SCIENTIFIC LITERACY AND
EDUCATION FOR SUSTAINABLE DEVELOPMENT:
DEVELOPING SCIENTIFIC LITERACY IN ITS FUNDAMENTAL
AND DERIVED SENSES

by

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Promoter: Professor Paul Webb
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ABSTRACT

The importance of developing learners’ scientific literacy in both the fundamental and derived senses has been highlighted by Norris & Phillips (2003). Development of the derived sense of science, which is dependent on the development of a sound fundamental sense of science, aims at promoting scientifically literate societies who are able to make informed decisions concerning the natural environment and the promotion of sustainable livelihoods. In turn, response to increasing recognition of environmental degradation, the United Nations’ Decade of Education for Sustainable Development advocated that the principles, values and practices of sustainable development should be integrated into all aspects of education and learning. However, despite these aspirations, the difficulties of insufficient teacher knowledge and a lack of in-service training, both abroad and within South Africa, remain a challenge. In response to this challenge this study investigated the potential of an Integrated Scientific Literacy Strategy (which aimed at increasing in-service teacher knowledge and skills) to contribute to ESD by developing more scientifically literate teachers and learners in primary education.

The study was conducted in 2010 in the Port Elizabeth Metropolitan area in the Eastern Cape, South Africa. The study sample comprised seven schools, with a total of nine teachers and 243 learners participating. As the research is situated within the pragmatic paradigm, a mixed methods approach was followed using Creswell and Plano Clark’s (2007) embedded design’s correlational model whereby quantitative data are rooted within a qualitative design to help verify and explain the outcomes. Qualitative measures were generated through teacher interviews and an analysis of their written portfolios. These data were triangulated against quantitative test data gained from an ANCOVA statistical analysis of the learners’ pre- and post-tests, and both the qualitative and quantitative data gleaned from classroom observations and an analysis of the learners’ science notebooks.
The data suggest that, when properly implemented, the Integrated Scientific Literacy Strategy can be used to help teachers develop their learners’ scientific literacy by exposing them to open-ended inquiry investigations. Statistically significant differences (p ≤ 0.01; d=0.88) were noted when comparing improvements in learners’ abilities and understandings of scientific investigations (graphs, variables, inquiry and investigable questions) between those learners whose teachers successfully implemented the strategy in their classrooms, and those learners whose teachers were considered to be ‘non-implementers’ of the strategy.

Data from this study also suggest that the successful use of the ISLS enables teachers to integrate issues relating to sustainable development into their natural science lessons. In addition, the learner-orientated approach of the strategy also enabled the learners to engage in autonomous learning environments, aspects of which have been identified as being important for meaningfully learning about and internalising important issues related to ESD.

**KEYWORDS:** Scientific literacy; Education for Sustainable Development; inquiry-based investigation; fundamental and derived senses of science, integrated strategy.
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<td>ANCOVA</td>
<td>Analysis of co-variance</td>
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<td>ANOVA</td>
<td>Analysis of variance</td>
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<td>ESD</td>
<td>Education for Sustainable Development</td>
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<td>GET</td>
<td>General Education and Training</td>
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<td>ISLS</td>
<td>Integrated Scientific Literacy Strategy</td>
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<td>LOL</td>
<td>Line of learning</td>
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<td>NCS</td>
<td>National Curriculum Statement (South Africa)</td>
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<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
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<td>PISA</td>
<td>Programme for International Student Assessment</td>
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<tr>
<td>UN</td>
<td>United Nations</td>
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<td>UNCED</td>
<td>United Nations Commission on the Environment and Development</td>
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<td>UNESCO</td>
<td>United Nations Educational Scientific and Cultural Organisation</td>
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<td>WCED</td>
<td>World Commission on Environment and Development</td>
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1. INTRODUCTION

Over the last two decades the notion of scientific literacy and its importance to technological societies has been a topic of academic and political research and debate (Fensham, 2008). According to Fensham (2004), being scientifically literate implies an ability to apply scientific content and process skills to life, work, culture, society, and civic responsibility when making decisions that affect personal and political well-being. In turn, Norris and Phillips (2003) have framed scientific literacy in two senses, viz. the fundamental and derived senses of science. The fundamental sense encompasses reading, writing, doing and presenting science, while the derived sense includes knowing, understanding and applying content, seeing the big picture, making judgements. Yore and Treagust (2006) believe that the development of scientific literacy in terms of these senses is an imperative of science education and school curricula internationally.

A scientific literacy issue that is currently high on the scientific and political agenda is the notion of sustainable development (Fensham, 2008; Millar, 2008). Education for sustainable development (ESD) aims at promoting scientifically literate societies which are able to make informed decisions concerning the natural environment and the promotion of sustainable livelihoods (Læssøe, Schnack, Breiting & Rolls, 2009, Mckeown, 2002). For Rosenberg (2007), “ESD is a life-wide and life-long learning endeavour which challenges individuals, institutions and society to view tomorrow as a day that belongs to all of us, or it will not belong to anyone” (2007, p.2). This study investigates the potential of a particular scientific literacy strategy (which promotes the development of scientific literacy in both the fundamental and derived senses) to contribute to effective teaching and learning of science in the field of education for sustainable development.
Chapter 1: Introduction and Overview

2. BACKGROUND TO THE STUDY

Fensham (2008) notes that there was a shift in the 1980’s from content-based school curricula aimed at educating learner’s to become science specialists towards the application of scientific knowledge. For Marks & Eilks (2009), science education needs to progress beyond scientific problem solving and application to encompass socio-scientific decision making abilities, thereby preparing educated citizens who are able to participate responsibly in the real world.

Makgato and Mji (2006), and Mashile (2001), contend that it is at the school science level where learners should begin their preparation to engage in a world where industrial and economic development progresses in a socially and environmentally sustainable manner. According to Bybee (1997) and Millar (2008), school science education should aim to provide learners’ with a multidimensional understanding of science where learners are able to apply their knowledge within their personal lives and society. Similarly, Holbrook and Rannikmae (2009) maintain that one of the more important goals of scientific literacy is to provide learners with the ability to make responsible decisions based on knowledge and the ability to interpret, understand and apply relevant scientific concepts and ideas. These understandings of scientific literacy seem to be especially important considering the myriad of environmental crises facing society today (Connelly & Smith, 1999; McKeown, 2010, Rosenberg, 2007), and Laugksch (2000) and Mashile (2001) emphasise that a scientifically literate society can significantly improve the process and quality of public-decision making. When considering global challenges such as global warming and questions of sustainability, Læssøe et al., (2009) call for a new way of thinking and understanding the world, emphasising the crucial role that education needs to play in educating the minds of our future leaders and decision makers.

In the late 1970’s and early 1980’s, questions of sustainability and concerns for the Earth’s limited natural resources, led to the initiation of the concept of sustainable development, defined by the Brundlandt Report of 1987 as “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Connelly & Smith, 1999:2). In 1992 this concept was further elaborated on
at the United Nations Commission on the Environment and Development (UNCED) (Marcinkowski, 2010; Breiting, 2009; Lotz-Sisitka, 2006). The most important outcome from the UNCED was Agenda 21, which dealt with the principles of Sustainable Development and how they could be achieved. In chapter 36 (Promoting Education, Public Awareness, and Training), the concept of ESD was introduced as an essential component for meeting the challenges of sustainable development. ESD would play an important role in meeting these challenges by helping learners to develop the attitudes, skills and knowledge required to make and act upon informed decisions for themselves, others and future generations (McKeown, 2002; Heimlich & Storksdieck, 2007).

ESD has since gained increasing recognition and influence as the reality of environmental degradation, climate change and increasing poverty become more evident and transparent (Breiting, 2009; Heimlich & Storksdieck, 2007). In 2005 the United Nations (UN) declared ‘The United Nations Decade of Education for Sustainable Development’ (2005 – 2014) as part of their commitment to address the social, economic, cultural and environmental problems of the 21st century (Rosenburg, 2007). In their definition of ESD, the United Nations Educational, Scientific and Cultural Organisation (UNESCO) (2004) advocated that the principles, values and practices of sustainable development should be integrated into all aspects of education and learning (Lotz-Sisitka, 2006).

3. RELEVANCE OF THE STUDY AND PROBLEM STATEMENT

The focus of ESD is not merely to provide information and knowledge, but to equip and enable individuals to re-orientate society towards sustainable practices (Breiting, 2009, McKeown, 2010; Rosenberg, 2007). Breiting (2009) heralds ESD as an innovative form of future education which links learner’s development with the future challenges of society and advises that it is imperative that education is directed towards what will be truly useful and meaningful for each individual in society in the future.

While the need to live more sustainable lives will make demands on all sectors of society, O’Donoghue (2007) maintains that schools will have a critical role to play in how they teach and model sustainable practices. McKeown (2002) emphasises that in
order for an effective framework for teaching ESD to be developed, teachers need to be equipped to help learners identify and think about the complexities relating to sustainable development and the need to acquire the necessary skills to analyse the issues and problems relating to ESD.

From the outset, the fundamental role which teachers would play in ensuring the success of ESD was acknowledged. In 1987, the World Commission on Environment and Development (WCED) emphasised their importance in the opening paragraphs of the Brundtland Report: “But first and foremost our message [sustainable development] is directed towards people, whose well-being is the ultimate goal of all environment and development policies. In particular, the Commission is addressing the young. The world’s teachers will have a central role to play in bringing this to them” (Connelly & Smith, 1999:3 citing WCED, 1987). Yet, despite these aspirations, Læssøe at al. (2009) and McKeown (2010) maintain that the dominant obstacle facing ESD internationally is insufficient teacher knowledge, understanding and in-service training.

Within South African education, Le Grange (2010) and Winter (2009) argue that one of the greatest challenges facing ESD in the South Africa is the lack of capable and knowledgeable teachers, and the challenges of training teachers to effectively teach the concepts, skills and knowledge associated with ESD. Research has shown that, in general, South African teachers appear unable to communicate attitudes of curiosity and critical reflection necessary for the development of higher-order cognitive skills (Taylor & Vinjevold, 1999). In response to this condition, Lotz-Sisitka (2006) contends that appropriate teacher education programmes, which promote critical and creative thinking, are essential for overcoming the challenge of implementing ESD in South African education.

Lotz-Sisitka (2006, 2007) suggests that participatory approaches to ESD, with the aim of strengthening critical and creative thinking, can be enhanced through the use of open-ended questions, inquiry-based investigation and research. According to Meece (2003), inquiry-based learning approaches should help to promote the development of scientific conceptual understandings and high-order critical thinking skills. For Webb (2009) and Millar (1996), the use of inquiry-based investigations can be used to
encourage learners to engage in authentic scientific experiences, promoting the
development of scientific literacy.

Scientific literacy requires a derived sense of understanding the nature of
science, technology, society and the environment and the interactions between them
(Fensham, 2008; Millar, 2008). Yore and Treagust (2006) encourage the effort to move
teachers towards a more current view of the nature of science and to embrace more
participatory and interactive methods of teaching science in order to gain improved
scientific literacy for the learners. An integrated strategy for promoting scientific
literacy, known as the Integrated Scientific Literacy Strategy (ISLS), has been
developed in South Africa. This strategy focuses on the use of reading, writing, taking,
arguing and inquiry-based investigations to promote scientific literacy (England, Huber,
Nesbit, Roger & Webb, 2008) as research has shown that teachers who participate in
extensive in-service courses that use these approaches have improved their methods of
teaching science (Webb, 2009; Villanueva, 2010).

While Daniels (2010), Villanueva (2010) and Webb (2009) have found that
using such approaches have resulted in improvements in learners’ basic scientific skills
(the fundamental sense of scientific literacy) at the primary education phase, the
potential for the ISLS strategy to promote and develop learners’ derived senses of
science has yet to be researched. In addition, explorations into the potential contribution
of promoting scientific literacy to ESD teaching and learning in South Africa are
limited. More specifically, while the use of inquiry-based methods have been suggested
to promote effective ESD internationally (Meece, 2003) and within South Africa (Lotz-
Sisitka, 2006), no evidence of research into the use of inquiry-based methods as an
approach to teaching ESD in South African primary education could be found.

The discussion above has highlighted the following challenges: a) the need for
science education to develop scientifically literate learners who are able to apply
scientific principles and knowledge to their own lives, b) the charge to incorporate ESD
into existing education systems and c) the problem of teachers with an insufficient
knowledge base to do so. In response to these challenges this study investigates the
potential contribution of the Integrated Scientific Literacy Strategy towards improving scientific literacy, with specific reference to ESD into the South African context.

4. RESEARCH QUESTIONS

This study uses the Integrated Scientific Literacy Strategy (ISLS) as a framework for developing inquiry-based activities and teacher training aimed at promoting some of the skills and knowledge required by ESD of grade 6 and 7 teachers and their learners.

The primary research question for this study is:

Can the Integrated Scientific Literacy Strategy (ISLS) make a contribution towards teaching ESD in South African primary education by developing more scientifically literate learners in grade 6 and 7 classrooms?

In order to answer this primary question the following sub-questions need to be answered:

- Can teachers be trained to properly implement the ISLS in grade 6 and 7 Natural Science classrooms?
- If implemented properly, can the ISLS be used to develop grade 6 and 7 learners with skills and understandings needed for scientific investigations (graphs, variables, process of investigation, formulating questions)?
- Can the teachers use the ISLS to integrate topics relating to sustainable development into their Natural Science lessons?
- Can the successful implementation of the strategy provide opportunity for learners to engage in communication, critical thinking, democratic decision making and problem solving opportunities (skills required for ESD)?

5. SAMPLE AND SETTING

The study was conducted between April and November, 2010, in the urban area of Port Elizabeth in the Eastern Cape, South Africa, when the potential of the Integrated Scientific Literacy Strategy to contribute towards more effective teaching and learning
of ESD in primary schools within the Port Elizabeth Metropolitan area was investigated. Considering that McKeown (2002) highlights the need for a strong foundation of basic education before ESD can be effectively implemented, and advises that until a basic level of competence has been achieved teachers will struggle to understand and implement aspects of ESD, an initial pilot study was run to investigate the current status of teachers’ and learners’ knowledge and understanding of ESD related issues in schools in Port Elizabeth. The findings were that teacher understandings of ESD and its implementation within the education system were often extremely weak and allowed the researcher to distinguish between the various teachers’ understandings. Taking heed of McKeown’s (2002) caveat, the study targeted schools with teachers who exhibited an appropriate level of understanding of ESD. These teachers were mostly teaching in Model C schools. The term ‘model C’ refers to schools which were formally administered by the House of Assembly (‘White’ parliament) during the apartheid regime in South Africa (Cronje, 2010). The schools, which were for white children only, were funded at a much higher level than schools for Black, Coloured and Indian children were, and were characterised by better-quality facilities, qualified teaching staff and good school leaving results (Makhubu, 2011, Roodt, 2010). These schools are now integrated racially, and government funding has been equalised throughout the schooling system, but they still reflect many of the previous advantages they enjoyed in earlier decades, notably the calibre of teaching staff.

Therefore, as a starting point, forty previously Model C schools in the Port Elizabeth Metropolitan area were invited to participate in the study. Seven schools accepted the invitation, and a total of nine teachers attended the training workshop and implemented the strategy in their classrooms. The approximate sizes of the classes were 25 – 30 learners per class, with 243 learners in total. While the small sample of teachers made it possible to generate insightful and rich information regarding the implementation of the strategy, the larger sample of learners allowed for statistical analysis of their pre-post tests.

Previous research in the value and usefulness of the ISLS has been done with grade 6 and 7 classes and revealed positive results in terms of improved teacher practice and learners’ language and reasoning skills (Daniels, 2010; Mayaba, 2009; Villanueva,
Chapter 1: Introduction and Overview

In order to contribute further to the existing research regarding the ISLS, the study was also conducted with teachers who taught grade 6 and 7 learners. In addition, the researcher felt that these children were old enough to comprehend and grasp the knowledge and skills associated with ESD.

