebook process, serves as an important component of this study as it centres on the learners’ ability to develop a deeper understanding about the target concept following the investigation. During the line of learning, the teacher and learners put forth their questions and conceptual understandings about the investigation. However, the teacher plays the primary role in developing learners’ derived sense of science by mediating their thoughts, experiences and questions with the key explanatory ideas about the investigation. Mortimer and Scott (2003, p. 1) aptly state that practical activities cannot “speak for themselves,” suggesting that the learners may not be aware of the intended focus of the investigation.

Therefore, it is the responsibility of the teacher to clarify concepts, introduce new vocabulary, and develop meaningful understandings which will assist learners to construct scientific ideas and arguments consistent with those of the scientific community (Bazerman, 1988; Latour & Woolgar, 1979).

At the onset of the observations, the teachers' displayed inadequate or weak conceptual knowledge related to the concepts taught. Teachers often overlooked learners' misconceptions or provided incomplete or incorrect explanations to the concepts or the vocabulary presented. The teachers' substandard content knowledge, however, is not exclusive to teachers of the Eastern Cape or Southern Africa. Internationally, primary science teachers lack confidence in and knowledge of science (Fensham, 2008). None of the teachers from the experimental schools studied the Natural Sciences in their later years of schooling, at teachers' training college or university, nor were they particularly interested in teaching science. While professional qualifications are not necessarily a benchmark for learner success, researchers such as Ball, Thames and Phelps (2008, p. 392) suggest that specialised training should focus on the content-specific knowledge of student conceptions, particularly on misconceptions, and "acknowledge that accounting for how students understand a content domain is a key feature of the work of teaching that content."

Teachers were forthright about their lack of confidence and poor mastery of science content and often shared that their transition into teaching science transpired because of staff shortages at their schools. One teacher, C_{iv} from Tyumie Valley addressed her need for additional training by enrolling and completing a 2-year Advanced Certificate course in science, mathematics and technology education two years prior to the intervention. Unsurprisingly, this teacher was the most receptive about the scientific literacy model and demonstrated high levels of implementing the various strategies. For the remaining teachers,

professional development in science education rests on the annual training provided by the Department of Education.

The lack of previous quality professional development opportunities, science education qualifications, and overall disinterest in teaching science are problems that explain the low frequency of observations during which teachers displayed a clear and complete understanding of the scientific concepts taught in class. There was, however, evidence that teachers displayed adequate knowledge about surface tension and magnetism, the two topics presented at the professional development workshops. An 'adequate' understanding implies that the content of magnetism and surface tension were clearly and correctly expressed (i.e. concepts were sound), albeit often through the use direct instruction as opposed to more constructivist methods. During the training aspect of this intervention, the participating teachers gained specialised content knowledge, teaching techniques and problem solving strategies. Despite the intervention they still were not particularly adept at recognising and analysing learners' misconceptions or at selecting appropriate methods for teaching topics, especially when the topics were not addressed during the training (Ball & Bass, 2000).

The majority of the classroom observations suggested that the learners from both studies were either unable to fully contribute their ideas or questions during the line of learning. Learners seldom offered insights to their findings and there were few observations where learners sufficiently increased their understanding of the concepts through their social exchanges and classroom participation. There were several factors, however, that appeared to influence the learners' capacity to expand their understanding during the line of learning. One such factor was the ways in which teachers produced a classroom environment conducive to effective discussion, questioning and feedback. Another factor was the teachers' ability to develop the respective concepts. Previous sections of this report

addressed the way teacher-learner and learner-learner discussions and interactions serve as the fundamental means to develop learners' individual understanding (Mortimer & Scott, 2003; Vygotsky, 1978). From the sections on classroom discussion and teacher questioning, it was evident that pedagogical shifts occurred when a more student-centred approach to teaching was taken, as opposed to when a teacher-dominated approach was used. The change in classroom environment and teachers' practice appeared to be the catalyst for improved learner interactions and improved scientific understanding.

In addition to classroom environment and teachers' practices, the learners' ability to communicate their ideas is another factor that must be taken in to consideration when analysing learners' ideas in the line of learning. The line of learning is an intensive language and cognitive component, which requires that learners discuss and comprehend a range of science texts, contexts and multimodal representations such as the written word, symbols, formulae, diagrams and analogies (Yore & Treagust, 2006). Based on the evidence generated from the classroom observations and the analysis of learners science notebooks, learners appeared to have struggled to process and develop their scientific and instructional language and to understand in English while reconciling these understandings with their home language of isiXhosa (Zimmerman, et al., 2008). While the learners' lack of English skills may have inhibited both their understanding and expression (Roseberry-McKibbin & Brice, 2000; Sarinjeive, 1999), Moodie (2009, p. 8) cautions:

what appears to be a "second-language problem" may, in fact, be a problem of concept development... Where teachers fail to create experiences and activities for learners that illustrate or extend the concept, the learners' later lack of understanding can be mis-interpreted as a language deficit.

Moodie (2009, p. 8)

Assessing learners' scientific understanding through argumentation

The process of coordinating evidence and theories to support or refute an explanatory conclusion, model or prediction, is a critically important task and discourse process in science (Simon, Erduran, & Osborne, 2002; Suppe, 1998). As such, the Tyumie Valley and Port Elizabeth learners' understanding of the investigation was assessed through their arguments, which were presented in class. Due to the time constraints of the lessons, however, learners' argumentation and presentation skills were not always evident during the classroom observations and, therefore, some presentations were not evaluated. This led to the low frequency of responses that were generated in the results section.

The majority of learners or groups of learners (as most presentations were conducted in groups) were able to implement limited aspects of Toulmin's argumentation framework. Learners' arguments were often incomplete as data from their investigations or procedural steps were presented without putting forward their claims, warrants or backings. Similarly, learners communicated their claims and their data, but omitted their reasons, assumptions or counter-claims. Overall, the use of argumentation improved only marginally during the intervention and, accordingly, there was little evidence to suggest that learners had clear conceptual understandings of their topics. The low frequency of observations which reflected adequate or clear understanding is ascribed to the teachers' lack of instructions regarding the presentations. Despite the fact that Toulmin's (1958) model for argumentation was discussed and the framework was practiced at the professional development workshops, only one out of the eleven teachers taught argumentation explicitly through suitable instruction, task structuring and modelling (Driver, et al, 1998; Simon, et al., 2002). The majority of the teachers instructed learners to present their findings, but offered little instruction on how to effectively do so. Teacher C_{TV}, who made the most gains in Tyumie Valley, initially used the

broad statement, “Present your results”, but later guided her learners to assemble the information from their results and use the line of learning to construct their arguments. The findings of this component seem to corroborate research, which contends that argumentation is a process that takes time, as well as skilful and purposeful implementation by teachers if it is to be adopted and fully utilised by learners (Driver, et al., 1998; Hogan & Maglienti, 2001; Shakespeare, 2003;). Nevertheless, the sequential steps of the investigation and the concepts linked to the data collection, such as the fair test or reliability, were aspects which learners appeared to be moderately proficient.

Simon, et al.’s (2002) acknowledge that learners’ attempts to construct arguments, however flawed, will provide vital insights into the form and type of reasoning that underlies science and is the first stage to developing learners’ thinking and reasoning skills, which appears to have occurred in a minority of cases in this study. There was some evidence that where learners used the argumentation writing frame based on Toulmin’s (1958) more frequently, the quality of the argument also improved. For example, in a class where argumentation activities were regularly promoted, the learners were able to provide respectable claims. In one investigation, learners tested the strength of the repelling force between two circular magnets. The learners placed a pencil through the circular magnets, held the pencil vertically and tested the strength, but asking: How many washers will it take to make the two magnets touch? One learner claimed, “Our magnets are very strong because we can place a lot of washers on the top magnet without the magnets ever touching”. In addition, this group of learners supported their ideas with the facts gleaned from their data and suggested reasons that justify their claim, such as:

Even though we were able to put a lot, like, about fifty-seven washers on the top magnet, they never touched all the way because of their strong repelling force. If we used the other side of the [top] magnet, the magnets would have touched straight away because they would have attracted.

In this example, the learner was able to substantiate the group's claim about the magnets (*a lot of washers...without the magnets touching*) by providing the evidence (*fifty-seven washers*), while making accurate associations (*never touched... strong repelling force*) and comparisons (*touched... attracted*).

2.4 Learners' science notebooks

Kazeni and Hubbard (2008) suggest that the analysis of student work in professional development initiatives serves the dual function of making sense of learners thinking to design further instruction and serving as an evaluation tool for teachers' instruction. For the purposes of this study, the analysis of learners' science notebook leans toward Kazeni and Hubbard's (2008) assumptions. As such, the qualitative data from the science notebooks provided insight regarding the effects of the integrated teaching strategies approach on learners' writing and inquiry abilities, as well as to support and clarify data gleaned from the classroom observations.

While the use of the science notebook improved over the course of the study, learners still displayed poor writing ability in grammar, syntax and structure when they were asked to write independently (the science notebook approach does not emphasise these aspects, but aims at learners' formalising their thinking in words). Learners often copied their teachers' writings from the blackboard or, alternatively, they used bullet points or short incomplete sentences in their entries. Although writing-to-learn strategies in science are promoted to develop learners' scientific understandings, in the context of this study, learners' weak conceptual and procedural knowledge, as well as linguistic abilities, were contributing factors

which influenced not only learners' writings (Gunel, Hand, Prain, 2007), but also their ability to construct conclusions.

Developing appropriate conclusions to the investigations appeared to be the most challenging step for learners to perform as a number of their explanations were incorrect or excluded relevant detail in the science notebook. The learners from both studies displayed similar challenges with respect to drawing conclusions. The most common challenge was that some learners simply reiterated the steps of their procedure and repeated their data without critically analysing the relationship between the prediction and the results. Learners in the study were asked to reflect on their prior knowledge and assumptions of the prediction and also evaluate empirical evidence of the results. However, they missed the opportunity to reconstruct or reconfirm their ideas about the investigation. The process of drawing conclusions in science mirrors the cognitive demands of argumentation. In this process, learners are to "give a fair account of the social practice of science and develop a knowledge and understanding of the evaluative criteria used to establish scientific theories" (Driver, et al., 1997, p. 287). However, Gott, et al. (2008) assert that certain ideas which underpin the collection, analysis and interpretation of data must be understood before learners can handle scientific evidence effectively. Yet, despite learners' weak writing ability, it appears likely that they were still able to develop their conceptual and language skills through the inquiry and science notebook process (Kessler & Quinn, 1987).