All of the schools which participated in the study are government schools and follow the South African National Curriculum Statement (NCS). The teachers were all drawn from the Natural Science’s learning area and taught science at either grade 6 or 7 level. The average number of years teaching experience was 16 years. The teacher with the most experience had taught for 29 years and, the least experienced for three years.

6. RESEARCH DESIGN AND METHODOLOGY

This research study is situated within the pragmatic paradigm, which holds the position that the set of research 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). The approaches chosen to investigate the questions above include qualitative attempts to gain deeper understandings of social realities and the use of empirical evidence for data generation, placing this study within both the interpretive and positivist paradigms, as elaborated by Burrell and Morgan (1979). A mixed methods approach to research was therefore followed (Bergman, 2007; Creswell, 2007; Johnson, Onwuegbuzie & Turner, 2007).

Research took place across four phases. The first phase focused on the participating teachers from local Port Elizabeth primary schools, who were interviewed to determine and identify their knowledge of and experience with teaching ESD. These exploratory interviews explored the extent to which the concept of ESD is understood and promoted within local schools, and also identified certain challenges and obstacles experienced by the participating teachers.

The intervention period occurred during phases two and three of the research process. During the second phase, the participating teachers attended workshops where they received training on the Integrated Scientific Literacy Strategy (ISLS) and ESD.
These in-service training workshops provided the teachers with opportunities for reflection and clarification of the strategy and ESD.

The third phase involved the implementation of the strategy. Each teacher was tasked with using the strategy at least twice, with two different topics, during the following academic term. The competence of learners was tested according to a pre-and-post-test-design (Cobern, Schuster, Adams, Applegate, Skjold, Undreiu, Loving & Gobert, 2010; Webb, 2009), with the learners’ pre-test being applied before implementation began and again at the end of the implementation phase. During the implementation phase, classroom observations took place in order to generate data concerning the teachers’ implementation of the strategy and their learners’ responses. During this time, teachers were encouraged to provide opportunities for their learners to continuously write in their science notebooks. These notebooks were collected at the end of the implementation phase and used as an indication of how their teacher implemented the strategy, as well as investigating their progression concerning scientific investigations. The teachers were also tasked with submitting a portfolio, containing evidence of how they implemented the strategy in their classroom and a reflective essay recording their experiences and perspectives of the strategy. Finally, the teachers each participated in a reflective interview, which explored their understandings of the process and perspectives of their experiences in greater depth.

The fourth phase of research involved the analysis of the data collected in phases one and three. As previously discussed, the use of both qualitative and quantitative instruments and analyses were used in order to gain a better understanding of the implementation of the strategy and its impact on the participating teachers and their learners. These methods were conducted concurrently, with the mixing of the qualitative and quantitative methods occurring during the interpretation and analysis of the data in order to provide a greater degree of accuracy during interpretation. For example, the statistical analysis of the learners’ pre-post test scores were compared and corroborated with the qualitative descriptions taken during the interviews, classroom observations and from the mixed-methods analysis of the learners’ science notebooks. Additionally, both the ten-point assessment schedule and the learners’ science notebook checklist reflect Creswell and Plano Clark’s (2007) embedded design’s correlational
model whereby quantitative data are rooted within a qualitative design to help verify and explain the outcomes. These instruments both utilised a quantitative scale to measure performance and included additional space on the instrument for the researchers’ qualitative observations, descriptions and explanations.

There are, however, certain limitations when conducting such a study. The external validity of this research may be in question due to the small sample of schools from Port Elizabeth, which cannot be considered by any means to represent all South African classrooms. Therefore, the findings of this study cannot be generalised to the South African education system as a whole. In addition, there are possibilities that the classroom observations were not completely ‘authentic’. For example, the teachers may have prepared the lesson specifically for the observation, and therefore the lesson observed may not be a true reflection of their implementation throughout the implementation phase. However, the learners’ continued to use their science notebooks throughout the intervention period, perhaps providing better insight into their teachers’ implementation of the strategy. Yet, despite these limitations, this research still provides some insight into the factors which contribute to the successes and challenges of using an integrated strategy to improve scientific literacy, and its potential contribution to ESD.

7. DATA GATHERING INSTRUMENTS

Kitchen and Tate (2000) advise a combination of a variety of methods to ensure a more holistic and accurate enquiry, especially when complexity abounds, as is the case in human behaviour. As noted earlier, the data collection methods employed included teacher interviews, learners’ pre-post tests, classroom observations, teacher portfolios and the learners’ science notebooks. The data were analysed on completion of the intervention and corroborated with one another in an attempt to reach valid conclusions and appropriate recommendations.

Semi-structured interviews with open-ended questions were used for the teachers’ initial exploratory interviews and their final reflective interviews. This approach provided openings to probe and clarify responses, as well as and providing opportunities
for the teachers’ to expand on issues and clarify responses (Wilson, 1996; Kitchen & Tate, 2000).

The classroom observations, teacher portfolios, final reflective interviews and the learners’ science notebooks were used to generate data on the implementation of the Integrated Scientific Literacy Strategy (ISLS). While the teachers’ reflective interviews and portfolios were only analysed qualitatively, the classroom observations and learners’ science notebooks were analysed using a mixed methods approach. In addition to the qualitative observations recorded, a scale-based rubric was used to generate both quantitative and qualitative data. This rubric was developed using a modified version of a validated assessment schedule (Webb, 2009; Kurup, 2010; Villanueva, 2010), which was customized for this study. Both the classroom observations and science notebooks were analysed according to the customised ten point assessment schedule so that comparisons could be made between the different data sources.

Additionally, a Science Notebooks Checklist (Nesbit, Hargrove, Harrelson & Maxey, 2003, Villanueva, 2010) was used to assess the learners’ level of scientific literacy. The 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 learners’ pre-post tests used in this study provided the opportunity to generate data on their understanding and ability relating to scientific investigation, as well as providing an indication of their views towards environmental issues. These tests were completed prior to the implementation of the strategy, and once again after implementation, in an attempt to ascertain if the strategy had impacted the learners’ response to environmental issues or their abilities regarding scientific investigation.

The first two questions in the pre-post test focused on the learners’ environmental attitudes and awareness, and were developed using Menzel and Bogehölz’s (2010) model to explain adolescent’s commitment to protect biodiversity. Questions three to six of the learner’s test were taken from the Programme for International Student Assessment (PISA) Science Project (OECD, 2009). These questions were aimed at
assessing their understandings and abilities in terms of scientific investigations related to environmental issues.

The quantitative data generated was statistically analysed and evaluated in an attempt to discover if there was any change in the learners’ abilities concerning scientific investigations as a result of the implementation of the ISLS. Analysis of co-variance (ANCOVA) was applied as the pre-test scores were statistically significantly different in terms of the samples being compared (Donnelly & Trochim, 2006; Gravetter & Wallnau, 2008).

8. ETHICAL CONSIDERATIONS

Researchers have a moral obligation to search for truth and knowledge, while simultaneously protecting the rights of individuals in society (Mouton, 2001). Prior to the commencement of the research, an application was made to the Faculty of Education Ethics Committee to obtain ethical clearance based on informed consent. All principals and teachers involved in the study were informed of the nature and scope of the research and were given the option to choose whether or not they would like to be part of the research process, prior to any data collection taking place. Individual learner consent was based on the teachers and principals acting in loco parentis on behalf of the learners. In addition, the principals and teachers right to anonymity was discussed, as well as their right to full disclosure regarding the research topic, results and recommendations.

9. OUTLINE OF STUDY

This research study is comprised of six chapters. Chapter one is the introduction and presents a concise overview concerning the study’s background, relevance and problem statement, before stating the primary and secondary research questions. The chapter continues with discussions on research methodology, sample and setting, and ethical considerations.

The theoretical framework of the study is discussed in chapters two and three. The primary concern of the literature review, chapter two, is to contextualise scientific
Chapter 1: Introduction and Overview

literacy and ESD. By illustrating the potential connections between the two concepts, the review provides the theoretical background and justification for the research taking place. Chapter three bridges the gap between theory and practice by explaining the research methodology utilised in this study. Specific attention is given to the use of mixed methods research as this approach forms the foundation of the research experience.

Chapter four presents the results of the investigation and illustrates the correlations and differences between the qualitative and quantitative data collected. Chapter five is a discussion of the results in light of data presented in chapter four and the literature reviewed in chapter two. The chapter includes a discussion of the significance of the research for current practice and theory.

Finally, chapter six provides the conclusions and recommendations by revisiting the primary and secondary questions set out for the dissertation and discussing how these have or have not been achieved through the research process. Overall, the study is an attempt to add to the emergent resources on scientific literacy and ESD research in the South African context.
CHAPTER TWO
LITERATURE REVIEW

1. INTRODUCTION

This chapter further develops the brief introductions to scientific literacy and ESD discussed in the preceding chapter and reviews relevant literature concerning the role of scientific literacy in preparing learners for responsible citizenship and the importance of ESD in science education today. After establishing a theoretical foundation for scientific literacy, the review focuses on the use of inquiry-based approaches for promoting literacy, curiosity and learner participation within science classrooms. In response to these approaches, an Integrated Scientific Literacy Strategy (ISLS) is introduced as an example of inquiry-based investigation. Current discourses regarding ESD are highlighted, with specific reference to formal education and the South African context.

2. SCIENTIFIC LITERACY

The 1980’s were characterised by a reassessment of the content and goals of school science, which resulted in a shift of curricula away from a content-based curriculum aimed at educating learner’s to become science specialists, towards a school science aimed at educating learners to become responsible citizens (Fensham, 2008). Slogans such as Science for All; Science, Technology and Society; and Scientific Literacy gained increasing popularity within the prevalent discourse, despite dispute and contention regarding their definitions, purposes and desired outcomes (Coll &Taylor, 2009; Fensham, 2008; Laugksch, 2000; Turner, 2008; UNESCO, 1999).

Debates concerning school science curricula continue today, fuelled by increasing disinterest from learners for the subject (Fensham, 2008, Millar, 2008). Fewer students are choosing to study the subject due to its perceived difficulty and limited relevance and the challenge remains to rethink the educational role of science in school curricula (Fensham, 2008, Millar, 2008, Tytler, 2007). It is within these perspectives that science
educators and researchers have grappled with the notions of scientific literacy (Yuenyong & Narjaikaew, 2009).

While, as previously noted, definitions and interpretations of scientific literacy are diverse (Laugksch, 2000), the essence of the concept constitutes what the general public should know about science and implies an appreciation for the nature and purpose of science coupled with an understanding of important scientific ideas (Jenkins, 1992; Laugksch, 2000; Preczewski, Alexandra, Mittler & Tillotson, 2009). Scientific literacy emphasises, among others, the role of science in promoting personal, democratic, socio-economic and scientific well being in attempt to make science more applicable and relevant to the ordinary person (Fensham, 2008; Holbrook & Rannikmae 1997; Millar 2008, UNESCO, 1999).

A comprehensive definition, which amalgamates many current interpretations and perspectives of the concept, is provided by the Organisation for Economic Co-operation and Development (OECD) 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, p. 12)

The extensive list of what it means to be scientifically literate suggests that it is something which is difficult to attain. Bybee (1997) contends that despite the comprehensive list of what it means to be scientifically literate, scientific literacy is, and always has been, an intrinsic goal of science education. The value of the scientific literacy slogan rests in its ability to initiate contemporary reform and to reaffirm the purpose of learning science (Bybee, 1997).

The literature also suggests that learning science is vital for people to be able to make connections in order to understand the natural world (Powell & Aram, 2007) and to enable citizens to become informed and participate in the public debate about science,
technology and environmental issues within the society (Yore, Pimm & Tuan, 2007). Makgato & Mji (2006) and Mashile (2001) argue that it is at the school science level where learners should begin preparation to engage in a world where industrial and economic development progresses in a socially and environmentally sustainable manner.

From a global perspective, Fensham (2008) states that the current quality of school science education has “never before been of such critical importance” (p.4), due to the demands made on citizens to make responsible, democratic decisions. In response to this reality, Fensham (2008) notes that consensus has been reached in the science education community that there is a need to focus on scientific literacy which emphasises scientific knowledge and applications. However, a more recent consensus that has emerged within sectors of the science education community is the need to focus more on the literacy aspects of scientific literacy (Norris & Phillips, 2003, Yore, Bisanz, & Hand, 2003).

For Norris and Phillips (2003) scientific literacy encompasses both a fundamental and derived sense of science. The distinction that they draw between these senses of science is that the fundamental sense requires proficiency in science language and thinking and refers to the use of language in science contexts. In comparison, being proficient in the derived sense signifies being able to make informed judgements on scientific societal issues and deals with understandings or abilities relative to science (Norris & Phillips, 2003). In Table 2.1, Yore, et al. (2007) illustrate the interrelatedness of Norris and Phillip’s (2003) fundamental and derived senses of science.
Table 2.1 Interacting Senses of Scientific Literacy (Yore, et al., 2007, p. 568)

<table>
<thead>
<tr>
<th>Fundamental Sense</th>
<th>Cognitive and Metacognitive Abilities</th>
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<tbody>
<tr>
<td></td>
<td>Critical Thinking/ Plausible Reasoning</td>
</tr>
<tr>
<td></td>
<td>Habits of Mind</td>
</tr>
<tr>
<td></td>
<td>Scientific Language Arts (reading, writing, speaking, listening, viewing and representing in science)</td>
</tr>
<tr>
<td></td>
<td>Information Communication</td>
</tr>
<tr>
<td></td>
<td>Technologies</td>
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</table>

<table>
<thead>
<tr>
<th>Derived Sense</th>
<th>Understanding the Big Ideas and Unifying Concepts of Science</th>
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<tbody>
<tr>
<td></td>
<td>Nature of Science</td>
</tr>
<tr>
<td></td>
<td>Scientific Inquiry</td>
</tr>
<tr>
<td></td>
<td>Technological Design</td>
</tr>
<tr>
<td></td>
<td>Relationships among Science, Technology, Society, and Environment</td>
</tr>
</tbody>
</table>

While there is some 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 lead to the problematic and recurrent separation of content and process in science. However, Yore (2008) argues that these two aspects of science are not meant to be viewed as separate and distinct, but should rather be integrated into a more holistic science curriculum.

Norris and Phillips (2003) maintain that by strengthening learners’ fundamental sense of science, such as their ability to read, write and communicate; the overarching goals of understanding the derived sense of science, will be achieved. Furthermore, if students are to participate and employ scientific thinking 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). As such, the argument is that any science curriculum, which focuses on content and memorisation, should be challenged and transformed by addressing scientific literacy by empowering people to be fluent in the discourses of science, i.e. reading, writing and talking science (Hand, Prain, Lawrence & Yore, 1999; Powell, 2006; Yore & Treagust, 2006; Yore, et al., 2007).

In this study the research focuses on using inquiry-based techniques to develop scientific literacy in the fundamental sense and to enable learners to understand the application of scientific knowledge and skills with specific reference to the natural environment and the importance of sustainability. In other words, it attempts to investigate whether using the Integrated Scientific Literacy Strategy can provide opportunities which enable learners to better understand the natural world and become more informed citizens (Mashile, 2001; Marks & Eilks, 2009), thereby contributing towards ESD in formal South African education.

3. PROMOTING SCIENTIFIC LITERACY

The strategy used in this study to promote scientific literacy towards understanding ESD aims to incorporate authentic science experiences, developing literacy skills, promoting curiosity, and learner centred teaching and learning techniques, each of which is discussed below.

3.1 Authentic science experiences

Webb (2009) and Millar (1996) maintain that scientific literacy can be promoted by encouraging students to engage in authentic science experiences such as the use of open-ended investigations which encourage learners to extract meaning from their own findings. However, in most cases, the essence of inquiry has been lost in school science and replaced with a more time efficient pseudo-inquiry which only requires learners to follow a set of instructions set out in a textbook or worksheet. Such investigations are
short, generally verify what has already been studied, and the purpose is often not understood by students (Barrow, 2010; Powell & Aram, 2007). Furthermore, local and international examinations focus on the simple recall and application of scientific knowledge, and the true nature of open-ended investigations, which represent genuine scientific inquiry, are rare if present at all (Fensham, 2008).

The American Association for the Advancement of Science (1993) suggests that authentic scientific processes are able to blend logic and imagination whilst demanding evidence to support claims; ideas which are often overlooked in classrooms. It is suggested that for learners to engage in genuine, inquiry-based scientific process, they should able to develop their own authentic questions through stimuli such as readings, discussions or discrepant events (England & Webb, 2008) and be active participants in the planning, development, conducting and evaluation of the project and activities (Webb, 2008). It is also suggested that learners learn to formulate their own theories and become aware and take ownership of their learning process through gathering data and observing patterns in the results (Suchman, 1996).

An authentic inquiry-based approach hinges on instruction based on authentic investigations, empirical techniques, open-ended problem solving and a reliance on evidence in constructing new knowledge. Such an approach aims at capturing the process of discovery within the classroom and provides learners’ with a sense of how science produces new knowledge (Cobern et al., 2010; Hume & Coll, 2010). Pearson, Moje & Greenleaf (2010), point out that inquiry activities have the potential to go beyond learner enjoyment and participation to developing literacy skills as they argue that, when science is presented through authentic inquiry, it provides opportunities for learners’ to evaluate information, develop conclusions and engage in arguments based on evidence – the very skills necessary to develop proficient talkers, readers and writers. Marks and Eilks (2009) also emphasise the importance of the communication skills that are gained through inquiry-based approaches, and which can be applied beyond science and are essential for the learner to actively engage in the interactions between science and society.
3.2 Developing literacy skills

Other research into science education has specifically highlighted the need for developing learners’ literacy skills, particularly in reading and writing, as an integrated component of science curricula (Norris & Phillips, 2003; Yore & Treagust, 2006; Webb, 2010). Yore and Treagust (2006) stress the importance of empowering learners to be literate in the discourses of science in order to be able to talk, read and write science effectively. Gee (2005) reiterates this view and praises the learning area of science in its goal of training learners to communicate orally, with the written word, and also symbolically with the use of diagrams. Powell and Aram (2007) also encourage educators to use reading and writing as tools to expand learners’ science thinking and conceptual development within the context of inquiry-based learning experiences which encourage children to engage in learner-orientated, hands-on inquiries that provide opportunities to read and write at each stage of the investigation (Powell & Aram, 2007).

Christie et al. (2007) state that one of the great challenges facing educators today is motivating learners to read. Powell and Aram (2007) urge educators to encourage learners to actively seek out answers for their questions through investigation or further reading, in this way motivating them to read to learn. When children have constructed an idea based on their own experiences, the opportunity exists to encourage them to read further to clarify, confirm or extend their findings and formulations. Powell and Aram (2007) continue to suggest that scientific inquiry and open-ended investigation are important catalysts for further reading as hands-on investigations lead to curiosity and questions which cannot be answered through more investigation. According to Barrow (2010), it is the learners’ curiosity which initiates inquiry, and which leads to questions which can be used to form the basis of the learning process and motivate learners to want to learn more (Barrow, 2010).

3.3 Promoting curiosity

For Fensham (2008) and Barrow (2010), the process of equipping learners to participate in important socio-scientific issues facing society today begins with developing a natural curiosity and appreciation for the natural world through the avenue
Chapter 2: Literature Review

of scientific inquiry in the primary school years. Preczewski, Mittler & Tillotson (2009) encourage educators to constantly link the learners’ everyday experiences with their classroom studies and to embrace a less formal process of inquiry when approaching scientific investigation. In response to their research, they urge teachers to move away from a content-focused approach, and rather focus on the process and interaction of science with the natural world.

Shaheen (2010) maintains that the scientific process of inquiry provides an opportunity to develop and encourage critical and creative thought in learners through stimulating their curiosity about natural phenomenon and the world around them, and believes that school education should be focused on developing “freely creative and original thinkers” by providing opportunities for learners to become innovative and enterprising (p. 166). Knowledge alone is no longer seen as a sufficient outcome of education as learners need the ability to think creatively and critically in order to solve problems and make a difference in their sphere of influence (Hume & Coll, 2010; Pearson et al., 2010). Barrow (2010) concludes that this outcome is most often achieved through learner-centred approaches to education.

3.4 Learner-orientated approaches

Theorists such as Barrow (2010), Hume and Coll (2010) and Paris and Combs (2006) emphasise the role of learner-orientated learning in the process of inquiry and its ability to foster curiosity amongst learners. Hume & Coll (2010) point out that in order to appreciate scientific enquiry, students need to have ownership of open-ended problem solving opportunities where they are required to use their current scientific knowledge to analyse problems, implement investigations and evaluate information. Barrow (2010) urges educators to use the following three aspects of inquiry to foster curiosity and learner participation amongst learners: a) encourage students to design scientific investigations in response to testable questions, b) allow them to work in small groups as they design and carry out their investigations, and c) provide opportunities for them to present their findings to their peers.

The term learner-centred has been frequently associated with excellence in inquiry-based teaching methods and developmentally appropriate education (Carter, 2010; Paris
& Combs, 2006). Bansberg (2003) and Paris and Combs (2006) describe recent progression in formal education to be characterised by the transition away from instructional methods aimed at delivering masses of knowledge to a silent audience, towards more participatory, learner-centred approaches. Descriptions of learner-centred approaches include a respect and appreciation for learners’ interests and needs, the development of learner autonomy and an active engagement of learners in the learning process; all leading towards increased motivation and interest (Bansberg, 2003; Carter, 2010; Daniels & Perry, 2003; Meece, 2003). In Table 2.2 Barrow (2010) provides an overview of the variations of inquiry which a science teacher could implement and how the degree of learner centeredness can vary for each attribute.
### Table 2.2 Essential features of classroom inquiry and their variations (Barrow, 2010, p. 13)

<table>
<thead>
<tr>
<th>Essential Features</th>
<th>Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner engages in scientifically oriented questions</td>
<td>Learner poses a question Learner selects among questions, poses new questions Learner sharpens or clarifies question provided by teacher, materials, or other source Learner engages in question provided by teacher, materials, or other source</td>
</tr>
<tr>
<td>Learner gives priority to evidence in responding to questions</td>
<td>Learner determines what constitutes evidence and collects it Learner directed to collect certain data Learner given data and asked to analyze</td>
</tr>
<tr>
<td>Learner formulates explanations from evidence</td>
<td>Learner formulates explanations after summarizing evidence Learner guided in process of formulating explanations from evidence Learner given possible ways to use evidence to formulate explanation Learner provided with evidence</td>
</tr>
<tr>
<td>Learner connects explanations to scientific knowledge</td>
<td>Learner independently examines other resources and forms links to explanations Learner directed toward areas and sources of scientific knowledge</td>
</tr>
<tr>
<td>Learner communicates and justifies explanations</td>
<td>Learner forms reasonable and logical argument to communicate explanations Learner coached in development of communication Learner provided broad guidelines to sharpen communication Learner given steps and procedures for communication</td>
</tr>
</tbody>
</table>

More------------------------Amount of Learner Self-Direction------------------------Less

Less------------------------Amount of Direction from Teacher or Material------------------------More

Research by Daniels and Perry (2003), Meece (2003) and Wood (2008) has shown the potential for learner-centered learning to enhance learning outcomes via the implementation of teaching practices which allow learners to personally engage in challenging activities with support and guidance from their educator. Learners
participate actively in different learning tasks and are given opportunities to choose their own approaches (Carter, 2010, Meece, 2003; Wood, 2008). In comparison, teacher-centered approaches place more emphasis on learners following uniform instructions and directions on academic tasks. Educators generally believe that they need to be in control of the learning process, that some students are not naturally motivated or capable of learning and that learners should work alone, following precise instructions (Daniels, Kalkman & McCombs, 2001; Paris & Combs, 2006; Wood, 2008).

Daniels, et al., (2001), Daniels & Perry (2003) and Paris & Combs (2006) argue the importance of the need for young learners’ to participate actively in class, noting that when teacher’s embraced learner-centred approaches their learners were more motivated, placed a higher value on learning, and were more meaningfully engaged in their school work. They attributed these achievements to the fact that learners felt they were participating in interesting learning activities, that they were allowed to make their own choices, and that they were given opportunities to work with their classmates. In a similar vein, Daniels et al., (2001) found that optimum learning occurred when leaders were engaged, focused on problem-solving and working in small groups. Learner-centred approaches should recognise the individuals own ability to think creatively and reflectively, and the value of democratic decision making and cooperative engagement in the construction of knowledge. By implication learner-centred approaches should be collaborative and flexible, enabling learners’ autonomy and creativity as they develop their own questions and processes for investigation.

The integrated strategy for promoting scientific literacy that was used in this study seeks to enhance the nature of open-ended authentic scientific inquiry by allowing learners optimum participation in the direction and nature of the learning process via stimulation of curiosity through discussion towards investigable questions, designing and executing open-ended investigations, and extending knowledge through reading and writing to learn science (Webb, 2009).
4. AN INTEGRATED STRATEGY FOR PROMOTING SCIENTIFIC LITERACY

Yore and Treagust (2006) state that socio-political perspectives of scientific literacy have led to curricula which do not emphasise the development of the necessary cognitive tools and communication abilities required to lead children through the fundamental processes of scientific literacy which are required if they are to attain scientific literacy in the derived sense (Norris & Phillips, 2003). In South Africa an integrated strategy for promoting scientific literacy was developed and researched (Webb, 2009) in an attempt to support teachers to develop their learners’ fundamental sense of science. This Integrated Scientific Literacy Strategy (ISLS) focuses on the role of reading, writing, talking and doing science to promote scientific literacy as illustrated in figure 2.1. Lind (2001) suggests that scientists know that the best way to learn science is to do science. This way of learning can best be accomplished with children by allowing them to learn and discover through asking and answering questions, doing investigations, and by applying problem-solving skills.
Figure 2.1  Integrated Scientific Literacy Strategy implemented in this study (Webb, 2008c, p. 152)
4.1 Stimulus: Promoting curiosity

The strategy begins with a stimulus event aimed at inspiring interest and enthusiasm for the topic at hand. The stimulus may be reading content-specific literature, or a discrepant event stimulating curiosity amongst the learners, with the aim of enabling them to develop with their own investigable questions (England & Webb, 2008). Marks and Eilks (2009) illustrated the benefits of using stimuli through use of authentic, current and controversial problems being debated within society. These were used to effectively introduce the topic and provoke questions and discussions amongst the learners. Their study concluded that the use of a relevant stimulus drastically increased the learners’ motivation to learn and participate in the subject because the learners were able to see the relevance and application of what they were learning to their own lives.

Powell and Aram (2007) argue that if educators can create sufficient curiosity about a specific topic, learners can be motivated to read and write to learn. Planning lessons around a central theme has long been considered an advantageous method of integrating language and content instructions into lessons, particularly at the primary school level (Gianelli, 1991). For England and Webb (2008), the use of carefully selected stories, which are both interesting and fun for the learners, can provide opportunities for learners to develop literacy and cognitive skills and competencies, as well as promoting content knowledge of the relevant concepts and processes. Powell and Aram (2007) encourage educators to use reading and writing as tools to expand learners’ science thinking and conceptual development within the context of inquiry-based learning experiences. When children engage in learner-orientated, hands-on inquiries, they should be encouraged to read and write at each stage of the investigation, thereby developing both their communication skills and scientific understanding.

England and Webb (2008) highlight the importance of using stories to promote reading through the use reading approaches such as read-aloud, shared reading, guided reading and independent reading. In particular, the use of shared reading seems to create opportunities for the learners to discuss scientific concepts and develop investigable questions, tasks which are usually difficult for learners to achieve. Webb (2008, 2010)
claims that 'discrepant events' and reading to learn science can play an important role in promoting exploratory talk which facilitates the planning and execution of an investigation. The stimulation that is provided should have the potential to encourage and guide the learners to discuss, share and find out together, build on their prior skills, knowledge and experiences, and extend their scientific knowledge base.

4.2 Investigable question: Promoting discussion

Teachers are expected to encourage discussion and exploratory talk amongst the learners, which should lead to questions which can be categorised as either investigable (can be answered in the classroom) or researchable (can only be answered using books, the internet or experts, etc.). The teacher is then expected to guide the learners toward investigable questions which are feasible in the context of their classroom, after which groups of learners choose which particular question they would most like to investigate and design their own investigation using accepted scientific methodology (prediction, procedure, data collection, and conclusion).

For Webb (2008), exploratory talk occurs when learners are engaged in critical and constructive discussion. Learners’ ideas are discussed, challenged and alternative viewpoints are offered for consideration. Decision-making is a collective process through which learners can come to a consensus about the idea. Through this process, the learners’ contributions and ideas are accepted, challenged, negotiated and the group is held accountable for their assertions (Mercer, 1996). Researchers 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 limited evidence of meaningful discussion in school classrooms, particularly those that were previously disadvantaged under the system of Apartheid (Taylor & Vinjevold, 1999). The authoritarian teaching and learning environment associated with the Apartheid education system, was characterised by rote propositions that endorsed neither analysis nor critique (Webb, 2009). Apartheid schooling generally followed a teacher-led exchange of initiation-response-evaluation, where the teacher poses a close-ended or lower-order thinking question, to which
students reply with an answer in a one word, or shortened response (Edwards & Mercer, 1987; Mortimer & Scott, 2003).

The above type of classroom environment fostered little discussion and may explain why international research has found that learners have a vague understanding of the purpose behind their classroom activities and are so often perplexed, unfocused and unproductive in their use of language (Barnes & Todd, 1995; Edwards & Mercer, 1987; Sheeran & Barnes, 1991). Educators employing initiation-response-evaluation 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).

As previously stated, the ISLS used in this study aims at promoting talking towards questions and discovery through exploratory talk. The more specific purpose of engaging the learners’ in exploratory talk is the development of a list of questions, some of which are investigable. An integral challenge to inquiry-based teaching and learning is developing an investigable question to initiate the investigative process (Webb 2009). 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. The challenge for the 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 (Webb, 2008).

However, Yore, et al. (2007) emphasise that this challenge is often too great for teachers to attain as they “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” (p. 64). The use of inquiry in the ISLS recognises Yore, et al.’s (2007) perspective and strives to provide teachers with a strategy to guide and enable them to meet the challenges of inquiry-based teaching.
4.3 Inquiry Investigation: The science notebook approach

Webb (2008a) maintains that one of the benefits of using inquiry investigations is the opportunity to develop cognitive abilities such as reasoning with data, constructing arguments and making coherent explanations. Both cognitive and procedural aspects play essential complementary roles in investigations because the validity of the findings depends on the understanding about the science being investigated (cognitive) and the processes used (procedure) (Webb, 2008a).

According to the South African national curriculum (Department of Education, 2002) investigations provide the opportunity for learners to practice their reading, writing, discussion, argumentation and presentation skills. Learners should be afforded opportunities to formulate and ask questions, test hypotheses, and depict data graphically. Further to this they should engage in data analysis, work in teams, solve problems, communicate findings and draw conclusions both orally and in writing. The ISLS aims to achieve these goals through the use of the science notebooks approach.

Throughout the ISLS, learners should be encouraged to make notes and draw diagrams in their personal science notebooks, allowing them to freely record their questions, predictions, observations, and conclusions (Nesbit, 2008). Research in the use of science notebooks in elementary education within the United States (Fulton & Campbell, 2003; Miller & Calfee, 2004) has illustrated their ability to foster a comprehensive understanding of scientific concepts and procedure through recording inquiry-based investigations (Ruiz-Primo, Lin & Shavelson, 2002). For, Powell & Aram (2007) the use of science notebooks provides an opportunity to integrate science and language learning, which enhances the learners’ conceptual development.

Within this particular strategy, learners are required to describe their investigation, record data, offer conclusions and also to engage in theoretical research to gain further insight and understanding of the relevant concepts. Learners are encouraged to record their ideas and questions at each stage of the investigation, allowing them to document their emerging understandings as they progress through the process of inquiry. Each step recorded explains what was predicted, what was planned, what was done and what was found out. Students are encouraged to make drawings, mind maps and notes as they
conducted an investigation. Table 2.3 provides a revised summary of the descriptions of the seven science notebook components (Villanueva, 2010).