To supplement the experimental procedure and the data collection, learners were supposed to be encouraged to make use of scientific drawings in their science notebooks. Although visual aspects of scientific practice are central to the process of constructing knowledge (Latour, 1995; Lynch, 2006), scientific drawings were not heavily promoted in the classroom. For example, while instructing learners in data collection, one teacher from

Port Elizabeth briefly stated, “You can also draw what you see.” However, there was no further elaboration or follow-up in this regard. Despite the lack of instruction on drawings, nearly two-thirds of the notebook entries contained original drawings related to the investigation. Drawings expressing the set-up of their apparatus were more prevalent in the Tyumie Valley sample. Many of the Tyumie Valley learners dedicated space in their notebooks for drawings, as opposed to merely drawing in the margins or within the text, which may suggest that they were more inclined to communicate their ideas through pictures. Considering the general low use of English in the classroom, it is probable that learners lacked the skill and relevant language necessary to communicate their experimental procedures that promoted the use of visual representation. Learners who have difficulty conveying their thoughts through formal writing often exercise their artistic abilities as a means of communication. A growing body of research suggests that the use of multi-modal representation assists learners in developing concepts and meaning in science, thus creating a connection between words and concepts (Airey & Linder, 2006; Alverman, 2004; Lemke, 1998). Although some of the drawings lacked pertinent details such as labelling, it seems that scientific drawings could be used as a springboard to develop language skills while improving procedural understandings of investigations.

2.5 Teacher interviews

The experimental teacher interviews had three main purposes: 1) to explore teachers’ perceptions about scientific literacy, 2) to identify teachers’ pedagogical approaches to literacy and scientific investigations prior to the intervention, and 3) to illicit professional feedback regarding the implementation of the scientific literacy model. Identical semi-structured interview techniques and questions asked were applied for both studies. However, the probing questions varied according to the teachers’ responses. Qualitative data from the

interviews provided insight in to the effects of the integrated teaching strategies approach on learners' problem-solving abilities, and also supported or clarified data gleaned from the classroom observations and science notebooks.

Teachers' perceptions about scientific literacy

The Tyumie Valley and Port Elizabeth teachers' initial ideas regarding scientific literacy were similar to the OECD's (2003) foremost aspect of scientific literacy as "an individual's scientific knowledge" or knowledge with respect to substantive or conceptual understandings, such as scientific laws, theories, and principles (Gott, et al., 2008; Gott & Dugan, 1995; Gott & Mashiter, 1991). Their perspective about what it means to be scientifically literate supports the traditional views of science as a subject which focuses on the transmission of facts, rather than constructing understandings by solving real-world problems (Crawford, 2000). Some teachers state that scientific literacy meant knowing "ideas about science". However, their ideas reflect an association with science explanations, as opposed to ideas-about-science which relate to key features of the processes and practices of science, such as data and its limitations, the scientific community, and making decisions about science and technology (Hanley, et al., 2007).

The ideas of the teachers from the Tyumie Valley and Port Elizabeth changed substantially from originally perceiving scientific literacy to signify knowledge and knowledge acquisition, to incorporating aspects of language and literacy to science. The most obvious explanation for the teachers' shift in perspective is the professional development workshops, which stressed the use of language and literacy for promoting scientific literacy. During one post-intervention interview, a Tyumie Valley teacher expressed, "scientific literacy is more than just knowing facts. It is also about understanding of science concepts and words in English, as well as isiXhosa". As teachers from Port

Elizabeth were stricter about using English as the medium of instruction, they placed greater emphasis on scientific literacy's ability to develop learners' academic and scientific language skills.

The various strategies promoted in the model undoubtedly influenced teachers' perceptions about scientific literacy. Many of the Tyumie Valley teachers commented that the integrated teaching strategies approach itself was "a new way of teaching" which "gives learners opportunities to learn science by using a variety of methods." One Port Elizabeth teacher stated that her idea of scientific literacy changed through her new awareness of various teaching strategies and modifications to her classroom instruction. Similar to her counterparts in the study, her science lessons originally focused on the mastery of content, placed little emphasis on the development of skills and the nurturing of inquiring attitudes (Baxter, et al., 2000; Maree & Fraser, 2004). This teacher added that she now places greater importance on developing learners' inquiry-skills during investigations, as opposed to her former practice of using experiments to prove that the content is "true", a common characteristic of traditional verification laboratory exercises (Crawford, 2000). Another teacher in Port Elizabeth remarked that her understanding of scientific literacy has expanded from facilitating reading activities to stimulating learners' questions about the procedural aspects of inquiry. When asked to elaborate on her answer, she suggested that the readings stimulated learners' thoughts and, therefore, prompted them to ask more questions throughout the investigation.

Teachers' also expanded their ideas about scientific literacy to include aspects regarding 'knowledge', such as understanding content, knowledge acquisition and the use of knowledge to identify questions. While the application of scientific knowledge for questioning was, perhaps, the most significant development in terms of teachers' thinking and

practice, the explicit recognition and implementation of language and literacy strategies in science was equally noteworthy. However, responses from the interviews indicate that teachers still lacked a clear understanding of the ‘big ideas’ of science, such as: the nature of science; major conceptual themes in the physical, earth or biological sciences; or how fuller debates on science, society and the environment issues which contribute to improving scientific literacy (Klein, 2006; Norris & Phillips, 2003; Yore & Treagust, 2006).

Teachers’ literacy and investigative strategies prior to the intervention

The language and literacy aspects of science are an essential aspect of developing learners who are scientifically literate (for examples see Baxter, et al., 2000; Cervetti, et al., 2006; England, et al., 2007; Halliday & Martin, 1993; Hand, et al., 2004; Norris & Phillips, 2003; Powell & Aram, 2007; Yore & Treagust, 2006). The established argument within science literacy discourse suggests that the development of learners’ communication abilities, i.e. reading, writing and talking science, will not only improve understanding, but will also empower learners in decision-making and participation in scientific, societal and environmental issues. As such, prior to the intervention, the participating teachers were asked to comment on the reading, writing and investigative activities that learners were engaged in during their science classes.

Reading

In Tyumie Valley and Port Elizabeth, all eleven teachers stated that reading activities were promoted on a daily basis and ten out of the eleven teachers affirmed regular writing practices. Teachers noted their classroom reading activities, such as reading class notes, worksheets, vocabulary words and several sentences on the blackboard and “instructions for the experiment”. However, as was observed in the classroom observations and reflected in the literacy tests, the quality of text and the levels of reading engagements were insufficient

to foster a deeper understanding of science. Powell and Aram (2007) posit that learners require a repertoire of reading opportunities in science to develop, and later connect, their conceptual understandings to additional readings and investigations.

The majority of teachers cited a lack of books and other reading material as the primary reason for not facilitating more (in terms of quality and quantity) reading activities. Evidence from the classroom observations and informal observations of the school environment, however, indicated that reading materials were, in fact, available at the schools. Each classroom in the Tyumie Valley schools housed a small collection of books (donated by a national literacy organisation) and a stock room full of current and old textbooks. Likewise, the Port Elizabeth schools kept their collection of textbooks from years past and each school possessed a small library. A possible explanation for the discrepancy between the teachers' responses and what was available could be that, although resources existed, teachers did not have access to, or were unaware of how they could obtain, appropriate content-based material to match the needs of their lesson and the reading levels of their learners. Despite the fact that several Port Elizabeth teachers improvised by developing reading material, such as posters and note cards, this practice – although noteworthy – is not a viable approach for all schools. Issues of expertise, time and resources are all factors which contribute to developing quality reading material for science, and human and material resources differ from school to school.

Teachers also cited learners' poor literacy skills as grounds to not facilitate more reading activities in the classroom. Although it can be argued that the lack of reading activities further exacerbates poor competencies in literacy, one teacher in the Tyumie Valley stated that, "Reading [in class] would take up too much time as the learners don't even read at home. Sometimes they cannot even read the sentences in class properly. Most of our parents

here are also illiterate.” The teacher’s reason for the lack of reading is due to the deficiencies of a reading environment at home, as well as learners’ personal motivation to engage in reading. Research suggests that various socio-cultural factors, such as social class or communication traditions, influence reading competencies. Rose (2005) indicates that learners who come from oral cultural backgrounds generally lack an early exposure to both books and experience in parent-child reading. Compared to literate middle-class families who experience an average of 1000 hours of reading before starting school (Bergin, 2001), learners from low socio-economic status are often at an academic disadvantage (Du Plessis & Naude, 2003; Lemmer, 1995; Rose, 2005).

Writing

The challenges that teachers experienced with regard to promoting reading in their science classrooms were also echoed in their learners’ weak writing abilities and, again, teachers cited learners’ poor academic performance as the main challenge to the incorporation of more meaningful writing activities. Similar to Rose’s (2005) assertions regarding socio-cultural factors that effect reading abilities, Gee (2004) and Alvermann (2004) confirm that socio-cultural context and identity factors are crucial in understanding students’ engagement with learning from writing. Moodie (2009, p. 7) illustrates the challenges to developing cognitive scientific and academic language in South African schools:

Cognitive Academic Language Proficiency (CALP) in science deals less with narrative/story text and far more with expository and procedural text. This text has fewer contextual clues, deals with abstract ideas, and is written more than spoken. Intermediate Phase [grades 4-6] teachers who themselves may have difficulty with CALP tend to stay in the realm of Basic Interpersonal Communication Skills (BICS) when teaching language, and this means that children's language lessons might not help them in subjects like maths, science and geography.

Moodie (2009, p. 7)

Although the majority of the teachers interviewed indicated that their learners were engaged in writing during science classes, the writing activities prior to the intervention were limited to writing simple class notes, tests vocabulary words and completing worksheets. While these forms of writing and information recollection serves a purpose of affirming science concepts, the information does not necessarily assist learners in crafting their writing skills in order to develop arguments about scientific theories or observations. Unstimulating activities, such as filling in the blanks or writing short answers to teacher-generated questions, emphasises knowledge telling and the transmission of recalled information (Halliday & Martin, 1994) but does not allow learners to communicate their thought processes and the rationale behind their thinking. Furthermore, these activities imply that teachers' own CALP may be inadequate for science and language instruction.

An additional problem regarding low levels of writing in science classrooms is that science teachers did believe it was their responsibility to foster learners' reading and writing abilities. One teacher from the Tyumie Valley stated that he did not facilitate much writing in his science class and maintained that it was the "job of the English teacher" to do so. This tension between integrating science and language is a familiar one, to some science educators who are sceptical about the possible shifts in educational objectives (Powell & Arum, 2007). The PISA considers literacy to "involve cross-disciplinary capacities of people to apply

knowledge and abilities in different content areas and to analyse, reason and communicate as they pose, solve and interpret real-life problems” (OECD, 2003, p. 13). Common arguments against the integration of literacy instruction with science lessons are that investigative science may morph into simply reading or writing about a science-related topic (Powell & Aram, 2007), or that science educators are not language educators and, therefore, may not possess the necessary competencies or interest to teach learners how to read and write. Despite these contentions, research recognises that learning area integration is an indispensable part of the science curriculum (Cervetti, et al., 2006; Yore & Treagust, 2006).

Scientific investigations

In addition to exploring the experimental teachers’ literacy practices in science, they were also asked to comment on the investigative practices promoted in their classroom during the observations. Teachers from the Tyumie Valley indicated that investigations were common practice and were conducted fortnightly, yet data from the initial classroom observations and further questioning contradicted these responses. Most learners from the study appeared unfamiliar with investigative processes such as handling apparatus and data collection. During the post-intervention interviews, some teachers retracted their statements and stated that they did not have enough equipment for learners to engage in practical work.