Table 2.3  

<table>
<thead>
<tr>
<th>Component</th>
<th>Simplified term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date &amp; time</td>
<td>Date and time of the investigation</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>What I want to know</td>
<td>The key problem to be investigated.</td>
</tr>
<tr>
<td>Prediction</td>
<td>What I think</td>
<td>Learners make an educated guess and provide an explanation or reason to their prediction.</td>
</tr>
<tr>
<td>Procedure</td>
<td>What I did</td>
<td>All materials and steps of the investigation are recorded. The procedure gives insight to the design and fair test of the investigation, as well validity.</td>
</tr>
<tr>
<td>Results</td>
<td>What I found out</td>
<td>Data are recorded in this section. One may check for reliability of the results. Data is communicated in graphs, tables and/or scientific drawings.</td>
</tr>
<tr>
<td>Conclusion</td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>Line of Learning</td>
<td></td>
<td>Learners develop deeper understanding about the target concept. Teachers facilitate the application of the concept to new situations and the development of new vocabulary.</td>
</tr>
</tbody>
</table>
4.4 Line of learning: Further research

Once the investigation is completed, a Line of Learning (LOL) is drawn in the notebooks to indicate that the investigation can go no further in terms of providing more insight into answering the relevant questions (Nesbit, 2008; Powell & Aram, 2007). Learners are then encouraged to engage in further research to deepen their understanding of the topic. Learners are given the opportunity to consider the additional questions raised during the investigation as well as the researchable questions formulated at the beginning of the investigation. The line of learning is then extended by using other sources of information, such as further reading, experts, teacher and peer information and the internet. In this way many of the researchable questions that have been identified can be answered and incorporated into the learners' presentation of their findings (and provide warrants and backings for their arguments) and the assimilation of new information. Finally, learners are required to present their findings using argumentation to substantiate their claims (Webb, 2008b).

4.5 Argumentation and presentation: Promoting thinking, talking and writing strategies

According to Newton, Driver and Osborne (1999), the previous two decades have witnessed a shift from the idea that learning is a restricted process in the mind of the individual, towards the view that learning is a social process, involving collaboration between learners, their peers and the teacher (Alexepoulou & Driver, 1996). This view implies that learning is no longer viewed as the transfer of factual knowledge through observation and teaching, but rather is considered the social processing of knowledge (Webb, 2008b), where the importance of classroom talk is recognised by educational researchers (Selley, 2000).

Research by Selley (2000), Driver, Newton and Osborne (1998) emphasises the importance of promoting classroom talk in enabling learners to develop their understanding of scientific ideas. Unfortunately, classroom talk is often dominated by the teachers’ questions and short answers from the learners. In comparison Webb (2008b) calls for discussion which allows the learners’ to think and plan their arguments as a group. This type of discussion helps learners to accept the views of others, while the
inclusion of different ideas obliges them to elaborate and defend the argument at hand (Webb, 2008b). As learners’ conceptions change through discussion and thinking together, they are able to develop a conceptual understanding (Driver at al., 1998).

When learners engage in argumentation concerning their views and ideas, a cognitive conflict exists, which leads learners to think about their own thinking processes. This process is known as metacognition (Selley, 2000). The ISLS promotes metacognitive strategies by providing opportunities for the learners to draw on the information recorded in their science notebooks to prepare scientific arguments through oral presentations or school reports. The results from research in argumentation in science (Hand, Prain & Yore, 2001) suggest that the effects of student learning are greater when learners are engaged in the dual practices of reflection and modification subsequent to cognitive actions.

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; Wallace, 2004). Webb (2008b) suggests that as learners use inquiry-based activities to test questions and gather supporting evidence, the use of an argumentation-based writing framework, based on a revision of Toulmin’s (1958) model, be used to engage learners in the coordination of conceptual goals (Table 2.4).
Table 2.4  Argumentation framework – revision of Toulmin’s (1958) argumentation model

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

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 (Webb, 2008b).

Finally, the learners’ are tasked with presenting their claims and evidence for others to see. Through presenting their findings both orally and/or in a written form, the ISLS provides learners with an opportunity to see that both the data they have collected, and the way in which they have chosen to argue and represent their findings, are both important for constructing meaningful understandings (Webb, 2008b).

4.6 Learner participation in the ISLS investigations

The underlying assumption throughout the ISLS is that the learners engage and participate in each step of the inquiry-based process (Webb, 2008c). The teacher guides the class discussion, helping the learners to pose their own questions, and to choose
which ones should be investigated. The learners are encouraged to design original investigations and provide their own data and conclusions. It is the learners who draw the LOL and decide which avenue to research further. The learners then present their argumentation in a structure that requires evidence, backings and warrants to support their claims. Throughout the strategy learners are engaged in the processes of doing, talking, reading and writing and are therefore developing the fundamental skills of science (Webb, 2009, Villanueva, 2010).

In summary the strategy aims to:

- *Enhance reading to learn science and learning to read for science*;
- *Improve classroom discussion and exploratory talk towards investigable questions*;
- *Facilitate planning and doing an investigation in the classroom*;
- *Scaffold writing to learn science*; and
- *Scaffold argumentation and critical thinking*  

(Webb, 2009, p. 328)

### 4.7 Research findings

Recent research into the application of the various components of the strategy has shown significant improvements in learners’ problem solving skills, as well as increased communication and literacy skills through the use of the science notebooks and the opportunity to present their arguments (Webb, 2009). Villanueva (2010) piloted the strategy in two milieus in the Eastern Cape, South Africa. The first was the deep rural setting of the Tyumie Valley, and the second was the urban townships area east of Port Elizabeth. The application of the strategy focused on the fundamental components (Norris & Phillips, 2003) of scientific literacy and the teachers’ ability to use the strategy in their classrooms. The data collected suggested improve problem solving as well as improved literacy and language skills among the learners. The teachers’ gradual improvements in their application of the model suggested that they were able to use the strategy to develop scientific literacy amongst their learners (Villanueva, 2010).

In addition, Daniels (2010) investigated whether aspects of the ISLS could be successfully employed in a museum context with grade 6 and 7 learners. The ISLS was
used as part of the education programmes at the Port Elizabeth Museum School, where the teachers’ ability to adopt the strategy, the teachers’ perceptions of teaching and learning, and aspects of the strategy which the learners adopted most readily were investigated. The findings suggested that active engagement in the process resulted in effective adoption of the strategy by the teachers, improved attitudes towards science learning by both the teachers and children who participated in the process, and improved scientific literacy in both (Daniels, 2010).

This study focused on primary schools in urban Port Elizabeth and sought to determine how the ISLS could contribute towards teaching ESD in science classrooms through its ability to foster and develop inquiry-based teaching.

5. SCIENTIFIC LITERACY AND EDUCATION FOR SUSTAINABLE DEVELOPMENT

One of the goals of scientific literacy is to provide learners with the ability to operate as a citizen in society, and make responsible decisions based on knowledge and the ability to interpret, understand and apply relevant scientific concepts and ideas (Holbrook & Rannikmae, 2009; UNESCO, 1999). Preczewski, et al. (2009) and Marks & Eilks (2009) contend that science education needs to progress beyond scientific problem solving to encompass socio-scientific decision making abilities preparing citizens to participate in the real world. According to Bybee (1997) and Millar (2008), school science education should aim to provide learners’ with a multidimensional understanding of science where learners are able to apply their knowledge within their personal lives and society.

This integrated understanding seems to be especially important considering the myriad of environmental crises facing society today such as global warming, ozone layer depletion and overpopulation (Rosenburg, 2007). Laugksch (2000) and Mashile (2001) emphasise the fact that a scientifically literate society can significantly improve the process and quality of public-decision making because decisions are made in response to an adequate understanding of the key issues at hand.

In July 2007 the World Conference on Science and Technology was held in Perth, Australia, from which The Perth Declaration on Science and Technology was issued.
The declaration expressed strong concern about the state of science and technology education worldwide, specifically in terms of its responsibility to meet current societal issues:

We, the participants at the 2007 World Conference on Science and Technology Education, held in Perth, Western Australia, 9-12 July 200… believe in the importance of science and technology for sustainable, responsible, global development, and in the need to bridge the gap between science and technology and the public… We, the participants, are committed to ensuring that students are scientifically and technologically literate and able to contribute to sustainable, responsible, global development in their respective nations. (Perth Declaration, cited in Fensham, 2008, p. 44)

Among their nine recommendations to governments world-wide, the Declaration urged policy makers to revise school science and technology curricula with the intention of increasing student interest and recognition in the roles which science plays in society, with specific reference to the fundamental integration of science and technology in achieving environmental, cultural, social and sustainable development goals (Fensham, 2008). Fensham (2008) continues to discuss the broader impact on society of scientifically and technologically informed citizens. Without adequate understanding, many citizens would support short term interests at the expense of long term progress through sustainability.

Educational reforms in science education, such as those discussed in relation to scientific literacy, have opened the door for a more public friendly and relevant school science curriculum (Fensham, 2008). School science has transitioned away from the content and specialist focused nature of school science, to a curriculum aimed at preparing learners’ to act as responsible citizens (Millar, 2008).

Rosenburg (2007) calls for a science curriculum focused on sustainability and the environment, which can endeavour to broaden public understanding of the vital role education plays in moving society towards ecological sustainability and social justice. Congruently, Linder, Ostman & Wickman (2007), stress the importance of a scientifically literate society when dealing with both global and local environmental issues:
As long as their school science is not equipping them to be scientifically literate citizens about these issues and the role that science and technology must play, there is little hope that these great issues will be given the political priority and the public support or rejection that they need. (Linder et al., 2007, p. 8)

While the importance of scientific literacy for responsible citizenship has been clearly illustrated, the question of what knowledge and skills enable people to deal more confidently and effectively with responsible citizenship remains (Mashile, 2001). It is within this discourse that ESD has gained increasing recognition.

6. EDUCATION FOR SUSTAINABLE DEVELOPMENT

For Selby (2006), one of the more productive outcomes of the 2002 World Summit on Sustainable Development held in Johannesburg, South Africa, was the UN’s declaration of the The United Nations Decade of Education for Sustainable Development (2005 – 2014). The decade was proclaimed as part of the UN’s commitment to address the social, economic, cultural and environmental problems of the 21st century (Jickling & Wals, 2008; Rode & Michelsen, 2008; Selby 2006). UNESCO was placed as the lead agency with the task of integrating the principles, values and practices of sustainable development into all levels and aspects of education and learning (Lotz-Sisitka, 2006; McKeown, 2010; UNESCO, 2004). Delegates agreed that without the active role of education, sustainable development would remain yet another interesting concept with no real ramifications or impact (Jickling & Wals, 2008; Rosenberg, 2007). In response, UNESCO provided the following definition of Education for Sustainable Development:

To integrate the principles, values, and practices of sustainable development into all aspects of education and learning. This education effort will encourage change in behavior that will create a more sustainable future in terms of environmental integrity, economic viability, and a just society for present and future generations. (Lotz-Sisitka, 2006, p.11 citing UNESCO, 2004)

While considerable research is focused on the controversy surrounding the definitions of Sustainable Development and ESD, the effectiveness of ESD in comparison to previous ideologies, and the manner in which ESD is taught (Bonnet, 2006; Benedict, 1999; Landorf, Doscher & Rocco, 2008; Reid, 2002; Selby, 2006),
UNESCO has maintained that sustainable development is the ‘ultimate goal’ of the man-made environment (Sauve, 1996, p. 7). Selby (2006) affirms that despite heated debate, ESD has managed to stand firm and has acquired global support, unified a range of issue-specific interest groups and secured its place in international education arenas.

6.1 ESD and Environmental Education

McKeown and Hopkins (2007) argue that Environmental Education (EE) and ESD are ‘distinct yet complementary’ (2007, p. 20). The concept of EE originated in the 1970’s, where the protection of the environment was of great concern (Hungerford, 2009, Sauve 1999). In comparison, ESD found its roots in the Sustainable Development movement of the 1990’s and thus incorporates concern for economic and human development to environmental protection (Heimlich, 2007; McKeown & Hopkins, 2007). The United Nations declaration of its decade for ESD (2005 – 2014), highlighted the difference between EE and ESD as the following:

[Environmental education] is a well-established discipline, which focuses on humankind’s relationship with the natural environment and on ways to conserve and preserve it and properly steward its resources ... Education for sustainable development, encompasses environmental education but sets it in the broader context of socio-cultural factors and the socio-political issues of equity, poverty, democracy and quality of life. (Venkataraman 2010, p. 8 citing UNESCO, 2004)

Despite having distinct origins, the two concepts share many similarities such as their vision for a better world, a more just and equitable society, environmental stewardship and protection and community-based decision making (McKeown & Hopkins, 2007). Early definitions of EE included aspects such as consideration for socio-environmental issues; interactions between the economy, environment and development; the recognition of both local and global perspectives and the importance of international solidarity on environmental issues (Reid, 2002; Sauve, 1996). EE therefore played an important role in preceding and shaping ESD as we know it today (Chatzifotiou, 2006; Jicklings & Wals, 2008; Reid, 2002).

Much discourse surrounds the issue of EE verses ESD (Heimlich, 2007; Reid, 2002). Questions regarding the distinction between the two concepts (McKeown & Hopkins, 2007; Sauve, 1999), the transformation of EE into ESD (Jicklings & Wals,
2008) and the continued relevance and need for EE (Hungerford, 2009) punctuate current dialogue and theory. However, while acknowledging the controversy, this study will not delve into current debate, but rather focus on current rhetoric regarding ESD.

6.2 ESD: Purpose and practice

Breiting (2009) heralds ESD as an innovative form of future education which links learner’s development with the future challenges of society. From both a global and local perspective, it is imperative that education is directed towards what will be truly useful and meaningful for each individual in society in the future (Landorf et al., 2008; Sauve, Berryman & Brunelle, 2007). According to Wals (2007), ESD should be centred around creating a close link between education and real life experiences by focusing on sustainability related problems experienced within people’s own communities.

ESD seeks to help learners develop the attitudes, skills and knowledge required to make and act upon informed decisions for themselves, others, and future generations (Lotz-Sisitka, 2006; McKeown, 2002; Rosenburg, 2007). ESD aims to address all three pillars of sustainable development: society, environment and economy; and the interactions between the three. The integrated and holistic study of this dynamic relationship enables individuals to develop the knowledge, perspectives, values and skills necessary to participate in decisions to improve quality of life on both a local and global scale (Bourn, 2005; Corney, 2006; Higgs, 2002; Reid, 2002; Ventakaraman, 2010).

Embracing ESD throughout education systems is paramount to developing citizens that adopt sustainable development as a guiding principle for their lives (Venkataraman, 2010). McKeown (2002) maintains that once basic education levels have been improved, the second priority of ESD is to re-orient basic and secondary education to address issues of sustainability. In comparison to environmental education which existed as a separate entity in the curriculum, McKeown (2002) advocates that the skills, knowledge and values of ESD be reflected throughout the learning system. Similarly, in their definition of ESD, UNESCO (2004) advocate that the skills, values and practices of sustainable development should be integrated into all aspects of education and learning (Lotz-Sisitka, 2006).
The following lists describe some of the skills learners will need as adults:

- The ability to communicate effectively (both orally and in writing)
- The ability to think in time - to forecast, to think ahead, and to plan
- The ability to think critically
- The ability to work cooperatively with other people.
- The capacity to use these processes: knowing, inquiring, acting, judging, imagining connecting, valuing, and choosing.

(McKeown, 2002, p. 20)

6.3 ESD within school education

Higgs (2002) emphasises that genuine education is not synonymous with the acquisition of knowledge and skills. The importance of education is found in the use of knowledge and skills, the value thereof and how the acquisition of knowledge has affected a person’s mind, attitudes, ideas and values. Higgs (2002) continues to argue that prescriptive education renders independent, critical thinking extremely difficult and where conformity is expected, creativity and innovation are stifled. Therefore, for ESD to flourish, education systems will need to embrace personal engagement, participation, innovation and critical thinking (Higgs, 2002).

Issues of sustainability are often dealt with at a community level with interested and affected stakeholders. These issues require active participation and engagement from many people who, most often, don’t share similar values, ideals or understandings (Wals, 2007). According to Bonnet (2006), if ESD is really going to enable learners to address issues of sustainable development, it needs to focus on society’s motives and the fundamental ways in which we think about ourselves and the world. For Lotz-Sisitka (2008), it is therefore important that ESD encourages learners’ to explore and critically engage with environmental issues so that they develop their own ability to interpret the issues they face.

Lotz-Sisitka (2006, 2008) identifies participatory learning and creative and critical thinking as essential to ESD. According to McKeown (2002, 2010), ESD should also give learners the practical skills required so that they may continue learning after they leave school and continue to make sustainable choices regarding their own lives.
McKeown (2002, p. 20) includes the following skills as essential to ESD: a) the ability to communicate effectively the ability to think critically and the capacity to use the processes of knowing, and b) inquiring, judging, imagining, connecting and choosing.

The opinions discussed above suggest that ESD should not be taught in an authoritative, top-down approach (Venkataraman, 2010). Bourn (2005) and Landorf et al. (2008) state that for ESD to be genuinely effective it needs to be firmly established in learning approaches that are participatory. Bonnet (1999; 2006) and Higgs (2002) urge educators to embrace democratic teaching approaches, which encourage greater personal engagement from the learners, and, therefore, a fuller and deeper understanding of the issues at hand. For Lotz-Sisitka (2006), participatory approaches in ESD can be achieved through inquiry-based methods, critical learning through debates and group work and opportunities for experiential learning.

### 6.4 ESD and the Integrated Scientific Literacy Strategy

As previously discussed, the ISLS aims to develop scientific literacy among learners through learner-centred learning and open-ended scientific inquiry and aims to cultivate learner-centered approaches through inquiry based learning (Webb, 2009; 2010). The primary research question of this study seeks to investigate the potential for the integrated scientific literacy strategy to contribute towards teaching ESD in South African education. According to Lotz-Sisitka (2006), introducing participatory approaches to ESD with the aim of strengthening critical and creative thinking can be enhanced through the use of open-ended questions, investigation and research. In addition, Meece (2003) argues that the use of learner-centred inquiry-based learning approaches should help to promote the development of conceptual understanding and high-order, critical thinking skills.

The strategy aims to provide teachers with ideas and techniques to stimulate their learners to develop their own investigable questions, plan and execute a successful investigation in the classroom, and present their findings to an authentic audience (Webb, 2009). This seems to be significant to South African education, where one of the greatest challenges facing ESD in the South African context is not the lack of its specific mention within the National Curriculum Statement, but rather a lack of capable and
knowledgeable teachers, and the challenges of training teachers to effectively teach the concepts, skills and knowledge associated with ESD (Le Grange, 2010; Winter, 2009). Reddy (2006) maintains that improving the quality of science teachers being produced and developing in-service teachers is fundamental to the challenge of advancing science education in South Africa.

7. SCIENTIFIC LITERACY AND ESD IN THE SOUTH AFRICAN CONTEXT

In 1994, the new democratic government of South Africa was tasked with the challenge of restructuring a drastically unequal education system. The previous education system was characterised by the under-development of human potential, particularly for the black population (Makgato & Mji, 2006). According to the Department of Education the learning areas worst affected were mathematics, science and technology (Department of Education, 2001). The Department of Education aimed to address these problems through various learning areas, with specific learning outcomes (Dillon, 2009).

In 2002 the government released the National Curriculum Statement Department of Education (NCS) (Department of Education, 2002). The NCS introduced two stages of education within the formal schooling program – General Education and Training (GET) and Further Education and Training. The GET stage encompasses the first nine years of compulsory schooling and has eight learning areas, each with their own learning outcomes (Department of Education, 2002; Le Grange, 2010).

In contrast to the traditional, content-based focus of the previous regime, the NCS emphasised specific learning outcomes and the competencies that each learner must achieve. The new curriculum was founded on critical and developmental outcomes, which were in keeping with the new constitution’s ideals of democracy, equity and redress. These critical and developmental outcomes focused on the development of learners who are creative and critical problem solvers, team workers, responsible persons, collectors and analyzers of information, effective communicators and informed and skilled in the use of science and technology (Department of Education, 2002; Webb, 2009). These outcomes applied to all aspects of the education system and described the
“kind of citizen the education and training system should aim to create” (Department of Education, 2002, p. 11).

7.1 New curriculum 2011

While there has been positive support for the 2002 curriculum, there has also been considerable criticism, specifically in reference to its implementation causing teacher overload, widespread confusion and stress, and learner underperformance in international and local assessments. In July 2009 the Minister of Basic Education appointed a task team to investigate the nature of the challenges, problems and flaws experienced in the implementation of the NCS, and to develop a set of recommendations for the way forward (Department of Education, 2009; 2010).

The task team’s report provided a five-year plan with three phases for improving curriculum implementation and the improvement of teaching and learning in South African schools. The first phase involved streamlining policy into more concise and coherent documents, for implementation in January 2011 (Department of Education, 2009; 2010).

While set in the midst of change, the teachers in this study were still operating under the principles and guidelines of the 2002 NCS (Department of Education, 2002). Therefore, this study will focus on the influence of the 2002 NCS document on scientific literacy and ESD in the South African context.

7.2 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 have 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
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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, 2006).

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 (Department of Education, 2002) asserts that the underpinning philosophy of Natural Science Learning Area is to promote scientific literacy through the achievement of the three learning outcomes:

*Learning Outcome 1: Scientific Investigations:* The learner will be able to act confidently on curiosity about natural phenomena, and to investigate relationships and solve problems in scientific, technological and environmental contexts.

*Learning Outcome 2: Constructing Science Knowledge:* The learner will know and be able to interpret and apply scientific, technological and environmental knowledge.

*Learning Outcome 3: Science, Society and the Environment:* The learner will be able to demonstrate an understanding of the interrelationships between science and technology, society and the environment (Department of Education, 2002, p. 6).

Each of the learning outcomes above promotes learning through inquiry, requiring learners to be able to develop testable questions and to find the most appropriate solutions for the problem at hand. The learning outcomes emphasize the learner’s ability to apply science knowledge, and not merely to attain it. This is in line with the learning area’s core purpose which is to promote scientific literacy as illustrated by the following expectations: “ a) the development and use of science process skills in a variety of settings; b) the development and application of scientific knowledge and understanding; and c) appreciation of the relationships and responsibilities between science, society and the environment” (Department of Education, 2002, p. 4).

The NCS embraces the notion of scientific literacy further in its transition away from content and knowledge based science, towards a more integrated and relevant approach to science (Mashile, 2009, Kallaway, 2007; Keane, 2008). The third learning outcome of the Natural Sciences is congruent with the international move towards
contextually relevant science education, which invites a shift from content based pedagogies to those that investigate socio-scientific issues, many of which will be environmental issues (Le Grange, 2010).

7.3 ESD in the South African context

The NCS critical outcomes emphasised the need for problem solving skills, critical thinking, teamwork, communication skills, ability to collect, apply and evaluate information, and, most importantly for ESD, the effective and critical use of science and technology demonstrating responsibility towards the environment and health of others (Department of Education, 2002, Winter, 2009). One of the five critical outcomes on which the NCS is based, calls for social justice, a healthy environment, human rights and inclusivity; which suggest that learning areas should be developed with the environment in mind (Le Grange, 2010).

According to Winter (2009), while the implicit concept of ESD is not mentioned in the South African National Curriculum, the concepts of sustainable development and sustainability are incorporated into the curriculum within the framework of environmental education. During the period leading up to the announcement of the UNDESD, South Africa was involved in the preparation of their own National Curriculum Statements (NCS) and thus by the time the UNDESD was declared, it was already too late to incorporate the terminology and discourse into the NCS. However, the NCS incorporates many aspects of ESD through its focus on aspects such as social responsibility, environmental education and holistic education across subject boundaries (Department of Education, 2002; Winter, 2009). The Natural Sciences learning area incorporates the sustainable use of the earth’s resources, as well as preparing learners to participate in a democratic society, where human rights are valued and environmental services are promoted responsibility (Winter, 2009).

However, the discourse on ESD within South African education is still embryonic and has not made significant impacts in the South African school curriculum. This largely due to confusion between EE and ESD, and an insufficient understanding of the uniqueness of the ESD concept (Le Grange, 2010). While general ESD principles are
present, an inadequate appreciation of how sustainable development discourse should challenge socio-political, economic and environmental dynamics is evident in the curriculum. Merely raising awareness about sustainable development, without challenging the economic status quo, will under-prepare a young nation facing an uncertain future (Le Grange, 2010, Winter, 2009). Lotz-Sisitka (2006) warns that unless ESD is based on challenging critical understandings of an unsustainable world, sustainable development will become just another ideology, which fails to lead to any genuine change or solution.

Chatzifotiou (2006) argues that the general inadequacy of school based ESD to promote critical thinking amongst learners, stems from the insufficient and limited knowledge base and information which teachers seem to possess in terms of their practices, teaching approaches and understandings of ESD. Læssøe et al. (2009) and McKeown (2002) emphasise the need for effective teacher training as they also consider insufficient teacher knowledge and understanding, and a lack of training to be one of the dominant obstacles facing ESD internationally. Within the South African context, Lotz-Sisitka (2006, 2008) identifies the lack of appropriate teacher education programmes, which promote critical and creative thinking, to be essential to overcoming the challenge of implementing ESD in South African education.

7.4 A lack of capable and knowledgeable teachers

Despite the NCS’s aspirations of an improved education system, recent studies show very little improvement in science education in South African classrooms (Christie et al., 2007; Howie, 2003). Within the field of science education, Fensham (2008) urges policy makers to prioritise the professional development of teachers aimed at raising their content knowledge and confidence in the science learning area. In particular, primary science education is marked by the presence of teachers with insufficient training and studies in the physical sciences in their later years of schooling or at university. Primary educators are trained as generalist teachers and lack the knowledge and content of their secondary counterparts, who are trained as learning area specialists (Pearson, et al., 2010).
The lack of capable science teachers within the GET phase in South African education can be attributed to several key factors. Firstly, many GET educators teaching the Natural Sciences are doing so due to staff shortages and were not trained as specialist science educators, but rather as generalist primary school teachers (Fensham, 2008, Pearson et al., 2010). This influences the second factor, which is their insufficient knowledge background, often lacking key aspects of science such as investigations (Villanueva & Webb, 2008). Thirdly, the majority of teachers were themselves taught in a traditional, rote fashion and were not exposed to models of effective learner-centered teaching. As a result of the lack of sufficient science training and experience in conducting investigations, many science educators within the GET phase have minimal skills in conducting inquiry-based activities or the knowledge on how to promote them (Webb & Glover, 2004).

Regardless of inappropriate training or experience, educators are still charged with understanding and teaching the broad themes of the NCS. According to the Department of Education’s (2000) Norms and Standards for Educators, educators are tasked with the roles of “learning mediators, designers of learning programmes and materials, leaders, administrators and managers, scholars, researchers and life-long learners, community members, citizens and pastors, assessors and learning area specialists” (Department of Education 2002, p. 3). However, the move to a more mediator-based role is no easy task and one fraught with many challenges in the South African classroom, particularly considering the legacy of educator-dominated teaching methods which is entrenched in the majority of teachers today (Mashile, 2009). As stated by Thomas & Pederson (2003), “a common maxim in the educational profession is that one teaches the way one is taught” (2003, p. 319). Hiebert, Morris & Glass (2003) agree that people learn to teach, predominantly, by the culture of education they were raised in. For those who served as passive apprentices for 12 years or more, when faced with the difficult challenges of educating learners, they will most likely revert to the teaching methods used by their previous teachers.

For Taylor and Vinjevold (1999), the reason teachers are not able to interpret and implement the new curriculum is due to an insufficient knowledge base. Many teachers across the spectrum of schooling in South Africa model superficial forms of learner-
centred activities without a genuine understanding of the founding philosophies or how to effectively implement them. Taylor and Vinjevold (1999) continue to suggest that educators who lack experience, confidence and general pedagogic content knowledge, will often resort to methods of expository teaching, rote learning and maintain strict control over classroom activities.

Pearson et al., (2010) also identify teacher knowledge as the key to advancing student achievement. Greater proficiency in science reading, writing, and inquiry for all students requires knowledgeable teachers who understand the vital role literacy plays in enhancing rather than replacing science learning and who can mentor their students in these practices. However, this mentorship requires deep conceptual change for teachers to help them adopt new ways of thinking and teaching in the classroom. Changes of this magnitude will require rethinking teacher preparation, professional development, and curriculum (Pearson et al., 2010).

For this reason, Pearson et al. (2010) call for teacher training which employs the very same inquiry processes for their own professional learning that they aspire to enact with their students. By making their own learning about literacy and science pedagogy the object of inquiry, teachers can simultaneously develop the insights and pedagogical strategies they will need to mentor their students. Makgato and Mji (2006) maintain that for South African education to progress, it is critical that educators are involved in courses which will instruct, inspire and motivate them to change their normal teaching practices.

In light of these arguments, this study investigates the potential for the Integrated Scientific Literacy Strategy to promote ESD within South African classrooms by helping teachers to building their knowledge base about science and ESD, to increase their confidence in learner-centred teaching approaches, and by providing a strategic tool to promote critical and creative thinking amongst their learners.

8. CHAPTER SUMMARY

This chapter began with a review of the literature regarding scientific literacy and its role in promoting responsible citizenship. Within this framework, scientific literacy
in formal education was considered, with specific focus on the role of inquiry-based teaching methods for promoting literacy, curiosity and learner participation. The Integrated Scientific Literacy Strategy was discussed as an example of how this may be achieved. The chapter progressed to provide a theoretical review of current literature regarding ESD and its role in formal education, before placing the concepts of scientific literacy and ESD within the South African context, focusing specifically on the need for teacher training programmes.
1. INTRODUCTION

This chapter describes and justifies the philosophical positions underpinning the study, the theoretical perspectives behind the methodology, and the methods of data collection and analysis. Due to the pragmatic approach taken, interpretivism and positivism are discussed as distinct paradigms before presenting an argument for using a mixed methods approach. Thereafter the research design is discussed, the chosen approach taken is elucidated, and the strategy used, and the methods of data collection and analysis are explained. In addition, the relevant ethical considerations and methodological limitations of the study are considered.

2. RESEARCH PARADIGMS

Skelton (2001, p. 89) states that as researchers we have to acknowledge that, “we are not neutral, scientific observers, untouched by the emotional and political contexts of places where we do our research. We are amalgams of our experiences… part of our honesty and integrity as researchers must be based upon considerations about ourselves, our positionalities and our identities and what role they might play in our research”. Acknowledgement of subjectivity in research has implications because it implies that “the scientific way of knowing is no longer regarded as a privileged discourse linking us to truth but rather one discourse among many... [with] questions of representation and communication being dependent upon prior questions of ontology (what constitutes reality), epistemology (how we come to know that reality) and science (the formal construction of such knowledge)” (Cosgrove & Domosh, 1993, p. 25, 28).

Researchers’ epistemological and ontological beliefs, i.e. the system of ideas which inform their reality; constitute the paradigm which influences their practices and the methodologies they employ (Guba, 1990; Hanson, Creswell, Plano, Clark & Creswell 2005; Morgan, 2007). More specifically, the researcher’s overarching paradigm (which
is consciously or unconsciously adopted) determines the conceptual model chosen and employed, determines their research methods, and dictates how they approach their data (Le Compte, Millory & Preissle, 1993).

Cronje (2011) suggests that it is important to consider a researcher’s belief in terms of what constitutes fundamental understanding and the nature of usefulness. This enables one to determine whether the researcher is concerned with the abstract or concrete. Cronje (2011) believes that once these positions are established one can place the research within an appropriate paradigm, and uses Burrell and Morgan’s (1979) research paradigm model to do so.