The Port Elizabeth teachers also stated that the lack of resources, such as laboratory equipment, prevented them from facilitating investigations on a regular basis. However, several teachers suggested that they were more inclined to conduct investigations that required household products, which the school could purchase. Each Port Elizabeth teacher reported that they conducted one to two hands-on activities per month prior to the intervention. One teacher acknowledged that her experiences in facilitating practical work

had been “largely unsuccessful” due to the lack of resources, discrepancies between learners’ results and a knowledge gap in the explanation of the concepts.

The issues presented by the teachers confirm South African and international research findings which suggest that primary school educators generally lack the confidence and knowledge required to teach science effectively (Fensham, 2008; Taylor & Vinjevold, 1999). Although the South African Department of Education provides annual training for science teachers, the views expressed by the majority of the teachers implied that the quality of the training in terms of the depth and breadth of the content and the knowledge and skills of the trainers, were unsatisfactory. The training received was also insufficient to facilitate the conceptual demands of the Natural Sciences and the pedagogical strategies of an outcomes-based curriculum. Three teachers in Port Elizabeth emphasised that they were “still unclear about how to teach science correctly” while one teacher expressed, “Sometimes I feel more confused after the training. I still don’t really even know what is an investigation.” Teachers’ lack of experience in conducting investigations compounds the problem of having science teachers who have minimal skills in conducting inquiry-based activities or strategies to promote them (Webb & Glover, 2004). In a recent report on the Rights to Basic Education (HSRC, 2006), educators maintain that Outcomes-Based Education, including the Natural Sciences Learning Area, cannot be successfully executed whilst many teachers have not had sufficient training on the implementation of the curriculum.

Best practices prior to the intervention

In an attempt to investigate other teaching methods employed in the classroom prior to the intervention, teachers were also encouraged to comment on their best practices. Teachers from the Tyumie Valley and Port Elizabeth provided responses which centred on their ability to “encourage group work” and “provide hands-on learning experiences”.

Interestingly, however, a number of teachers briefly offered their best practices, but then quickly shifted to the negative aspects of teaching science. One possible explanation may be that the respondents attempted to be humble about their best practices. However, the pessimism of the teachers' answers rather suggested a lack of confidence in their teaching skills (as discussed in the previous section) and their frustration of teaching science in schools from disadvantaged socio-economic backgrounds. Poor conditions for teaching and learning, e.g. dusty classrooms, large classes, uneducated and illiterate parents, were more commonly expressed amongst - yet not exclusive to - the teachers in the Tyumie Valley. The Port Elizabeth teachers also articulated challenges relating to learner performance, time and science instruction. For example, one teacher stated, "There is so much that I need to cover by the end of the term, but my class is too slow to learn. These students are not motivated to learn."

3. CHAPTER SUMMARY

The discussion in this chapter focused on the quantitative and qualitative data generated from this study. The emphasis was on the results that emerged during the data analysis of learners' performance, i.e. pre- and post-tests for the Raven's Progressive Standard Matrices, as well as the English and isiXhosa literacy tests. These data were examined within the literature review in Chapter 2 and was used to support the qualitative data gathered from the teachers' implementation of the integrated teaching strategies approach during classroom observations, teacher interviews and analysis of learners' science notebooks. The quantitative and qualitative data suggest that the teachers' use of the integrated teaching strategies approach had a positive effect on learners' reasoning abilities and various aspects of learner reading, listening, writing and speaking in English, as well as in their mother tongue. The progress of the study is consistent with Norris and Phillip's

(2003) idea that teaching and learning in science should focus on learners' fundamental sense of science and that opportunities for reading (Cervetti, et al., 2006; Padilla, et al., 1991), discussion (Mercer, et al., 1995; Mortimer & Scott, 2003), scientific inquiry (Edwards, 1997; Meiring, et al., 2002), writing (Hand, et al., 2001; Hand, et al., 2004) and argumentation (Toulmin, 1958; Webb, et al., 2008) could enhance learners' derived sense of science. The findings of these researchers and the data generated in this study suggest the participating learners' increased abilities in general literacy, science processes and reasoning may be attributed to the professional development and support of the Grade 6 science teachers and their ability to implement strategies that promote scientific literacy.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

1. INTRODUCTION

Declining learner pass rate and interests in science, poor achievement scores on international assessments in science, mathematics and reading, as well as governments' calls for economic growth and productivity through science and technology have prompted international movements to improve the scientific literacy of all learners (Fensham, 2008; Turner, 2008). The ideological push to popularise science have encouraged various initiatives to define and shape how everyday citizens could understand science (Koulaidis & Dimopoulous, 2002; Laugksch, 2000; Miller, 1998). Some initiatives include the movement of the public understanding of science (Cross, 1999; Layton, et al., 1993;), history and philosophy of science in science education (Hodson, 1985; Matthews, 1994) and science-technology-society (STS) curricula (Bybee, 1986; Solomon & Aidenhead, 1994). The progression and transformation of these movements led to the operational phrase, *Scientific Literacy* (Fensham, 2008).

In South Africa, the notion of scientific literacy has emerged largely due to the government's recognition of the role that science and technology plays in economic growth, employment creation, social redress and social development (Department of Arts, Culture, Science and Technology, 1996). However, in light of South Africa's learner performance on international and national assessments such as TIMMS (2003) and PIRLS (2006), as well as the problems associated with teaching and learning in a second language, there appears to be a primary and pressing need to develop learners' fundamental sense of scientific literacy

(Norris & Phillips, 2003). Expanding learners' ability to read, write and communicate in science may provide the necessary framework for engaging learners in the critical principles and foundations of the scientific endeavour (Hand, et al, 2001; Yore & Treagust, 2006). As such, this study focused on equipping and training grade six and seven science teachers to improve their learners' scientific literacy skills via professional development workshops via a pedagogical strategy that supports reading, writing, talking and conducting ('doing') science through scientific investigations.

2. THE EFFECT OF THE INTEGRATED TEACHING STRATEGIES MODEL

The quantitative and qualitative data suggest that there was an increase in learners' problem solving competence, literacy skills and scientific understanding in the classes in which the scientific literacy strategy was implemented. Although the teachers' ability to implement the aspects of the strategy varied, the majority of the experimental group of teachers in the Tyumie Valley and Port Elizabeth demonstrated improvements in their practice over time. The advances made in this study are attributed to a number of factors, namely the theoretical and practical framework of the scientific literacy model, the professional development of the teachers, and the learners' responsiveness to the teachers' shift in pedagogical practices.

Research into educating second language learners affirms that teachers should define language and content objectives, as well as plan activities that are experiential, hands-on, collaborative/cooperative, context embedded and cognitively engaging (Cummins, 1981; Met, 1998). In this study the integration of specific pedagogical approaches, such as reading (Cervetti, et al., 2006; Padilla, et al., 1991), discussion (Mercer, et al., 1995; Mortimer & Scott, 2003), scientific inquiry (Edwards, 1997; Meiring, et al., 2002), writing (Hand, et al., 2001; Hand, et al., 2004) and argumentation (Toulmin, 1958; Webb, et al., 2008) appear to

have had a positive effect on the development of learners' fundamental sense of scientific literacy, and their problem solving, cognitive, language and science abilities. Moreover, teachers' feedback on the strategy suggests that this model can be utilised as a helpful instructional tool for science teachers who lack the knowledge and skills to teach the integrated disciplines of language and science. Initially, the teachers in the study had a limited understanding of the National Curriculum Statement's (NCS) goals to improve scientific literacy, but developed an appreciation of these objectives and an improved grasp of how these might be realised in the context of their bilingual classrooms while engaged with the intervention strategy.

The professional development workshops for the experimental teachers focused on improving their understanding of the notion of scientific literacy, but more importantly, emphasised how this understanding could be translated into their classroom practice. The findings from this study confirm Pianta and Hamre's (2009, p. 113) perspectives relating to teacher professional development according to which:

Instructional supports [should] not focus solely on the content of curriculum or learning activities, but rather on the ways in which teachers implement these to effectively support cognitive and academic development. Teachers, who use strategies that focus on higher order thinking skills, give consistent, timely and process-oriented feedback; and work to extend learners' language skills tend to have students who make greater achievement gains.

Pianta and Hamre (2009, p. 113)

Teachers' questioning and feedback skills showed the greatest and most consistent improvements, as did the teachers' ability to facilitate reading, writing and aspects of inquiry. On the other hand, teachers expressed and demonstrated challenges in their questioning strategies; helping learners' synthesise their results in order to develop appropriate conclusions; and the facilitation of exploratory talk and argumentation. Despite these

difficulties, the teachers' progress was commendable especially in light of the pre-intervention teaching and learning scenarios they exhibited. Undertaking new pedagogical approaches made considerable demands on them to revise lessons and adapt their teaching style to a new context, as well as having to assimilate a wide range of curriculum support materials (Hanely, et al., 2007). Furthermore, the teachers had to adapt to the changing roles required when using a constructivist approach to teach science. Traditionally, the teachers had adopted an authoritarian role of transmitting knowledge (Webb & Treagust, 2006), yet with the use of the scientific literacy model, they were able to engage in other multifaceted roles, such as being a motivator, modeller, mentor, a collaborator of ideas, and even a learner of new concepts (Crawford, 2000).

This study suggests that the scientific literacy model can be appropriately and successfully (to a degree) applied in a second-language teaching and learning context, and help them improve their knowledge of the discipline, their students and new instructional strategies (Ball & Bass, 2000; Shulman, 1986). The degree to which the participating teachers demonstrated an appropriate level of content knowledge appears to be directly linked to the topics addressed during the professional development workshops. While this confirmed that the content-based training aspects of the strategy strengthened teachers' knowledge about magnetism and surface tension, it was evident that teachers still require additional support on the ways in which learners' perspectives and responses influence the reconstruction of their lessons (Duit, et al., 2005). For example, low levels of learner participation during class discussions exhibited in some instances is a possible indicator that they lacked a clear understanding of, or harbour misconceptions about, a particular concept under investigation. As a result, teachers should be skilled at modifying their lessons or line of questioning to address their learners' needs. Some teachers in the study expressed concerns that they might revert to traditional methods of expository teaching when they did

not feel confident and knowledgeable about a particular topic, an apprehension that underscores a number of researchers' findings that teachers require a great deal of support in order to teach science effectively (Johnson, 2007).

The third question of the study centres on the effect of the scientific literacy strategy on the way children engage in the processes and procedures required for scientific investigations. The findings from the study suggest that the teachers' scope of activity widened with the use of the model, thus providing greater opportunities for learners to participate and hone their skills in inquiry. Greater familiarity with the process of inquiry resulted in higher proficiency of procedural skills. Learners were exposed to various tactile experiences such as measuring liquids and temperature and were also engaged in cognitive operations including classification and the sequencing of events. All of these experiences build the concrete operational thought that is required beyond primary (elementary) school level (Moodie, 2009). As these activities demand a significant shift in what learners, as well as their teachers, do in the classroom (Crawford, 2009), it is understandable that learners demonstrated only emerging inquiry skills. Learners relied on their teacher to model aspects of the inquiry process, such as developing the procedure and recording results, and it was evident that the activities were more complex and cognitively more challenging (Chinn & Malhotra, 2001) than those to which the learners were previously exposed, or which their teachers could be expected to adapt to easily.