Burrell and Morgan (1979) identified four mutually exclusive paradigms within two dimensions of social science research: the nature of social science and the nature of society. They juxtaposed these dimensions at right angles to each other (Figure 3.1). Along the x-axis, the nature of social science ranges from subjectivity to objectivity; and along the y-axis between sociology of radical change and one of regulation and order in society.

As this study used a mixed-method approach, which includes the qualitative dimension of interpretivism and the quantitative dimension of positivism, both interpretivism and positivism will be discussed as separate and distinct paradigms before attempting to explain its pragmatic positioning.
2.1 Positivism

Research conducted prior to the 1970’s was dominated by a positivist approach characterised by the authority of science. Positivism was established on the premise that characteristics of the human world were similar to those of the natural world and, therefore, could be studied using the same scientific methods (Unwin, 1997; Rumutsindela, 2002). The 19th century French philosopher, Auguste Comte, is credited with developing this term 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).

Positivism is associated with the idea that laws govern social 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, Thorpe, & Lowe, 2002). This thinking 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).

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.

However, the 1970’s witnessed an increasing dissatisfaction with the singular use of positivist methods to explain human phenomena (Kitchen & Tate, 2000). Increasingly, researchers realised that social research could not avoid subjectivity and must acknowledge the central position of the human agent and the influence of human cognition and intentions on their behaviour. These subjective approaches to research radically altered the means by which social studies were conducted (Cosgrove & Domosh, 1993; Denzin & Lincoln, 2003), and afforded researchers the privilege of choice between qualitative and quantitative approaches (Kitchen & Tate, 2000).
2.2 Interpretivism

Dwyer and Limb (2001) argue that one of the most significant aspects of qualitative research is that it is not based on the assumption that there is a pre-existing reality that can be measured or known. Rather, the desire to understand the social world is based on the understanding that societal realities are dynamic and are always being reconstructed through interaction between cultural, economic, social and political processes. The emphasis when using qualitative approaches is, therefore, to seek to understand lived experiences. As opposed to statistical descriptions or generalized models, qualitative approaches, such as those associated with interpretivism, seek subjective understandings of localised social realities (Dwyer & Limb, 2001; Mouton, 2001).

The interpretive paradigm focuses on meanings and attempts to understand the context and totality of each situation by employing a variety of qualitative methods (Mouton, 2001) and pays particular attention to the social construction of knowledge (Easterby-Smith, Thorpe & Lowe, 2002; Lather, 1991). The aim for the interpretive researcher is 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).

For Denzin and Lincoln (2003), the epistemology of interpretivism 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. Participants are considered to be active agents who are autonomous and able to create their own social reality. It is therefore important for the interpretivist researcher 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 (Denzin & Lincoln, 2003).

In order to gain this interpretivist understanding of individual behaviour, researchers attempt to observe ongoing processes, and consequently, generally select small samples to provide more in-depth descriptions and insight into the participants’ social reality (Appleton & King, 2002). 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 (Appleton & King, 2002; Denzin & Lincoln, 2003).

However, it must be noted that although subjective approaches allow for greater and more genuine understanding of social realities, Dwyer and Limb (2001) warn that there are limits and pitfalls that the researcher needs to be aware of. The researcher needs to guard against excessive self-reflection as this will cause the final written product to be flawed or exclusionary due to unwarranted self-justification and self-centeredness. Researchers need to be open to and aware of the unexpected and to the necessity to challenge preconceived assumptions and expectations (Dwyer & Limb, 2001). Considering the potential pitfalls of a purely interpretivist approach, the researcher chose to adopt a mixed-methods approach, thereby placing the research within a pragmatic context.

2.3 Pragmatic approach to this study

Pragmatism is generally regarded as the philosophical foundation for mixed method research (Creswell & Plano Clark, 2007; Johnson & Onwuegbuzie, 2004; Tashakkori & Teddlie, 2003). Bulmer (1983) stresses the importance of choosing research methodology that is appropriate to the research objectives, and urges researchers to ask the whether the chosen method will adequately produce the kind of data needed to answer the questions posed in the study. The pragmatic paradigm 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).

Johnson and Onwuegbuzie (2004) and Tashakkori and Teddlie (2003) suggest that researchers within the pragmatist tradition 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, such as a mixed methods approach, may offer greater insight, or the best chance of answering specific research
questions. As noted previously, this study employs both qualitative and quantitative methods, and therefore uses a mixed-methods approach.

2.4 Mixed methods approach

Research methodologies and approaches are grounded in the philosophical assumptions underpinning existing research (McFarlane, 2000). Traditionally, objective and subjective theories have been conventionally distinguished, as in Burrell and Morgan’s (1979) matrix, as purely quantitative approaches and purely qualitative approaches respectively (Johnson & Onwuegbuzie, 2004). However, a growing number of mixed method researchers suggest that research need not be restricted to exclusive paradigms and limited methodological practices (Creswell, 2003; Creswell & Plano Clark, 2007; Greene, Caracelli, & Graham, 1989; Tashakkori & Teddlie, 2003). In comparison to the above distinction, they state that one should choose a combination of methods that provides sufficient evidence for answering the research question (Jang, McDougall, Pollon, Herbert, & Russell, 2008).

The mixed method approach combines a distinct set of ideas and practices, which separates it from the traditional qualitative-quantitative divide. Leading mixed methodologists such as John Creswell, Jennifer Greene, Burke Johnson, David Morgan, Anthony Onwuegbuzie, Abbas Tashakkori, Charles Teddlie offer defining characteristics of the mixed method approach. Descombe (2008) adequately summarises these characteristics to involve 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 (Descombe, 2008, p. 272).
Creswell & Plano Clark (2007) argue that the majority of research questions generally cross paradigmatic boundaries and cannot be adequately addressed using the positivist or interpretivist philosophies exclusively. In fields such as sociological and educational research, where evaluation and achievement scores are as important as the 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; Tashakkori & Teddlie, 2006). In this study the qualitative data generated from interviews and observations, was weighed against quantitative data from scale-based rubrics to increase the validity and trustworthiness of the research results. This use of a mixed-method approach seems to help assist in providing a clearer understanding of the data generated (Creswell, 2003).

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 & Cresswell, 2007). This process helps to improve the accuracy of data (Bryman, 2007) and helps to produce a more holistic picture of the phenomenon under investigation (Creswell & Plano Clark, 2007; Descombe, 2008). Greene et al., (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 strengthening 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, Brady & Byrne, 2009). In addition to increased validity, the use of qualitative and quantitative methods provides a clearer illustration of the data (Creswell, 2003). This is deemed useful when providing qualitative explanations to quantitative findings (or vice versa). For example, in this study, the final teacher interviews were conducted to clarify the quantitative results from the learners’ science notebooks.
Chapter 3: Research Methodology

Challenges to the mixed method approach

A notable challenge when utilising a mixed method design centres on how the researcher is able to adopt an objective position of distance and neutrality (positivism) 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). Therefore, it is important that the researcher maintains and acknowledges the integrity of their positions and that knowledge claims cannot be mixed between what was derived from quantitative data, with that derived from qualitative data (Smith, 1983). Additionally, researchers are cautioned to use different research methods in such a way that the resulting combination has complementary strengths and not overlapping weaknesses (Johnson & Turner, 2002; Webb, Campbell, Schwartz, Sechrest, & Grove, 1981).

3. RESEARCH DESIGN

Hall and Howard (2008) maintain that the careful consideration of typological designs is essential for making mixed-method research design decisions within 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. In this study, the qualitative aspects were given greater emphasis due to the relatively small sample size of teachers involved and the need to understand their experience as fully as possible.

The second 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 separated throughout data collection and analysis while the combination of the two takes place at the level of interpretation and inference. On the contrary, the integrated design allows for incorporating and mixing
methods throughout the research process. This study followed an integrated design where methods were integrated throughout the research process.

The final considerations focus on the timing (Creswell & Plano Clark, 2007) and the sequence decisions (Morse, 1991), which address the stages and the order in which the qualitative and quantitative methods are used. Creswell and Plano Clark (2007) contend that a mixed-method approach can be undertaken in four different research designs, namely a triangulation design procedure, an embedded design, an explanatory design, or an exploratory design. The difference between these designs is found in the sequence of qualitative or quantitative data collection, and which of these two methods will be the starting point and main emphasis for the research (Creswell, 2003). The embedded design has been described as having one dominant method, with the other data set playing a supportive role (Doyle, et al., 2009). In this study, the emphasis is on qualitative methods, with quantitative methods playing a supportive role. The data collection schedules used in the classroom observations, science notebooks and teacher portfolios are an indication of the embedded design’s correlation model whereby the quantitative data gathered are rooted within a qualitative design to aid in explaining the outcomes (Caracelli & Green’s, 1997). These schedules utilised a quantitative scale to measure performance and provided additional space for qualitative descriptions and explanations, while interviews provided opportunities to explore the participants understanding and experience of the process in greater depth.

### 3.1 Design approaches in this study

This study seeks to investigate the potential for the ISLS to contribute towards ESD in South African schools. The use of the mixed methods approach allowed the researcher to seek clarity and deeper understandings by finding convergence and corroboration of the results from a variety of data sources. For example, the quantitative analysis of the learner’s tests and science notebooks was supplemented by descriptions of learner activities in the classrooms and the teachers’ perspectives on the impact of the strategy. The following table summarises how the study utilised both qualitative and quantitative approaches during the data collection, analysis and interpretation.
Table 3.1  Summary of mixed method approaches used in this study

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<td>Qualitative</td>
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<td>Exploratory interviews</td>
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<td>Learners’ Science Notebooks</td>
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<td>Learners’ pre and post Testing</td>
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Both qualitative and quantitative methods were used in order to gain the most accurate insight into the training and implementation of the ISLS and the teachers’ perceptions of its usefulness. During the data collection and analysis process, quantitative methods were used exclusively for the learners’ tests, and the teachers interviews and portfolios were analysed using qualitative methods. A mixed method approach was used for the classroom observations and the learners’ science notebooks. Throughout the analysis and interpretation process, data were also combined and compared to promote the most accurate representation of the findings as possible. For example, quantitative information from classroom observations, science notebooks and the learners’ tests were used to support and triangulate the qualitative information gathered from the interviews, portfolios and observations.
Chapter 3: Research Methodology

3.2 Research strategy

This study investigated the potential for the Integrated Scientific Literacy Strategy to contribute towards teaching ESD in previously Model C schools within the Port Elizabeth Metropolitan. The term ‘model C’ refers to schools which were formally administered by the House of Assembly (‘White’ parliament) during the apartheid regime in South Africa. The schools were for white children only and were characterised by high-quality facilities, good teaching staff and excellent school leaving results (Makhubu, 2011, Roodt, 2010).

In the early 1990’s these schools were given a choice of three models of schooling that would shape their characteristics and nature in the future: ‘Model A’ would make the schools fully private; ‘Model B’ would see them remain state schools; and ‘Model C’ would make schools semi-private (Cronje, 2010). In 2002, the Department of Education released their new curriculum for education, incorporating all schools under one umbrella (Department of Education, 2002), yet these schools are still referred to as previously or former Model C schools.

In 2009, the proportion of African pupils who passed the grade 12 examinations overall was 56%, with 88% of this percentage coming from previously Model C schools. This discrepancy illustrated the difference in the quality of education at former Model C schools, compared to non-Model C schools (Roodt, 2010). The results above suggest that the teaching ethos in most former Model C schools is still intact. In general, teachers are serious about their jobs, and dedicated to the children they teach (Cronje, 2010). The same cannot be said for many non-Model C schools, where teachers often do not teach for the full day and are often not in class at all, as exemplified by in a report in August 2009 by the South African President who revealed that at a number of schools teaching occurred for less than 3.5 hours per day (Roodt, 2010).

Prior to this research, a pilot study investigated the current status of teachers’ and learners’ knowledge and understanding of ESD related issues in schools in the township areas (former non-Model C schools) of Port Elizabeth. The findings were that teacher understandings of ESD and its implementation within the education system were extremely weak. McKeown (2002) highlights the need for a strong foundation of basic
education before ESD can be effectively implemented, and advises that until a basic level of competence has been achieved, teachers will struggle to understand and implement aspects of ESD. As many of the township schools appeared to be still struggling with challenges in maintaining basic education levels, previously Model C schools in Port Elizabeth, which illustrate stronger foundations in basic education, were chosen as the study sample.

As a starting point, forty previously Model C schools in the Port Elizabeth Metropolitan area were invited to participate in the study. Seven schools accepted the invitation, and a total of nine teachers attended the training workshop and implemented the strategy in their classrooms. The majority of schools who did not accept the invitation declined due to busy schedules.

Exploratory interviews with the nine participating teachers were conducted during the initial phase of research. These interviews provided an opportunity to gain insight into the teachers’ awareness and knowledge of ESD and their current approach to teaching ESD related topics in their classrooms. Challenges and obstacles which they currently faced were also discussed.

In the second phase, the teachers participated in a two six hour training workshops where they received training on the Integrated Scientific Literacy Strategy (ISLS) and ESD. The researcher and a Science Education Professor from the Nelson Mandela Metropolitan University facilitated the workshops, which consisted of discussions, lectures and practical experience with the ISLS. 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. In addition to the science kit, teachers were also supplied with the book, Scientific Literacy: A New Synthesis (England, et al., 2007) as a theoretical guide and reference tool for implementing the 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 provide concentrated and purposeful opportunities to experiment with aspects of practice, and
then learn from that experience (Grossman & McDonald, 2008). For this reason, the facilitators modelled the use of the material and instruction during the training so that they were engaged in the investigations and learning strategies associated with the ISLS, which they would be conducting with their learners. According to Kielborn & Gilmer (1999) the preparation of teachers to use inquiry methods to teach science can be difficult because many would not have experienced this type of instruction themselves. This was something that became evident when working with the participating teachers, and was reinforced when examining their responses to the strategy, as expressed in their portfolio essays and final interviews.

The third phase involved the implementation of the strategy. Each teacher was tasked with completing the strategy twice, with two different topics, over a period of three months. The teachers were not expected to follow any specific topic guides or prescriptions, but were expected to integrate the strategy within their normal curriculum teaching. Before the teachers began using the strategy, the learners were given a pre-test to determine their current understandings and views regarding ESD related topics and their ability to problem solve using inquiry-based investigations. These tests were repeated at the end of the process to determine if there had been any change in their views and / or problem solving abilities.

During the implementation process, the researcher attended two lessons per teacher for the purpose of observation. The learners’ science notebooks were evaluated at the end of the study to investigate their performance and to substantiate the data generated from the classroom observations. Each teacher also submitted a portfolio consisting of essays describing and explaining their understanding of the strategy, their experience and opinions, and evidence of how they implemented the strategy in their classrooms. Finally, reflective interviews were conducted with the participating teachers to discuss their experience with greater detail. During the fourth phase, the data collected were analysed and evaluated. Figure 3.2 provides a graphical representation of the research strategy followed, showing the procedure and the comparative links between the various data collection methods.
Phase

Phase 1.
Exploratory Interviews:
Knowledge and awareness of ESD?
Current use of ESD in classrooms?

Phase 2.
Scientific literacy training workshop:
Training in the ISLS and ESD

Phase 3.
Implementation of strategy in the classroom & data collection

Classroom Observations
Ability to implement strategy in classroom
Understanding of the strategy
Degree of learner participation

Teacher portfolios
Description of strategy implementation
Understanding of the strategy

Final interviews
Discussion of strategy implementation
Discussion of problems / challenges

PISA pre-test
Knowledge and attitudes relating to ESD
Knowledge and application of scientific investigation

Learner science notebooks
Literacy skills
Knowledge and application of scientific investigation
Degree of learner participation
Description of strategy implementation

PISA post-test
Has there been any change or improvement?

Figure 3.2  Summary of research design
3.3 Sample and setting

This study was conducted between April and November, 2010, in the urban area of Port Elizabeth in the Eastern Cape, South Africa. Nine teachers from seven participating schools attended the training workshop and implemented the strategy in their science classrooms.

Previous research in the value and usefulness of the ISLS has been done with grade 6 and 7 classes and revealed positive results in terms of improved teacher practice and learners’ language and reasoning skills (Daniels, 2010; Mayaba, 2009; Villanueva, 2010). In order to contribute further to the existing research regarding the ISLS, the study was also conducted with grade 6 and 7 learners. In addition, the researcher felt that the older learners within the General Education and Training phase (Grade 1 - 9) would have a better ability to comprehend and grasp the knowledge and skills associated with ESD compared with the younger learners. [In South African education the politically accepted term for pupils or students is ‘learners’ (Department of Education, 2002).]

All of the participating schools follow the national curriculum and the teachers were all drawn from the natural science learning area and taught science at either grade 6 or 7 level. The average number of years teaching experience was 16 years. The teacher with the most experience has taught for 29 years and, the least experienced for 3 years.

The ages of the learners in the study ranged from 9 to 13 years, with 11 years as the median age for this group. The approximate sizes of the classes were 25 – 30 learners per class, with 243 learners in total.

4. DATA COLLECTION AND ANALYSIS

The combination of a variety of methods ensures a more holistic and accurate enquiry, especially when complexity abounds, as is the case in human behaviour (Kitchen & Tate, 2000). Sproull (1995) states that for any research involving opinions, attitudes, values or desires, the best source of information is the subject; an observation
which motivated the choice of qualitative and quantitative analyses of the teachers’ and
learners’ experiences when implementing the ISLS.

As noted earlier, the data collection methods employed included teacher
interviews, learners’ test, classroom observations, teacher portfolios and the learners’
science notebooks. 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. Table 3.2
summarises the timing of data collection in this study.

<table>
<thead>
<tr>
<th>Table 3.2</th>
<th>Summary of the data collection timing in this study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-implementation</td>
</tr>
<tr>
<td>Exploratory Interviews</td>
<td>√</td>
</tr>
<tr>
<td>Learner tests</td>
<td>√</td>
</tr>
<tr>
<td>Classroom Observations</td>
<td></td>
</tr>
<tr>
<td>Teacher Portfolios</td>
<td></td>
</tr>
<tr>
<td>Learners’ Science Notebooks</td>
<td></td>
</tr>
<tr>
<td>Reflective Interviews</td>
<td></td>
</tr>
</tbody>
</table>
4.1 Exploratory interviews

Interviews allow researchers to produce a complex and varied data set that is acquired in a less formal setting. As opposed to the questionnaire that seeks specific information, the interview allows for a more thorough and broad examination of the interviewee’s experiences, feelings and opinions that cannot be captured through a questionnaire. Interviews have the advantage of being flexible, and generally, a very high response rate, providing an in-depth source of data on people’s experiences, opinions, aspirations and feelings (Kitchen & Tate, 2000, Johnson & Christensen, 2004; McMillan & Schumacher, 1993; Wilson, 1996). According to Sproull (1995) the advantages of interviews include:

- **Gaining information directly from the people involved;**
- **Allows opportunities for probing deeper into issues to discover why people think and act the way they do;**
- **Allows for clarification of information as it is given;**
- **Creates opportunities to explain complex information; and**
- **Allows opportunity to clarify and verify previously collected data.**

However, Sproull (1995) also lists disadvantages which researchers need to be aware of:

- **The cost of time needed for each individual interview;**
- **Time requirements often lead to less information acquired;**
- **Probability of inaccurate data because people may lie, omit information or give answers that they feel are socially acceptable to avoid pre-conceived embarrassment; and**
- **Inaccuracies due to bias from the interviewer as well as from the interaction between the interviewer and respondent.**

Prior to the training workshop, each teacher participated in an interview concerning their experiences with teaching ESD. Semi-structured interviews with open-ended questions allowed the researcher to probe and clarify responses, and provided opportunities for the teachers’ to expand on issues and clarify responses (Kitchen & Tate, 2000; Sproull, 1995; Wilson, 1996). The researcher used the Exploratory
Interview Questions (Appendix A) protocol to discover, a) their general awareness concerning ESD issues; b) their perspectives concerning their learners’ responses to ESD related topics; and c) challenges and obstacles faced when teaching ESD related topics.

4.2 Learners’ tests

The learners’ tests (Appendix B) used in this study provided the opportunity to generate data on their understanding and ability relating to scientific investigation, as well as providing an indication of their views towards environmental issues. These tests were completed prior to the implementation of the strategy, and once again after implementation, in an attempt to ascertain if the strategy had impacted the learners’ response to environmental issues or their abilities regarding scientific investigation. In other words, a pre-post test design was used.

The first two questions in the test focused on the learners’ environmental attitudes and awareness, and were developed using Menzel and Bogehölz’s (2010) model to explain adolescent’s commitment to protect biodiversity. Menzel and Bogehölz (2010) based their model on the Value-Belief-Norm theory (Stern, 1999; 2000), and in particular, on Dunlap and Van Liere’s New Ecological Paradigm (Dunlap, Van Liere, Mertig & Emmet Jones, 2000; Stern, 2000). The Value-Belief-Norm theory was developed in an attempt to explain commitments to protect the environment (Stern, 2000). Within this theory, the New Economic Paradigm is included as an indicator of pro-environmental beliefs, and has been frequently described as being conducive for a commitment to protect nature (Dunlap et al. 2000). Menzel and Bogehölz’s (2010) model was customised for adolescent learners, and thus provided a useful tool in guiding the development of questions concerning the learners’ attitudes towards and awareness of environmental issues.

Questions three to six of the learner’s test were taken from the OECD’s 2009 Programme for International Student Assessment (PISA) Science Project (OECD, 2009). These questions were aimed at assessing their understandings and abilities in terms of scientific investigations related to environmental issues.
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The PISA Framework documents specify that the project is concerned with learning that involves the transfer of knowledge for the application of science that is already known to new situations of relevance in today’s world. As such, the PISA tests focus on learners’ ability to use their knowledge and skills to meet real-life challenges, as opposed to testing only their ability to master a school curriculum (Bybee & McCrae, 2011; Coll, Dahsah & Faikhamta, 2010; Fensham, 2008; Holbrook & Rannikmae, 2009; Pinto & El Boudamoussi, 2009). Three scientific competencies were defined, each of which learners are expected to apply to unfamiliar, real world situations regarding science and technology. These competencies are i) identifying scientific issues, ii) explaining phenomena scientifically, and iii) using scientific evidence.

The PISA test also seeks to determine children’s interest in science, support for scientific enquiry, self-belief as science learners, and, their responsibility towards resources and the natural environment (OECD, 2006, 2009). Statements aimed at assessing the learners’ attitudes towards environmental issues are posed in response to scientific investigation-based questions, requiring critical thinking about the investigation and results provided.

The questions used in this study were selected on the following criteria: a) relevance to issues of sustainability and the environment, b) evidence of inquiry-based investigation, and c) the applicability of the questions to grade 6 and 7 level learners (the PISA questions are designed for Grade 9 learners (OECD, 2009), and thus it was important to choose questions on an applicable level of difficulty for the grade 6 and 7 learners who participated in this study).

Initially twelve questions were chosen from the PISA assessment, after which they were narrowed down to seven via a consultative process involving the teachers participating in the study. The participating teachers were given all twelve questions and asked to comment on the level of difficulty and time required for completion. As each teacher could only afford one lesson for each of the pre and post-tests respectively, the test could not require more than forty minutes to be completed. The final test items were chosen after careful consideration of the teachers’ feedback. The learners’ tests were divided into two sections based on whether the questions assessed a) the learners’
perspectives concerning environmental issues or b) the learners’ understandings and abilities relating to scientific investigation (Table 3.3).

The Learners’ Test Rubric (Appendix C) was used to generate data through the means of a scale-based rubric, providing valuable insight concerning the learners’ attitudes to the environment and their understanding and abilities regarding scientific inquiry-based investigation. The questions concerning the learners’ perspectives of environmental issues required the learners to respond to a group of statements indicating their view of a particular environmental issue. For example, they were asked whether they with various value-based statements. Data was generated according to the numbers of learners who strongly agreed, agreed, disagreed or strongly disagreed. In comparison, the scientific investigation questions were graded according to the learners’ ability to correctly answer each question. This allowed for comparisons to be made between the pre- and post-tests.

<table>
<thead>
<tr>
<th>Table 3.3</th>
<th>Assessment of the PISA tests</th>
</tr>
</thead>
</table>
| Environmental attitudes and awareness | There are serious environmental problems
| | Human actions are a main cause of environmental problems
| | Each person has a responsibility towards the environment
| | It is important that we learn about ways to protect the environment |
| Scientific investigation | Learners’ ability to understand and interpret scientific representation such as graphs
| | The use of variables and investigable questions
| | Learners’ comprehension of inquiry-based scientific investigation
| | Learner’s ability to formulate investigable questions |

Quantitative data generated using the Learners’ Test Rubric (Appendix C) was statistically analysed and evaluated in an attempt to discover if there was any change in the learners’ abilities concerning scientific investigations as a result of the implementation of the ISLS. 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 data, Cohen’s $d$ coefficient was calculated to determine the effect size (practical significance) of changes that were statistically significant.

### 4.3 Classroom observations

According to Johnson and Christensen (2004), observation is a valuable key in obtaining information about the behavioural patterns of people in certain situations, which may or may not prove to be useful in confirming practices against their stated positions. Subsequent to the training workshop, two classroom observation lessons were conducted with each teacher. Observations were conducted within the timeframe of thirty to forty minutes, depending on each school’s timetable. McMillan and Schumacher (1993) highlight the necessity of post-observation discussions between the researcher and the teacher in order that the researcher might gain a genuine understanding of the meaning and context of the events that took place during the observation, thus strengthening the validity of the data generated. Therefore, the researcher met with each teacher and discussed the relevant lesson directly after each of the two classroom observations had been completed. This provided opportunities for the researcher to discuss her observations and perceptions and to clarify potential misconceptions.

Quantitative and qualitative data were recorded through the means of a scale-based rubric, *Strategy Implementation Rubric* (Appendix D) and detailed descriptions, giving depth to each component observed. The data generated was used to evaluate the degree to which the teachers applied the strategy, as well as providing information concerning the learners’ response to the teaching approach. This was achieved through the use of the Assessment schedule for the implementation of the Integrated Scientific Literacy Strategy, which will be discussed in greater detail in section 4.7.

### 4.4 Teacher portfolios

The participating teachers were required to develop a portfolio of evidence (material used, examples of their learners work, etc.) to indicate how they applied and
Chapter 3: Research Methodology

implemented the ISLS during their lessons. The final component of each portfolio was a reflexive essay, answering the following two questions: a) What is your understanding of the Integrated Scientific Literacy Strategy, and b) How did you find the process of implementing the strategy in your classroom, particularly with reference to the implementation of ESD-related issues?

According to Sandelowski (2000), reflexivity is a characteristic of good qualitative research because it entails the preparedness of both researcher and participant to consider and recognize their contributions to the study. For Ryan (2009), it is important for progression in a teaching context to incorporate a reflexive process because it encourages introspection. Through introspection, one is able to determine the extent to which their experiences and interactions have been shaped and influenced by their context as well as other participants. It is a complex process that is applied in education research, particularly in terms of classroom activities, because of the positive effects of engaging in personal reflection towards self-development (Ryan, 2009).

The portfolios were analysed using the schedule, *Theoretical Understanding of the Strategy* (Appendix E), and gave an indication of the teachers’ understandings and perspectives of the strategy and how the implementation influenced the learners’ learning experience. The data generated from the portfolios was combined with the data gained from the final interviews to provide a more holistic indication of each teacher’s understanding and perception of the strategy.

4.5 Learners’ science notebooks

According to Fulton and Campbell (2003) and Miller and Calfee (2004), science notebooks have the potential to develop content and process skills, and at the same time function as a context to develop literacy. As discussed in the previous chapter, the teachers were expected to encourage their learners to write freely and frequently in their notebooks, recording their predictions, observations, discussion and findings as they worked through their various investigations. Due to the multi-dimensional nature of the learners notebooks described below, the notebooks were utilised to generated data concerning three different components: 1) an indication of each teacher’s
implementation of the strategy, 2) an indication of each teachers use of the science notebooks, and 3) an indication of the learners level of scientific literacy.

An indication of each teacher’s implementation of the strategy

The science notebooks provided information about how each teacher implemented the strategy throughout the intervention period, including when they were not observed. This process allowed comparison and correlation between the results generated from the classroom observations and those generated from the science notebooks, providing a more truthful and accurate picture of each teachers’ actual implementation throughout the intervention period. As with the classroom observations, both quantitative and qualitative data were recorded through the means of the scale-based rubric, Strategy Implementation Rubric (Appendix D), and detailed descriptions, giving depth to each component observed. In particular, The Strategy Implementation Rubric was used to determine the level of learner autonomy and participation during each phase of the strategy. In other words, were all the notebooks exactly the same indicating maximum teacher involvement, or did the notebooks reflect the individuality of each learner/small group of learners?

The teachers use of the learners science notebooks

The learners science notebooks were also used to determine if and how the teachers used the learners’ science notebooks during the implementation of the ISLS. As previously discussed in chapter 2, a central constituent within the ISLS is the use of science notebooks to foster learners’ abilities to read, write and do science (Nesbit, 2008; Webb, 2008c). Therefore, the Strategy Implementation Rubric included the teachers’ use of the learners science notebooks as one of the ten components assessed. Qualitative and quantitative data were generated and analysed in an attempt to discover if each teacher encouraged their learners to write their own thoughts and ideas in their books, or if their learners merely copied what the teacher had written on the board. Data was generated for this component during classroom observations, where the teachers’ use of the notebooks was observed first hand, and using the learners’ actual notebooks where evidence of how the teachers had approached this aspect of the ISLS was collected.
Thirdly, the science notebooks were used to generate and analyse data regarding the level of scientific literacy portrayed by the learners. As there was no evidence of the learners’ use of the science notebooks approach previous to this study, a comparison between the different classes could not be made to determine progress or improvements. Therefore, all the learners’ science notebooks from all the classes were analysed together as one complete group.

The **Science Notebooks Checklist** (Appendix F), based on the research instruments designed and validated by researchers at the University of North Carolina–Wilmington (UNCW), was used to assess the learners’ level of scientific as it has been validated in other studies within the South African context (Nesbit et al., 2003; Reid-Griffin, Nesbit & Rogers, 2005; Villanueva & Webb, 2008, Webb, 2009). Specifically, the checklist measured the level of learners’ writing in science, as well as their conceptual and procedural understanding when conducting scientific investigations, by assessing the following five questions:

- How well does the learner construct an investigable question?
- How well does the learner design and implement a plan to answer the question?
- How well did the learner record their data?
- How well does the learner draw their observations?
- How well does the learner construct scientific meaning from investigation?

### 4.6 Reflective interviews

The final, reflective teacher interviews (Appendix G) were conducted post-implementation of the strategy to ascertain the teachers’ perceptions of how effectively the strategy was implemented, their learners’ response to the strategy, challenges and obstacles faced, and their general impression of the strategy and its usefulness as a teaching tool. Interviews were recorded and, when necessary, verified with the relevant teacher to ensure that the participant’s ideas were accurately noted. The interviews provided rich information regarding common trends and experiences when
implementing the strategy, as well as highlighting important points to consider for further investigation. The schedule presented in Appendix E was used to assess how each teacher implemented the strategy.

### 4.7 Analysing teacher understanding and implementation

Both the strategy implementation rubric used to evaluate the classroom observations and science notebooks (Appendix D) and the qualitative schedule used to analyse the teachers’ portfolios and reflective interviews (Appendix E) were all based on a ten-point assessment schedule so that comparisons and verification could be made between the different data sources. This schedule was developed using a validated classroom observation rubric used in a number of other studies (Kurup, 2010; Villanueva, 2010; Webb, 2009) and customized for this study, resulting in the ten components listed in Table 3.4.