In addition to providing learners with increased opportunities to engage in the processes of inquiry, the teachers' use of the model also exposed learners to the nature of scientific inquiry. Teachers often motivated learners to 'do things like scientists do'; these 'things' being the kind of cognitive processes used by scientists including asking questions, making predictions, designing investigations, collecting data and drawing inferences (AAAS,

1993). The incorporation of inquiry in the science notebooks process allowed learners to gain experience in collecting data using an empirical method while learning that recording information that may influence the outcome of the investigation is of importance (Nesbit, et al., 2004). Additionally, learners' empirical evidence was used to construct learners' arguments about their investigations. The arguments presented during the study, however, lacked many of the critical elements and coherence required by Toulmin's (1958) argumentation framework. It is recognised that learners need to participate over time in explicit discussions in the norms and criteria that underlie scientific work (Hanley, et al., 2007; Hogan & Maglienti, 2001; Simon, et al., 2002) and that argumentation is a critical process of learning science. From the standpoint of scientific literacy, argumentation teaches learners "that the ideas that go into constructing their own claims can also be used to help in deconstructing the public claims of others" (Gott & Duggan, 2007, p. 272).

The final question in this study asks "What effect does the use of the strategy have on the learners' problem solving and general language and literacy abilities?" The experimental group learners' improvement in the RSPM over their comparison school counterparts suggest that in classrooms where reading, writing, talking and 'doing' science were implemented, there were noticeable (Tyumie Valley) and statistically significant (Port Elizabeth) increases in problem solving competence. These improvements can possibly be attributed to the effect of the scientific literacy model or what Raven, et al. (1995) allude to as 'environmental influences and cultural opportunities' that their teachers presented. This evidence is further corroborated by the results of the literacy tests.

What is important to note in terms of the pre-post literacy test data is the fact that the experimental groups' listening and writing skills improved in isiXhosa at a 99% level of confidence. Statistically significant changes also occurred in other sections of the literacy

test. For example, in the Tyumie Valley, the learners' English reading and listening, as well as isiXhosa listening improved. In Port Elizabeth the learners' English writing and speaking skills, as well as speaking in isiXhosa, improved statistically significantly. It is important to note that the participating learners gained literacy skills in both their home language and in English. The fact that teachers exercised code switching as a strategy to support learning to do this validates other research findings in South Africa, which suggest that code switching is a common and effective strategy used in classrooms where the language of teaching and learning is not the home language (Peires, 1994; Setati & Adler, 2000). The frequent use of code switching suggests that the language realities of second language classrooms requires instructional methods that acknowledges and is inclusive of learners' home language as well as the language of learning and teaching. As such, recognition of the role of language in learning science, coupled with promotion of the discourses of science by the scientific literacy approach, appear to be appropriate.

3. IMPLICATIONS FOR TEACHER DEVELOPMENT

The intervention focused on the way in which a small number of teachers in the Eastern Cape were able to use the scientific literacy strategy in their classrooms. Although results from the study cannot be generalised, the findings may provide some insight and constructive recommendations for science teacher development. As the study employs an integrated curriculum in science and language, it seems probable that pre-service and in-service training would benefit from integration of the intrinsic link between science and language and the ways in which language development is embedded in science instruction (Halliday & Martin, 1993). In order to do this, teachers require a strong foundation in the cognitive academic language of science and the skills to help negotiate learners' everyday language and understandings to the language of science (Yore & Treagust, 2006). Implicit in

this idea, however, is the recognition that effective science teachers are required to have a good command of the discipline itself. Yore (2008) suggests that users of science discourse cannot fully comprehend the discourse without appropriate knowledge of the nature of science, scientific inquiry, and the content of science. As such science teacher training must emphasise both literacy aspects and a more comprehensive view of the scientific endeavour.

The model used in this study aims at helping teachers to develop a deeper understanding of the fundamental sense of scientific literacy as the basis for developing the derived sense of scientific literacy. The results of a strategy over an academic year suggest that “once-off” workshops so often offered to South African in-service teachers are probably grossly insufficient for improving their subject matter knowledge, pedagogical content knowledge, and issues of scientific literacy (Moodie, 2009, p. 12). Learners’ cognitive and language development is contingent on the opportunities teachers provide to express existing skills and to scaffold more complex ones (Davis & Miyake, 2004; Skibbe, Behnke, & Justice, 2004; Vygotsky, 1991). As such, professional development programmes and initiatives must acknowledge issues of the quality of prior training, as well as the amount of time and the attention required for teachers to acquire new skills and assimilate these approaches to their teaching environments (Hanley, et al., 2007).

4. SUGGESTIONS FOR FURTHER RESEARCH

This study contributes to understanding how teachers can use an integrated teaching strategies approach to improve scientific literacy. However, further exploration is required to advance theoretical perspectives and practical approaches in science and language instruction. The majority of teachers in the study demonstrated that they were able to employ the informal writing strategy of science notebooks in their classrooms, yet the learners’ arguments were limited to oral presentations and the extension of learners’ ideas to

formalised writing was not regularly observed. The two questions which emerge from this observation relate to the construction of written explanations and arguments using speech-like and narrative language (Klein, 2006). Firstly, exactly how does the use of the science notebook assist second-language learners' to construct written explanations and arguments in English? Secondly, how does the use of learners' home language in the science notebook affect learners' cognitive and linguistic competencies when developing their written arguments? Furthermore, on the issue of language, the use of code-switching by teachers and learners was prevalent in Tyumie Valley and Port Elizabeth. Suitable questions for further investigations may be: are there specific components of the strategy where teachers could and should explicitly use code-switching? If so, to what extent, and how, does the explicit practice of code-switching during instruction enhance learners' understanding of target concepts or processes in science?

In addition, another finding of the study suggests that learners' procedural understandings improved as teachers consistently employed the integration of writing and inquiry strategies. While teachers gradually improved their ability to facilitate certain aspects of writing and inquiry, teachers found it exceptionally challenging to assist learners in developing investigable questions. As such, an empirical approach is needed to address the practical processes that are required to effectively develop productive questions in science classrooms. In other words, how can teachers mediate learners' questions to assist them in constructing investigable questions?

Finally, what exactly does it mean for the learners when they improve their scores on the Raven's Standard Progressive Matrices test? Is the improvement sustainable over time? What aspect of the strategy influences their RSPM scores? Is the improvement of their scores do to a 'science' aspect of the intervention, or simply because of the added effort and

concentration required by the interventions and which may be applicable to any field of study?

5. CONCLUSION

This chapter briefly revises the rationale of the study and summarises the main findings in relation to the four research questions:

- *Can the integrated teaching strategies approach be used as a strategy to improve scientific literacy in grade 6 classrooms?*
- *Can teachers be developed professionally to use the strategy successfully in their science classrooms?*
- *What effect does the use of the strategy have on the way children engage in the processes and procedures required for scientific investigations?*
- *What effect does the use of the strategy have on the learners' problem solving and general language and literacy abilities?*

A synopsis of the findings suggests that the scientific literacy strategy adopted appears to have impacted positively, to greater and lesser extents, in terms of all of the questions above, particularly apropos second-language learners' ability to develop their fundamental sense of science and general literacy skills in both their home language and the language of teaching and learning.

Being able to engage with science in a range of forms is an essential skill of a scientifically literate person (Crawford, 2000; Fensham, 2008; Norris & Phillips, 2003; Yore & Treagust, 2006). In this study, an empirical approach was taken to integrate existing theories on effective ways to teach science by developing a possibly useful model for scientific literacy instruction based on a range of contextually appropriate activities (Kazemi

& Hubbard, 2008). The findings, apart from suggesting areas of success, beg the question of further investigation of the details of student-teacher interactions when facilitating dialogue, engaging in science and literacy activities, and constructing meanings in various contexts of science classrooms. Such analyses could lead to richer understandings of how and what teachers and learners can do to improve their scientific literacy in the fundamental and derived senses (Norris & Phillips, 2003).

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APPENDIX A

SCIENTIFIC LITERACY PROJECT

RAVEN'S STANDARD PROGRESSIVE MATRICES



NAME: _____

BIRTHDATE: _____
(dd/mm/yr)

SCHOOL: _____

GRADE: _____

TODAY'S DATE: _____

Choose one answer only. Answer by **MAKING A CROSS (X)** over the appropriate number.

SET A						
A1	1	2	3	4	5	6
A2	1	2	3	4	5	6
A3	1	2	3	4	5	6
A4	1	2	3	4	5	6
A5	1	2	3	4	5	6
A6	1	2	3	4	5	6
A7	1	2	3	4	5	6
A8	1	2	3	4	5	6
A9	1	2	3	4	5	6
A10	1	2	3	4	5	6
A11	1	2	3	4	5	6
A12	1	2	3	4	5	6

SET B						
B1	1	2	3	4	5	6
B2	1	2	3	4	5	6
B3	1	2	3	4	5	6
B4	1	2	3	4	5	6
B5	1	2	3	4	5	6
B6	1	2	3	4	5	6
B7	1	2	3	4	5	6
B8	1	2	3	4	5	6
B9	1	2	3	4	5	6
B10	1	2	3	4	5	6
B11	1	2	3	4	5	6
B12	1	2	3	4	5	6

APPENDIX A: Raven's Standard Progression Matrices Answer Sheet

SET C								
C1	1	2	3	4	5	6	7	8
C2	1	2	3	4	5	6	7	8
C3	1	2	3	4	5	6	7	8
C4	1	2	3	4	5	6	7	8
C5	1	2	3	4	5	6	7	8
C6	1	2	3	4	5	6	7	8
C7	1	2	3	4	5	6	7	8
C8	1	2	3	4	5	6	7	8
C9	1	2	3	4	5	6	7	8
C10	1	2	3	4	5	6	7	8
C11	1	2	3	4	5	6	7	8
C12	1	2	3	4	5	6	7	8

SET D								
D1	1	2	3	4	5	6	7	8
D2	1	2	3	4	5	6	7	8
D3	1	2	3	4	5	6	7	8
D4	1	2	3	4	5	6	7	8
D5	1	2	3	4	5	6	7	8
D6	1	2	3	4	5	6	7	8
D7	1	2	3	4	5	6	7	8
D8	1	2	3	4	5	6	7	8
D9	1	2	3	4	5	6	7	8
D10	1	2	3	4	5	6	7	8
D11	1	2	3	4	5	6	7	8
D12	1	2	3	4	5	6	7	8

SET E								
E1	1	2	3	4	5	6	7	8
E2	1	2	3	4	5	6	7	8
E3	1	2	3	4	5	6	7	8
E4	1	2	3	4	5	6	7	8
E5	1	2	3	4	5	6	7	8
E6	1	2	3	4	5	6	7	8
E7	1	2	3	4	5	6	7	8
E8	1	2	3	4	5	6	7	8
E9	1	2	3	4	5	6	7	8
E10	1	2	3	4	5	6	7	8
E11	1	2	3	4	5	6	7	8
E12	1	2	3	4	5	6	7	8

APPENDIX B

ENGLISH LANGUAGE ASSESSMENT

READING, LISTENING AND WRITING

FIRST NAME:

LAST NAME:

SCHOOL:

GRADE:

AGE:

WRITE ALL YOUR ANSWERS IN THIS BOOKLET

SECTION A: READING COMPREHENSION

EXAMPLE QUESTION

Instructions: Read the short story below.

Thabo was reading a book when his mother called to him from the kitchen. He ran quickly to find her. She wanted him to go to the shop to buy some beans.

Example Question X

Put a tick in the box beside the correct answer.

X. What did Thabo's mother want him to do?

- A. (1) do his homework
- B. (2) go to the shop
- C. (3) ride his bicycle
- D. (4) look after the baby

Thabo's mother wanted him to go to the shop to buy beans.

So B is the correct answer. You must put a tick in the box beside B.

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD.

Read the passage below and then answer the questions that follow.

Zola and The Donkey

A bus pulled up at the edge of the pavement near where Zola was standing with the donkey by his side. Some people got out and others got in and as Zola watched them he had an idea. He jumped on to the bus with the rest of the crowd and the bus drove off, leaving the donkey behind.

Along the street went the bus, it turned the first corner and then rounded another. It travelled slowly, rattling as it went, for it was a rattling old bus. As it slowed down for another stop, Zola glanced through the window at the back. The donkey was galloping after the bus.

Zola closed his eyes tightly for a second. When he opened them again, there was a man standing in front of him with a big leather pouch slung over one shoulder. "Five cents, please" said the man, holding out his hand.

1. What pulled up near Zola?

- A. (1) A back window.
- B. (2) A pavement.
- C. (3) A man.
- D. (4) A bus.

2. What did Zola have by his side?

- A. (1) An idea.
- B. (2) A leather pouch.
- C. (3) People.
- D. (4) A donkey.

3. Zola got on to bus.

- A. (1) an old
- B. (2) a new
- C. (3) an empty
- D. (4) a free

4. What did the donkey do?

- A. (1) It closed its eyes.
- B. (2) It galloped after the bus.
- C. (3) It slowed down.
- D. (4) It rattled along the road.

5. In the passage "rattling" means....

- A. (1) brand new.
- B. (2) dirty.
- C. (3) clean.
- D. (4) noisy.

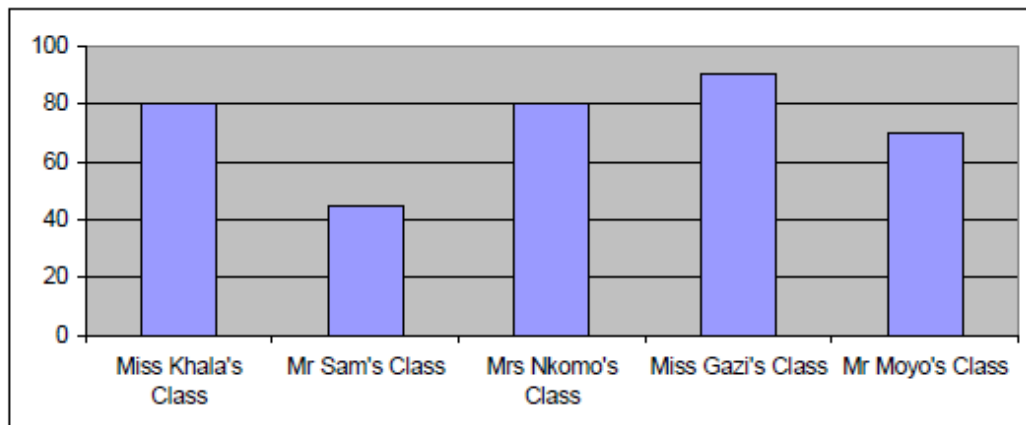
Read the passage and graph below and then answer the questions that follow.

Empty bottles

Ikhwezi School had a bottle collection. Children in each class brought empty bottles to school. The principal made a bar graph of the number of bottles from five classes.

Use this to answer the questions.

Number of bottles



Classes

6. Which class brought 45 bottles?

- A. (1) Miss Khala's class.
 B. (2) Miss Gazi's class.
 C. (3) Mrs Nkomo's class.
 D. (4) Mr Sam's class.

7. The principal asked each class to collect at least 50 bottles. How many classes have collected that many.

- A. (1) 2
B. (2) 3
C. (3) 4
D. (4) 5

8. Which class got the prize for collecting the most bottles?

- A. (1) Mr Sam's Class.
B. (2) Mr Moyo's Class.
C. (3) Miss Khala's Class.
D. (4) Miss Gazi's Class.

9. Which two classes collected exactly 80 bottles?

- A. (1) Miss Khala and Mrs Nkomo's classes.
B. (2) Miss Khala and Mr Moyo's classes.
C. (3) Miss Gazi and Mrs Nkomo's classes.
D. (4) Miss Gazi and Mr Moyo's classes.

Read the passage below and then answer the questions that follow.

Maize

The most important food crop in Malawi is maize. Maize is one of the many cereals. Cereals are plants which produce grain that is made into flour. The grain of maize comes from the cob. A good maize crop grows two to four metres high and has dark green leaves. Maize takes a lot of plant food from the soil, so it should not be grown on the same field for two full years.

Maize is planted **before** the rains begin in November and is ready for harvest in April. When maize is harvested, the cobs are stored in grain bins until they are needed. The bins are raised off the ground on posts too prevent animals from eating the grains. When maize grains are pounded, the outer part of the grain is made into bran and the inner part into white flour. Bran is often used as animal feed. If the maize is ground in a maize mill, the whole of the grain is made into a grey flour.

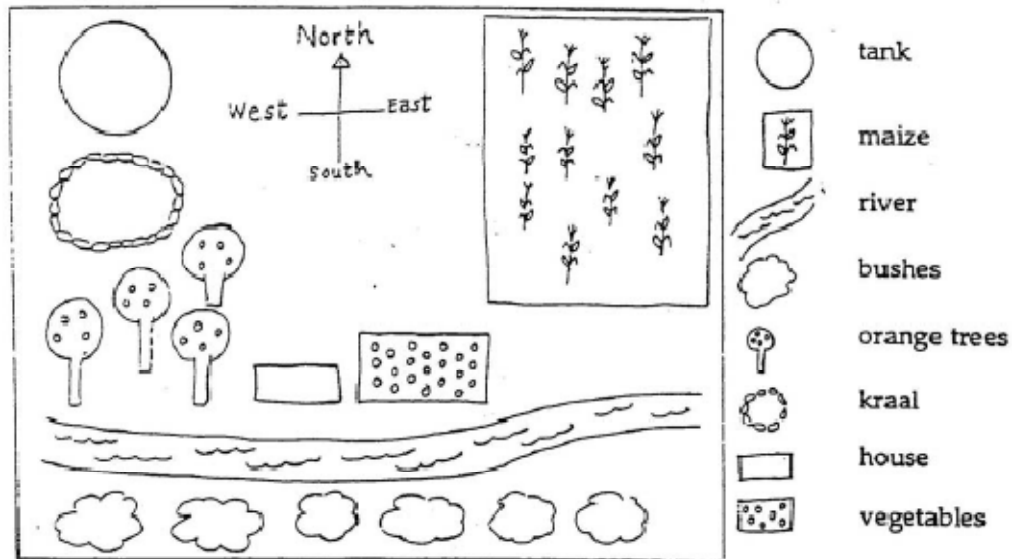
10. Maize is ...

- A. (1) plant food.
- B. (2) made of green leaves.
- C. (3) a food crop.
- D. (4) harvested once very two years.

11. How many months does it take from when maize is planted to when it is ready for harvest.
- A. (1) 12 months
B. (2) 9 months
C. (3) 6 months
D. (4) 3 months
12. In Malawi, maize is planted first before the rains begin because...
- A. (1) the workers do not want to get wet.
B. (2) it takes a lot of plant food from the soil.
C. (3) it needs water to grow.
D. (4) it does not need water to grow.
13. Maize has dark green leaves because...
- A. (1) it can provide bran, white flour, and grey flour.
B. (2) it gets plant food, sun and water.
C. (3) the leaves do not see the sun very much.
D. (4) it does not get enough water.
14. When maize is pounded, we get two products which are...
- A. (1) grey flour and white flour.
B. (2) grey flour and bran.
C. (3) white flour and bran.
D. (4) grey flour and cobs.
15. Grey flour comes from the grinding of ...
- A. (1) all of the maize grain.
B. (2) the outer part of the maize grain.
C. (3) the inner part of the maize grain.
D. (4) the whole grain.

Look at the map of Mr Makalima's farm below. Complete the description of the farm below the map by putting one word from the key in each blank.

Mr Makalima's Farm



Mr Makalima has a small farm. His farm is a mixed farm. His house is beside a small (22) from where he gets his water. The water is pumped up into a large cement storage (23) in the north west corner of the farm. Near there he has built a (24) for the cattle. He grows (25) in a big field on the east side of the farm. He grows a few (26) for his family and workers in a garden beside his house. On the other side of his house he has planted an orchard of (27) trees. The farm is quite profitable, but he has a big problem with the monkeys which live in the (28) on the other side of the river and raid his trees and crops.

B. LISTENING COMPREHENSION

Your teacher will read a story to you. Listen carefully to it and answer the questions below. **YOU WILL ONLY HEAR THE STORY ONCE.** You will be allowed to look at the questions before you hear the story. Listen carefully to this story and put a tick in the box beside the correct answer to the questions.

1. At what time did Themba leave his house?
 - A. (1) 06:00
 - B. (2) 11:00
 - C. (3) 03:00
 - D. (4) 09:00

2. Why did Themba climb onto one of his donkeys?
 - A. (1) Because he wanted to look for the sixth donkey.
 - B. (2) In order to take the donkeys to the market.
 - C. (3) In order to count the donkeys.
 - D. (4) Because he was tired of walking.

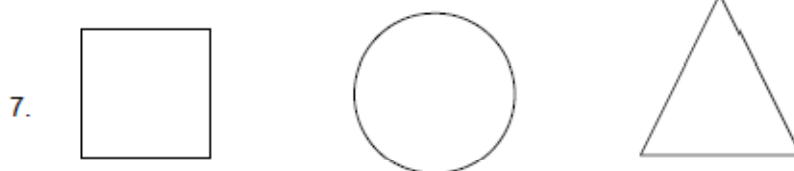
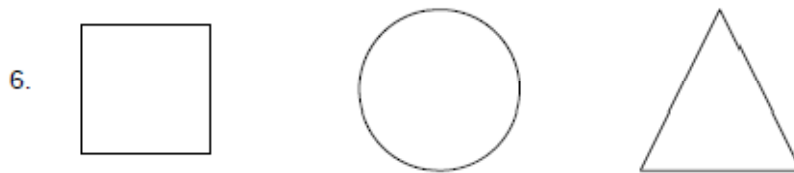
3. Why could Themba not find the sixth donkey?
 - A. (1) Because it had run away.
 - B. (2) Because his friend has it.
 - C. (3) Because there were only five.
 - D. (4) Because he was sitting on it.

4. Themba's friend was ...
 - A. (1) surprised.
 - B. (2) disappointed.
 - C. (3) amused.
 - D. (4) angry.

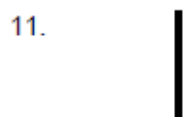
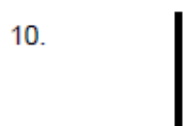
5. Themba's friend called him a donkey because he thought that Themba was ...

- A. (1) very clever.
- B. (2) very stupid.
- C. (3) in a hurry.
- D. (4) a donkey.

Your teacher will read instructions to you. Listen carefully to each instruction and follow it. YOU WILL ONLY HEAR THE INSTRUCTION ONCE.



- 9. A. (1)
- B. (2)
- C. (3)
- E. (4)



In this question you must write down your answers on the map provided below. Thami has to draw a sketch map of an accident. He has drawn the streets and the buildings, but he can't write in their names. He asks you to fill in the names. Look at the sketch map below. Listen to Thami and write on the map what he tells you to.

12. _____

13. _____

15. _____

14. _____

Listen to the information which your teacher will read to you, then fill in the information in the correct place in the table below.

	Where they live	Where they work	How many children they have
NOSISI	15.	<i>At a bank</i>	16.
Thabo	17.	18.	19.
Zanele	20.	21.	22.



APPENDIX C

UVAVANYO LWESIXHOSA

UKUFUNDA, UKUMAMELA NOKUBHALA

IGAMA:

IFANI:

ISIKOLO:

IBANGA:

IMINYAKA:

BHALA ZONKE IIMPENDULO ZAKHO KULE NCWADI

ICANDELO A: UVAVANYO LOKUQONDA

UMZEKELO WOMBUZO

IMIYALELO: Funda elibali lifutshane lingezantsi.

UThabo wayefunda incwadi ngelixa abizelwa ekhitshini ngumama wakhe. Wayembizela ukumthuma evenkileni ayokuthenga iimboty.

Umzekelo Wombuzo

Beka itick(✓) ecaleni kwempendulo oyikhethileyo.

Umama ka Thabo wayefuna enze ntoni?

- E. (1) umsebenzi wakhe wasekhaya
- F. (2) aye evenkileni
- G. (3) adlale ibhayisekile yakhe
- H. (4) ajonge umntwana wakowabo

Umama ka Thabo wayefuna aye evenkileni. Ngoko ke u B yimpendulo echanekileyo. Beka I tick(✓) kwibhokisi esecaleni kuka B.

**MUSA UKUTYHILA KWIPHEPHA ELILANDELAYO
UNGAXELELWANGA.**

Funda lomhlathi ungezantsi uze uphendule imibuzo elandelayo.

UZola ne Donki

Kwamisa ibhasi kwipavumente uZola awayeme kuyo kunye nedonki yakhe. Ithe yakumisa ibhasi, abantu behla abanye bakhwela. Ngalo lonke eloxesha uZola wayebabukele waze wagqiba ukuba akhwele ibhasi kwesosiphithiphithi sabantu abakhwelayo, ashiye idonki ngemva.

Ihambile ibhasi igogoza kuba yayigugile. Ithe xa isondela iza kumisa kwesinye isitalato, uZola wagqiba ukuba aphose amehlo efestileni ngasemva. Uthe akujonga waqaphela ukuba idonki iphala emva kwalebhasi ayikhweleyo.

Uye wavala amehlo akhe okwethutyana, waza wathi xa ewavula wabona indoda exakathe isingxobo esikhulu sesikhumba. Le ndoda iye yakhupha isandla isithi "isenti ezintlanu".

16. Kwamisa ntoni kufuphi noZola?

- A. (1) ifestile yasemva.
- B. (2) ipavumente.
- C. (3) indoda.
- D. (4) ibhasi.

17. Kwakume ntoni ecaleni kukaZola?

- A. (1) ingcinga.
- B. (2) isingxobo sesikhumba.
- C. (3) abantu.
- E. (4) idonki.

18. UZola wakhwela ibhasi eyayi

- A. (1) gugile
- B. (2) ntsha
- C. (3) ngenabantu
- C. (4) simahla

19. Yenza ntoni idonki?

- A. (1) ivale amehlo.
- B. (2) iphale emva kwebhasi.
- C. (3) ithobe isantya.
- E. (4) igoqoze endleleni.

20. Kulo mhiathi ungentia "Ukugoqoza " kuthetha....

- A. (1) ubutsha kraca.
- B. (2) ubumdaka
- C. (3) ukucoceka.
- E. (4) ukungxola

Funda lomhlathi ungezantsi kunye negrafu “graph” oyinikiweyo uze uphendule imibuzo elandelayo .

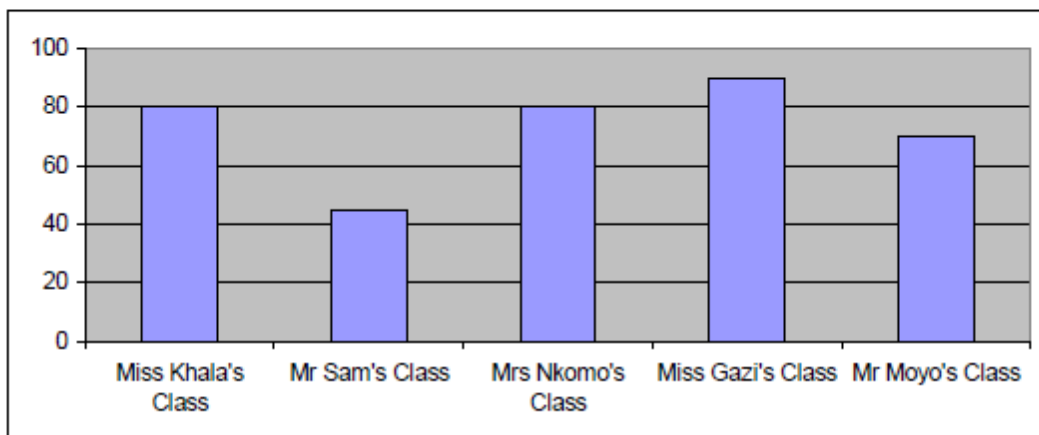
Iibhotile ezingenanto

Abantwana besikolo saseIkhwezi babekwiphulo lokuqokelela

iibhotile. Inqununu yenze “ibar grafu” ukuthelekisa iibhotile ezithe zaqokelelwa kwiiklasi ezintlanu.

Qaphela usebenzise le grafu “graph” ingezantsi ukuphendula imibuzo.

Inani leebhotile



Iiklasi

21. Yeyiphi iklasi ethe yeza neebhotile ezingama 45? Yeka...

- A. (1) Nkszn Khala .
 B. (2) Nkszn Gazi .
 C. (3) Nkskz Nkomo .
 E. (4) Mnu Sam' .

22. Zingaphi iiklasi ezathi zaqokelela ubuncinane iibhotile ezingama 50 ngokomyalelo wenqununu..

- A. (1) 2
- B. (2) 3
- C. (3) 4
- D. (4) 5

23. Yeyiphi iklasi eyathi yafumana ibhaso ngokuba iqokelele ezona bhotile zininzi? Yeka ...

- A. (1) Mnu Sam.
- B. (2) Mnu Moyo.
- C. (3) Nkszn Khala.
- E. (4) Nkszn Gazi.

24. Zeziphi iiklasi ezathi zaqokelela ngqo iibhotile ezingama 80?Zezika...

- A. (1) Nkszn Khala no Nkskz Nkomo.
- B. (2) Nkszn Khala no Mnu Moyo.
- C. (3) Nkszn Gazi no Nkskz Nkomo.
- E. (4) Nkszn Gazi no MnuMoyo.

Funda lo mhlathi ungezantsi uze uphendule imibuzo elandelayo.

Umbona

Okona kutya kubalulekileyo kuveliswa eMalawi ngumbona. Umbona yenyeyeesiriyeli. Iisiriyeli zizityalo ezivelisa iinkozo zokwenza umgubo. Iinkozo zombona zivela kwisikhwebu. Umbona ophilileyo uthi ukhule ube ngangeemitha ezimbini ukuya kwezintlanu ubude. Umbona uthatha izondlo ezisemhlabeni kungoko kungafuneki ukuba kulinywe emhlabeni omnye ixesha elingangeminyaka emibini

Umbona utyalwa ngaphambi kokuba kune iimvula zika Novemba, uze ulungele ukuvunwa ngo Apreli. Xa umbona uvunwa, izikhwebu zigcinwa kwiinkonxa zeenozo kude kube lixesha lokuzisebenzisa. Iinkonxa ziyaphakanyiswa zixhonywe ukuthintela izilwanyana zingazityi. Xa umbona ungqushwa. Iqokobhe leenozo lithi lenziwe amakhatshu uze umphakathi wenziwe umgubo. Amakhatshu la asetyenziswa njengokutya kwezilwanyana. Ukuba umbona usilwe ngelitye lokusila, ukhozo lulonke lwenziwa lube ngumgubo ongwevu

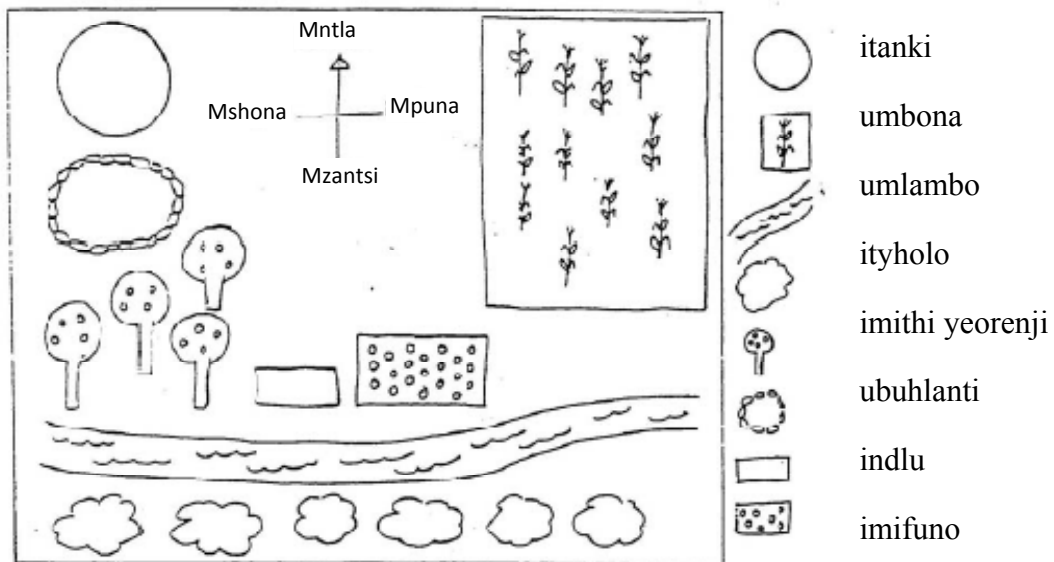
25. Umbona ...

- A. (1) sisondlo somhlaba.
- B. (2) wenziwe ngamagqabi aluhlaza.
- C. (3) sisityalo esivelisa ukutya.
- F. ... uvunwa kanve kwiminyaka emihini

26. Kuthatha iinyanga czingaphi ukuzc umbona ulungc ukuvunwa?
- A. (1) 12 iinyanga
- B. (2) 9 iinyanga
- C. (3) 6 iinyanga
- D. (4) 3 iinyanga
27. Kutheni lento umbona eMalawi utyalwa phambi kokuba kufike iimvula?
- A. (1) abasebenzi abafuni ukunethwa xa besebenza.
- B. (2) umbona uthatha izondlo ezisemhlabeni ezininzi.
- C. (3) umbona ufuna amanzi ukuze ukhule.
- E. (4) umbona awufuni manzi ukuze ukhule.
28. Umbona unamagqabi aluhlaza kuba...
- A. (1) uvelisa amakhathshu, umgubo omhlophe nongwevu.
- B. (2) ufumana izondlo ezisemhlabeni, ilanga namanzi.
- C. (3) amagqabi akatshiswa lilanga.
- E. (4) awufumani manzi oneleyo.
29. Xa umbona uthe wagutywa, uvelisa...
- A. (1) umgubo omhlophe nongwevu.
- B. (2) umgubo ongwevu namakhathshu.
- C. (3) umgubo omhlophe namakhathshu.
- D. (4) umgubo ongwevu nezikhwebu.
30. Umgubo ongwevu uveliswa ngokuguba ...
- A. (1) ukhozo lulonke lombona.
- B. (2) iqokobhe lokhozo lombona.
- C. (3) umphakathi wokhozo lombona.
- E. (4) ukhozo lulonke.

Jongisisa iMap yefama ka Mnu Makalima uze unike inkcazelo ngayo ngokuba ugwalise izikhewu ezikulomhlathi

Ifama ka Mnu Makalima



UMnu Makalima unefama encinci enezinto ezininzi. Indlu yakhe isecaleni KO₍₁₆₎ omncinci apho a'umana khona amanzi. Amanzi lawo athi ampontshelwe kwi₍₁₇₎..... .elikhulu lokugcina elenziwe ngesamente emntla ntshona yekona yefama yakhe.Ecaleni kwalapho wokhe U₍₁₀₎..... .benkomo zakhe.Utyale u (19).....kwimpuma yefama yakhe. Utyale ne (20)..... kwigadi yakhe esecaleni kwendlu esenzela usapho lwakhe nabasebenzi.Kwelinye icala lendlu yakhe utyale imithi yeziqhamo ye₍₂₁₎.....Inengeniso ifama yakhe ngaphandle nje kwengxaki yeenkawu ezihlala kwi₍₂₂₎.....elkwelinye icala lomlambo. Ezi nkawu zithi zimoshe izityalo zakhe nemithi.

B. UVAVANYO LOKUMAMELA

Utitshala wakho uzakufundela ibali.Limamelisise elibali, uze uphendulo imibuzo engezantsi.

UZAKULIFUNDELWA KANYE KUPHELA ELI BALI.

Uvumelekile ukuba ujonge imibuzo kuqala phambi kokuba ufundelwe elibali.Mamelisisa elibali uze ubeke itick(✓) kwibhokisi esecaleni kwempendulo oyikhethileyo.

6. Uhambe nini uThemba endlwini yakhe?

- A. (1) 06:00
 B. (2) 11:00
 C. (3) 03:00
 F. (4) 09:00

7. Kwakutheni uThemba aze ahambe ngenye yeedonki zakhe ?

- A. (1) Kuba wayekhangela idonki yakhe yesithandathu.
 B. (2) Ukuze ase iidonki zakhe emarikeneni.
 C. (3) Ukuze abale iidonki ezikhoyo.
 E. (4) Kuba wayekhathele ukuhamba ngeenyawo.

8. Kwakutheni uThemba angayifumani idonki yesithandathu?

- A. (1) Yayibalekile.
 B. (2) Yayikumhlobo wakhe.
 C. (3) Kuba iidonki zazintlanu kuphela.
 E. (4) Kuba wayekhwele yona.

9. Umhlobo kaThemba wa.....sesisenzo

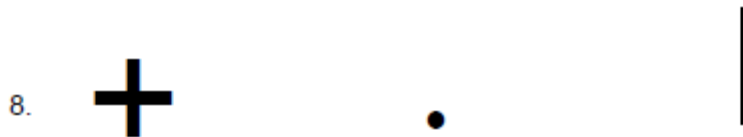
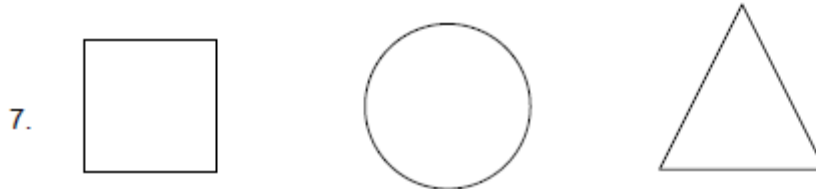
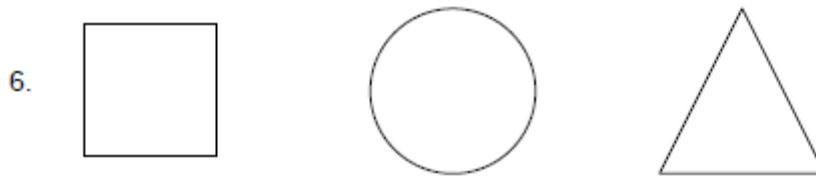
- A. (1) mangaliswa.
 B. (2) dana.
 C. (3) hickiswa.
 D. (4) banomsindo.

10. UThemba ubizwe ngokuba yidonki ngumhlobo wakhe kuba ...

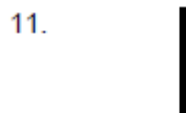
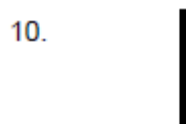
- A. (1) wayekrelekrele.
- B. (2) wayesisidenge.
- C. (3) wayengxamile.
- F. (4) wayeyidonki.

Utitshala wakho uzakufundela imiyayelo.Yimamelisise uze uyilandele.

LE MIYALELO IZAKUFUNDWA KANYE KUPHELA.



9. A. (1)
- B. (2)
- C. (3)
- G. (4)



Kulo umbuzo bhala iimpendulo zakho kule "Map" uyinikiweyo ngezantsi.
 UThami kufuneka ezobe i"Map" yentlekele ewayeyibukele. Uzizobile izitalato
 kunye nezindlu kodwa akakwazi ukubhala amagama azo.

Ngoko ke ,jongisisa i"Map" engezantsi uze umamelisise kuThami ukuze wena
 ubhale amagama ezitalato nezindlu.

12. _____

13. _____

15. _____

14. _____

Mamela inkcazelo ezokufundwa ngutitshala, uze ugcalise lonkcazelo akufundele yona kwizikhewu ezikule “table” ingezantsi.

	Apho bahlala khona	Apho basebenza khona	Bangaphi abantwana babo
Nosisi	15.	<i>Ebhankini</i>	16.
Thabo	17.	18.	19.
Zanele	20.	21.	22.



APPENDIX D

LISTENING TEXTS

Question 1

Themba left his house in the early morning with six donkeys. He was on his way to the market place to sell them. After a while he became tired and climbed onto one of his donkeys. As he was riding, he started to count his donkeys. "One, two, three, four, five...Now where is the sixth donkey?"

He climbed down and counted again, and there were six donkeys. He climbed up again and started his journey. After a while he counted his donkeys again. There were only five.

A friend passed by and Themba told him about his problem. "A while ago there were six donkeys, but then there were only five. Then there were six and now there are only five".

His friend laughed and said, "There are one, two, three, four, five donkeys, and you are sitting on the sixth donkey. You yourself are the seventh donkey."

Question 2

6. For question 6, put the letter K in the triangle
7. For question 7, draw a circle around the square
8. For question 8, draw a line from the plus sign to the full stop
9. For question 9, which line is the longest? Put a tick in the box beside the longest line.
10. For question 10, draw a plus sign on the left of the line
11. For question 11, draw a circle on the right of the line

Question 3

A young man ran out of Africa Bank.

He ran between two cars that were parked in front of the bank into Church Street in front of an on-coming car. Can you write Africa Bank on the building next to the two cars?

A car that **was travelling** along Church Street towards the Four-Way Stop at the intersection of Church Street and Nelson Mandela Drive **saw** the young man and **swerved** to the right in order to avoid hitting him. Can you please write Church Street on the street on the other side of the four way stop intersection and Nelson Mandela Drive next to number 14?

The car **crashed** head-on into a truck that had just **turned** into Church Street in front of the Checkers supermarket. Can you write Checkers on the building next to the truck please?

Question 4

Nosisi and Thabo both live in Alice. Nosisi works at a bank and Thabo works at PEP Stores. Nosisi has three children and Thabo has five children. Zanele has four children and she lives in Cathcart. She is a teacher and works at a school near Cathcart.

APPENDIX E

LISTENING TEXTS

Umbuzo 1

Ngenye intsasa, uThemba uvuke waya emarikeni eyokuthengisa iidonki zakhe ezintandathu. Emva kwexesha ehamba nazo iidonki, uzive ediniwe waza wagqiba ukukhwela enye yazo. Uthe esahamba njalo, waqalisa ukuzibala, “nye, mbini, ntathu, ne, ntlanu.” Uthe wamangaliswa akufumanisa ukuba idonki yesithathu akaiboni. Ngokukawuleza, wehlile kule donki ayikhweleyo, wabala kwakhona. Kwesi sihlando ufumanise ukuba ukuba iidonki zintandathu, wazewaqhubeleka nohambo lwakhe. Emva komgama ehambile, upinde wazibala ezidonki wafumanisa ukuba zintlanu.

Kukwelothuba kanye apho athe wadibana nomhlobo wakhe owayezihambela endleleni waze wambalisela ngengxaki yakhe. Uthe kumhlobo wakhe, “Ndisuke ekhaya needonki ezintandathu, ndathi xa ndisendleleni ndibala ndafumanisa ukuba zintlanu. Ndiphinde ndabala kwakhona ndafumanisa ukuba zintandathu, kodwa ngoku zimphinde zintlanu.

Umhlekele umhlobo wake waze wabala naye, “nye, mbini, ntathu, ne, ntlanu, eyesithandathu yile uyikhweleyo.” Ugqibezele ngokuxelela uThemba ukuba uyidonki yesixhenxe.

Umbuzo 2

6. Kumbuzo we6, beka u “K” kunxantathu.
7. Kumbuzo we7, zoba isangqa esijikeleze isikrwere.
8. Kumbuzo wesibhozo, zoba umgca osuka kuphawu olungudibanisa uyokusho kwisiphumliso.
9. Kumbuzo wethoba, ngowuphi umgca omde? Beka itick (✓) kwibhokisi esecaleni komgca omd.
10. Kumbuzo weshumi, zoba uphawu lukadibanisa ekhohlo lomgca obhaliweyo.
11. Kumbuzo weshumi elinanye, zoba isangqa ekunene komgca obhaliweyo.

Umbuzo 3

Umfana uphume ebaleka eAfrica Bank. Ubalekele phakathi kweemoto ezimbini ezazimise phambi kwebanka, wangena kwisitalato sase Church kwaye ngelolixa kwakusiza imoto ngaphambili.

Bhala iAfrica Bank kwisakhiwo esisecaleni kwezomoto zimbini.

Imoto eyayigqitha ngesitalato iChurch isiya kwiStop esinqamleze izitalato iChurch ne Nelson Mandela Drive iye yambona umfana lowo yaze yajikela amavili emoto ngasekunene ukuze ingamgili.

Bhala uChurch stalato kwelinye icala lendlela enqamlezileyo. Bhala uNelson Mandela Drive ecaleni kuka namba 14.

Imoto leyo ithe yangqzulana netrakhi eyayisandul’ ukungena esitalatweni sase Church phambi kwevenkile yakwaCheckers.

Bhala uCheckers kwisakhiwo esisecaleni kdwtrakhi.

Umbuzo 4

uNosisi no Thabo bahlala eAlice. uNosisi usebenza ebhankini, yena uThabo evenkileni yakswPep. Bathathu abantwana bakaNosisi, bona abakaThabo bahlanu. uZanele ohlala ecthcarth unabantwanta abane, kwaye ungutitshalakzi osebenza kwisikolo esikufphi ne Cathcart.

APPENDIX F

ASSESSMENT RUBRIC FOR SPEAKING

	1 ELEMENTARY	2 THRESHOLD	3 LOWER INTERMEDIATE	4 UPPER INTERMEDIATE	5 ADVANCED
Contribution to the discussion	Little or no contribution	Only partial contribution	Contributes meaningfully some of the time	Contributes meaningfully most of the time	Complete and enthusiastic interaction and participation
Fluency of speech	Not fluent. A lot of hesitation and/or repetition.	Partially fluent with a high frequency of hesitation and repetition.	Reasonably fluent with a fair amount of hesitation or repetition	Mostly fluent with only some hesitation or repetition	Completely fluent with not hesitation or repetition
Clarity of communication	Not clear or audible at all.	Partially clear and audible.	Reasonably clear and audible.	Clear and audible.	Completely clear and audible.
Comprehensibility of information provided by learners	Barely comprehensible – listener can barely understand	Partially comprehensible – difficult to understand the meaning	Reasonably comprehensible, but a fair amount of statements not clearly understandable.	Comprehensible, with only some statements not clearly understandable	Completely comprehensible.
Communication skill/confidence exhibited	Not at all confident – hardly establishes eye contact at all.	Partially confident, only establishes eye contact one or twice.	Reasonably confident – establishes, but maintains eye contact some of the time.	Confident – maintains eye contact most of the time.	Confident – maintains eye contact all of the time.
Appropriateness of language use	Language use is not appropriate to the communicative context.	Language use is partially appropriate to the communicative context.	Language use is reasonably appropriate to the communicative context.	Language use is mostly appropriate to the communicative context.	Language use is completely appropriate to the communicative context.
Turn taking	Does not follow turn-taking conventions.	Follows turn-taking conventions to a very limited extent.	Follows turn-taking conventions to a reasonable extent.	Follows turn-taking conventions to a large extent.	Follows turn-taking conventions completely.
Use of home language/code switching	Uses home language frequently.	Uses home language to a large extent	Uses home language to a reasonably limited extent.	Only uses home language on one or two occasions.	Does not use home language at all.
Grammatical error	A high frequency of errors	A reasonably high frequency of errors.	A reasonably limited degree of error	Very few errors	Only one or two errors.
Pronunciation error	A high frequency of errors that contribute to incomprehensibility of information communicated.	A reasonably high frequency of errors that result in partial incomprehensibility.	A reasonably limited degree of error that does not affect comprehensibility.	Very few errors that do not affect comprehensibility.	Only one or two errors that do not affect comprehensibility.

APPENDIX G

CLASSROOM OBSERVATION SCHEDULE – Scientific Literacy Project

School Name: Province:

Teacher Name: Gender: Qualifications:

Grade Level: Number of learners:

Observer Name: Date of observation:

Component 1: Use of Stimulus			
4 Educator uses a stimulus, such as a reading or discrepant event as an introduction to a science topic.	3 Educator begins the lesson by asking higher order questions and linking the questions to the science topic.	2 Educator provides a brief introduction and asks closed-ended questions to introduce the science topic.	1 Educator has no introduction which gets the students thinking about the science topic.
Description:			
Component 2: Exploratory talk and class discussion			
4 Educator facilitates exploratory talk.	3 Learners involved cumulative or disputational discussion.	2 Learners answer questions, but provide little else in terms of discussion.	1 No discussions in class. Educator lectures, learners listen to teacher
Description:			
Component 3: Investigable Question			
4 Learners pose investigable questions.	3 Educator guides learners in asking an investigable question.	2 Educator provides a question for learners to investigate.	1 There is no question for learners to investigate.
Description:			
Component 4: Planning an Investigation			
4 Groups of learners discuss problems, questions and come up with ways to answer the investigable question by themselves	3 Only two or three learners in a-large group interact and offer ideas in ways to answer the investigable question	2 Educator provides step-by-step instructions to answer the investigable question	1 Learners are unable to formulate ways to answer the investigable question
Description:			

Component 5: Doing an Investigation			
4 Each group of learners independently uses their apparatus, collect their data and draw conclusions appropriately	3 Educator guides students to use their apparatus, collect data and draw conclusions	2 Educator leads/demonstrates learners through the use of the apparatus, data collection and drawing conclusions of the investigation	1 Learners are unable to use their apparatus, collect data and draw conclusions
Description:			
.....			
.....			
Component 6: Learner Writing with Science Notebooks			
4 Learners write effectively to record findings and enhance their learning	3 Learners write to record their findings but the text is so simplified that it does not enhance their learning	2 Learners write ineffectively – reveals only incoherent findings	1 Learners do not write at all
Description:			
.....			
.....			
Component 6: Learner Reading			
4 Learners read effectively from written text to enhance their learning	3 Learners read from written text with limited effect on their learning	2 Learners struggle to read from written text with limited to no effect on their learning	1 Learners do not read at all
Description:			
.....			
.....			
Component 7: Questioning Skills			
4 Teachers ask a variety of questions, including open-ended questions that probe for learners' understanding	3 Asks mostly close-ended questions and 1 or 2 open-ended questions	2 Asks simple-recall questions only or close-ended questions	1 Teacher asks no questions
Description:			
.....			
.....			

Component 8: Teacher Feedback to Learners			
4 Gives feedback about correct and incorrect responses in a manner that encourages further effort	3 Gives feedback about incorrect responses only, in a manner that encourages further effort	2 Gives feedback about incorrect responses only, in a manner that discourages further effort	1 Gives no feedback
Description:			
.....			
.....			
Component 9: Line of Learning - Teacher Subject Knowledge			
4 Teachers demonstrate clear standing of concepts being taught	3 Teachers demonstrate adequate understanding of concepts being taught	2 Teachers demonstrate partial understanding of concepts being taught	1 Teachers demonstrate inadequate understanding of concepts being taught
Description:			
.....			
.....			
Component 10: Line of Learning – Student Generated Ideas			
4 Learners clearly expand their scientific understanding through their own efforts	3 Learners adequately expand their scientific understanding through their own efforts	2 Learners partially expand their scientific understanding through their own efforts	1 Learners are unable to expand their understanding through their own efforts
Description:			
.....			
.....			
Component 11: Learner Subject Knowledge – Argumentation and Presentation			
4 Through their presentations learners demonstrate clear understanding of concepts and procedures being taught	3 Through their presentations learners demonstrate adequate understanding of concepts being taught	2 Through their presentations learners demonstrate partial understanding of concepts being taught	1 Through their presentations learners demonstrate very limited understanding of concepts being taught
Description:			
.....			
.....			

APPENDIX H

SCIENCE NOTEBOOK CHECKLIST

Teacher's Name:

School:

Learner:

Constructing a Question	How well does the learner construct an investigable question?				
Investigable question	0	1	2	3	4
	There is no evidence of a question	Learner copies teacher's question	Learner writes a question using his/her own words. Question is not investigable	Learner writes an investigable question using his/her own words. The question is missing important details	Learner writes an investigable question using his/her own words. The question has all the relevant details
Comments:					

Designing the investigation	How well does the learner design and implement a plan to answer the question?				
Experimental Procedure	0	1	2	3	4
	There is no evidence of what was done	Learner copies teacher's sequential procedure	Learner writes a plan using his/her own words. Plan is incorrect for answering the question	Learner writes a plan correctly using his/her own words, but plan is missing details. Investigation cannot be replicated.	Learner writes a plan correctly using his/her own words. It contains relevant details. Investigation can be replicated.
Comments:					

APPENDIX H: Science Notebook Checklist

Collecting Data	How well did the learner record data?				
Testability	0	1	2	3	4
	There is no evidence of data collection	Learner copies teacher's data	Learner records his/her data. Data are not accurate.	Learner records his/her own data. Data are accurate, but incomplete.	Learner records his/her own data. Data are complete and accurate.
Comments:					

Scientific Drawings	How well does the learner draw their observations?				
Experimental Procedure	0	1	2	3	4
	There are no drawings	Learner copies teacher's drawings	Learner produces original drawings. They are not labelled correctly. Drawings have no relevant detail.	Learner produces his/her own drawings which are labelled and have limited relevant detail.	Learner produces his/her own drawings which are correctly labelled and have relevant detail.
Comments:					

Drawing Conclusions	How well does the learner construct scientific meaning from the investigation?				
Experimental Procedure	0	1	2	3	4
	There is no evidence of understanding the science concept investigated.	Learner copies the teacher's words for the explanation.	Learner explains the concepts in his/her own words. The explanation is not correct.	Learner writes a correct and complete explanation using his/her own words. The explanation is missing relevant detail.	Learner writes a correct and complete explanation using his/her own words. The explanation includes relevant detail.
Comments:					

APPENDIX I

TEACHER INTERVIEW QUESTIONS

Teacher's Name: _____ School: _____
Interview Dates: (Baseline-) _____ (Post-) _____

BASELINE INTERVIEW

A. Ideas about Scientific Literacy

- What does the term 'scientific literacy' mean to you?

B. Investigating Classroom Practice

- What do you think are useful strategies to teach science? What works best in your classroom?
- Do your learners read during your science lessons? If so, what do they read? How often do they read in science?
- Do your learners write during your science lessons? If so, what type of writing do they do? How often do they write in science?
- Do you conduct investigations with your learners?

POST INTERVIEW

A. Implementation

- Reflecting on the model that was presented for scientific literacy, what were some of the benefits and/or challenges to implementing the model?
- Did you find that you spent more time on certain components than others?

B. Training / Professional Development

- For future training sessions, are there any topics on which we should spend more time? Why?

C. Perceptions about Scientific Literacy

- If you had to explain the term 'scientific literacy' to another teacher or to a parent, what would you say? How would you explain it?
- Do you think this model has helped your learners understand science?