The researcher attended two classroom observation sessions for each teacher. During each of these observation sessions, the teachers’ implementation of the various stages of the strategy was evaluated both qualitatively and quantitatively using the scale based rubric (Appendix D). The classroom observations were planned so that there was little overlap in each teacher’s implementation of the strategy’s phases, ensuring that each teacher’s use of the entire strategy was observed and evaluated. Where there was overlap, and the teachers evaluation scores on the scale-based rubric differed, discussion concerning how the teacher was implementing the strategy were held in order to ascertain the most accurate impression of how the teacher was implementing each stage of the strategy. The learners’ notebooks were also evaluated using this scale based rubric as an indication of each teacher’s continued implementation of the strategy. Within each class, the learners’ notebooks were all analysed individually, after which the average was calculated to provide one score per teacher for each component. This allowed for a graphical comparison to be made as illustrated in chapter four.
### Table 3.4: Assessment schedule for the implementation of the Integrated Scientific Literacy Strategy

<table>
<thead>
<tr>
<th>Assessment Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of Stimulus</td>
<td>Does the teacher use a relevant stimulus to engage with the learners and create interest and enthusiasm for the topic?</td>
</tr>
<tr>
<td>Exploratory talk and class discussion</td>
<td>Does the educator facilitate exploratory talk amongst the learners themselves, or do they try to control class discussion, or even take over completely?</td>
</tr>
<tr>
<td>Investigable Question</td>
<td>Does the teacher guide the learners in developing their own question or do they provide the class with a question they have developed?</td>
</tr>
<tr>
<td>Planning an investigation</td>
<td>Does the teacher facilitate groups of learners in planning their own investigation, or do they lead the class in an experiment they have found or designed?</td>
</tr>
<tr>
<td>Doing an investigation</td>
<td>Does the teacher facilitate groups of learners in doing their own investigation, or do they show the class an experiment they have found or designed?</td>
</tr>
<tr>
<td>Learner Writing with Science Notebooks</td>
<td>Are the learners encouraged to write their own thoughts and ideas in their books, or do they merely copy what the teacher has written on the board?</td>
</tr>
<tr>
<td>LOL and further research</td>
<td>Are the learners encouraged to engage in further research by themselves, or does the teacher take control of this process by providing information they have found?</td>
</tr>
<tr>
<td>Learner subject knowledge – Argumentation and Presentation</td>
<td>How well do the learners demonstrate their understanding of the concepts and procedures taught in class?</td>
</tr>
<tr>
<td>Incorporation of Sustainable Development topics</td>
<td>Is the teacher able to effectively link the topic to relevant examples relating to sustainable development?</td>
</tr>
<tr>
<td>Degree of teacher control and pupil participation</td>
<td>Does the teacher control the process, or do they allow the learners to participate as fully as possible in making their own decisions?</td>
</tr>
</tbody>
</table>

The teacher portfolios and final interviews provided information regarding each teacher’s theoretical understanding of the strategy. In contrast, the scale rubric developed for the classroom observations and science notebooks sought to evaluate the actual implementation of the strategy (Appendix D). Comparison between the two
allowed insights into possible reasons for poor or incomplete implementation of the strategy, and provided opportunities to further discuss factors which may influence the effective use of the ISLS.

The scale rubric assessed the ten components on a rating scale indicating increasing learner ownership and the level at which the learners actively engaged in the learning process. The rating scales progressed from one to five, where level one indicated that there was no evidence of the component present, to level five where the learners were given the freedom to make decisions and own their learning process.

5. ETHICAL CONSIDERATIONS

Mouton (2001) argues that 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. 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 data collection. 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 serve in loco parentis for the children 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.

6. METHODOLOGICAL LIMITATIONS

The following methodological limitations are noted with respect to the research sample used and the classroom observations made in this study. The limitations associated with a researchers’ subjectivity are also discussed.

6.1 Sample size

The small sample of schools and teachers from the Nelson Mandela metropolitan area cannot be considered a reflection of classrooms in South Africa and, therefore, the results cannot 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 issues and initiate debate on how an integrated teaching strategies approach can be used to improve ESD 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 underpin more acute research questions in the future.

6.2 Classroom observations and learners’ science notebooks

In the case of classroom observations, there is always a possibility that the lessons presented are not ‘authentic’ in the sense that the teacher may have prepared the lesson by rehearsing it with the learners prior to the formal observation, or that a previously taught lesson is repeated. Additionally, the learners’ science notebooks may not be a true reflection of the learners’ original work, as the teachers may coach their learners in what to write. 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.

6.3 Subjectivity

Kuhn (1970) emphasises 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, and the influence of bias during qualitative data collection and analysis. This may also be influenced by the varying interpretations of the ISLS, and what is expected. 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. Additionally, the qualitative data were triangulated and corroborated with the quantitative data, to strengthen the validity and accuracy of the findings presented.

7. CHAPTER SUMMARY

This chapter discusses the theoretical framework for the chosen research design and elucidates the chosen design and the collection and evaluation of data. As the research design is influenced by both interpretivist and positivist perspectives, the study
Chapter 3: Research Methodology

is grounded in the theoretical framework of pragmatism. In light of this, a mixed-method approach was used for the collection of data and both qualitative and quantitative approaches were used to provide diverse perspectives on this study. The methods were conducted concurrently and the integration of the qualitative and quantitative methods occurred during the interpretation of the data.

Furthermore, the chapter discusses and justifies the sample type and size. The assumptions made in selecting the particular research methods used and the type of data collected through the teacher interviews, PISA tests, classroom observations, learners’ science notebooks, and, finally, teacher portfolios and essays are clarified in this chapter. In addition, the ethical considerations in terms of the participants, such as the right to privacy and full disclosure, as well as the methodological limitations of the study, are considered.
CHAPTE R FOUR
RESULTS

1. INTRODUCTION

This chapter reports on the qualitative and quantitative data that were gathered in an attempt to answer the central question in this study namely, *Can the integrated scientific literacy strategy contribute towards promoting Education for Sustainable Development in South African classrooms?* Exploratory interviews provided the qualitative data which revealed the participating teachers’ exposure to, understanding of, and previous experience of teaching ESD. Data concerning the participating teachers’ ability to implement the Integrated Scientific Literacy Strategy (ISLS) were generated via the Strategy Assessment Schedule’s ten components described in chapter three (Table 3.3). For each of the ten assessment components both the teachers’ ability to implement the strategy, and their perspectives and experiences when using the strategy, are described. The learners’ pre- and post-test scores, with particular attention given to the statistical analysis of the pre-post tests and the results generated from their science notebooks, are also presented.

2. EXPLORATORY INTERVIEWS

Prior to the Integrated Scientific Literacy Strategy (ISLS) training workshop, each teacher participated in an exploratory interview concerning their experiences when teaching ESD. The *ESD-Interview Questions* (Appendix B) protocol was used to discover, a) their general awareness concerning ESD issues; b) their perspectives concerning their learners’ responses to ESD related topics; and c) challenges and obstacles faced when teaching ESD related topics.

2.1 Awareness and knowledge of ESD

Both Lotz-Sistka (2007, 2008) and McKeown (2010), emphasise the importance of an understanding and appreciation of sustainable development when approaching
ESD, as ESD has been shaped by the values and principles associated with sustainable development (Heimlich, 2007; Rosenberg, 2007). The teachers were therefore initially asked about their knowledge of sustainable development, before focusing on their experiences and views regarding ESD (Heimlich, 2007; Rosenberg, 2007).

**Sustainable Development**

The interview data revealed that eight of the nine teachers were aware and informed regarding the concept of sustainable development, as indicated by comments such as “it means that you must use the environment in such a way that one can basically keep on using the resources without completing it” (Teacher A). Teacher G, despite not having heard the term, sustainable development, did have a general understanding of the concept, “It’s the first time that I hear those words, but I probably know what it means… it’s the interactions between nature and people and how people affect nature”. Only teacher I confessed that he did not really understand what sustainable development was about. He knew that it was about protecting the natural environment, but expressed his desire for a better understanding of the concept.

Eight of the teachers associated sustainable development predominantly with energy related topics such as global warming and the use of renewable and non-renewable resources, while five teachers also mentioned its application with in conservation of habitats and species, pollution and over population. Only three of the teachers indicated a specific awareness of the human component to sustainable development and spoke about the role of human actions in causing damage to the natural environment. They also noted the need for personal responsibility and action for the preservation of the environment, which they specified as an example of inter-relationships between society and the environment.

**Education for Sustainable Development**

After establishing the participating teachers’ understandings of sustainable development, the exploratory interviews progressed to focus on ESD. The interviews revealed that only three of the nine teachers (C, E and H) had actually heard the term, Education for Sustainable Development. The other six were able to explain ESD once they heard it as indicated in the following statements: “it’s obviously got to do with
how you teach the kids I guess to use the environment in a correct and in a sustainable way” (Teacher D) and “it’s about making children aware of the environmental crisis, so that they can grow up with the idea that it is my responsibility as a child as well” (Teacher F). The teachers recognised the importance and need for ESD, especially with regard to current problems such as climate change, pollution, extinction of species and over population. All of the nine teachers agreed in their interviews that environmental awareness is an essential part of the curriculum and that South African learners need to learn about sustainability and the impact that their lifestyles may have on the environment.

### 2.2 Current approach to teaching ESD

All nine teachers stated that they were teaching aspects of environmental education and, when doing so, relied on group discussions or projects in their teaching approach. The teachers also noted that they were dependent on DVDs (digital video data) and internet sources. Teachers B and F expressed preference for field trips and excursions, especially to educational centres such as Bay World and the Wildlife and Environment Society of South Africa centre in Port Elizabeth, as they considered these useful and effective for teaching topics relating to the environment.

When asked about ESD and the Department of Education’s National Curriculum Statement (NCS) (Department of Education, 2002), all nine teachers acknowledged that there were topics relating to the natural environment within the curriculum, but commented that “environmental science is the smallest part” (Teacher A). From the teachers’ perspectives, the curriculum did integrate topics and issues relating to the environment throughout the Natural Sciences Learning Area, but stated that the textbooks and information available was mostly surface level and minimal, “we basically touch on the topic and then move on” (Teacher G).

### 2.3 Teaching ESD: Approaches and challenges faced

According to the teachers’ exploratory interviews, their learners often enjoyed the sections of the curriculum relating to the environment because they enjoyed the field trips, DVDs and internet-based resources. However, six of the nine teachers also
commented that while their learners seem to know the right answers for exams and assignments, they demonstrate little, if any, genuine respect or value for the natural environment.

Teacher G commented that while he believed he was teaching important information and values, his learners were not “getting to a point where they are going to make a difference … it doesn’t sink in … I would like to do something where you can take them to a point where they say, ‘Alright, we are going to make a difference’”. In addition, seven teachers commented that their learners consider the sections based on the environment as just another section in the curriculum and merely more information that needed to be learnt for exams. These teachers were not confident in their ability to influence their learners at the level of values and attitudes. Teachers A, C, E and H commented that their teaching approach was very theoretical and that it needed to be more practical if it was going to really impact on their children in order to inspire them to think and act differently.

The second challenge identified during the exploratory interviews was that of resources and access to relevant and up to date information. The teachers felt that the Department of Education’s documents and other available textbooks have very limited information regarding the environment, and that environmental issues are glossed over at a very superficial level. All nine teachers emphasised their need for extra information and resources to help them engage their learners and keep them interested throughout the lessons.

A third challenge faced by teachers A, B, H and I was related to poverty, as their schools comprised mainly of learners from the poorer areas of Port Elizabeth. These teachers experience was that as their learners came from particularly poor home situations; the environment was not a priority when dealing with more pressing realities such as hunger, crime and abuse: “you know the families from the townships go out into the bush to collect wood. Now you teach them they shouldn’t use wood because it makes too much smoke and it releases too much carbon dioxide or whatever, but you know that their little fire is essential to them. It’s the energy they use to cook with” (Teacher B).
Chapter 4: Results

In summary, the exploratory interviews indicated that the teachers were aware of the necessity for ESD to be integrated into the Natural Sciences Learning Area of the curriculum as they felt it was important for the learners to become aware of current environmental issues, and the impact of human actions on the natural environment. The most common challenge described by the teachers interviewed was access to resources to help them teach in a more dynamic way, in order to have a greater impact on their learners. This challenge was motivated by the teachers’ common opinion that education about the environment should lead to a change in priorities and lifestyle.

3. TEACHERS’ IMPLEMENTATION OF THE STRATEGY

Following the training workshop on the ISLS and ESD, the teachers were tasked with implementing the strategy, at least twice, in their Natural Science lessons during the intervention period. Data were generated using the ten components from the assessment schedule described in Chapter 3 (Table 3.4). Classroom observations and the learners’ science notebooks were used to yield data considered to reflect the participating teachers’ ability to implement the strategy. As previously discussed, the use of the two classroom observations per teacher, the learners’ science notebooks, the teacher portfolios and the reflective interviews were combined and evaluated as a holistic indication of how each teacher implemented each step of the strategy. A score out of 5 was given for each of the ten components presented in table 3.4 and used to generate the graphical data used in this chapter. As no indication as to the use of a stimulus by the teacher, or what had transpired during the learners classroom discussions prior to identifying an investigable question, could be gleaned from the learners’ science notebooks, evidence for these components were only generated via the classroom observation schedule data. The teacher portfolios and final reflective interviews provided data about the teachers’ perspectives on a) the strategy as a teaching and learning tool, and b) their experience of implementing the strategy with their learners.
Chapter 4: Results

3.1 Use of a stimulus

The participating teachers’ use of a stimulus while implementing the strategy in their classrooms is illustrated in figure 4.1.

![Bar chart showing levels of stimulus use by teachers]

Levels achieved:
- 4: creative stimulus, extensive interaction from majority of pupils
- 3: brief stimulus, limited interaction
- 2: brief stimulus, no interaction
- 1: no stimulus, no interaction

Figure 4.1 Teachers’ use of a stimulus observed during the classroom observations

Implementation

The classroom observations revealed that the teachers’ choice of stimulus was varied. Teacher A provided the learners with equipment which they could “play around with”, with no discernable outcome or purpose. Teachers C, E, F and G all used a discrepant event which inspired curiosity amongst their learners. Teachers F and G chose magnets to create an unexpected event and teachers C and E used coins and drops of water. The latter two teachers’ learners were asked to predict how many drops of
water they thought could fit on a five cent piece, following which they carried out the procedure to see how close their predictions were to the actual number of drops they could fit on the coin. In each case, the learners’ predictions severely underestimated the actual number of drops, which stimulated enthusiasm and interest in why this happened.

Teacher B was the only one to use reading as a stimulus. She created her own story to enable her to introduce elements of sustainable development into the lesson from the very beginning. Similarly, Teacher D used a picture of penguins covered in oil, and later a game of ‘Survivor’ where learners had to choose types of foods to take on a journey, to link concepts relating to sustainable development to the investigation from the very beginning.

Teachers H and I each provided an object of interest for the learners to look at such as glass bowl containing various objects and a display of rocks. Although the teachers each asked questions about the objects, only a few learners responded with short answers.

Teachers’ perspectives

Data from the portfolios and final interviews indicated that all nine teachers had a clear understanding of what the purpose of the stimulus was, and how it should be used within the strategy to initiate interest, interaction and discussion within the classroom. The teachers expressed appreciation for this step in the strategy as it forced them to think creatively and innovatively, which they believed led to increased learner enthusiasm and interest in their classrooms.

One of the teachers (teacher I) commented that he had never thought of using a story or discrepant event to begin a lesson before and commented that his experience proved the benefits of doing so. In his first investigation he provided his learners with different shopping bags and began with a short question, “are all the shopping bags the same” which initiated a brief but limited discussion. In comparison, he began his second investigation with a discrepant event where he moved paper clips with a hidden magnet below the table. In the final interview, this teacher commented on the effectiveness of
this stimulus to arouse curiosity amongst the learners, as illustrated by one learner who, after seeing the paper clips moving across the desk without any apparent force, commented, “No mister, you are tricking us and you are doing naughty tricks!”

### 3.2 Exploratory talk and class discussion

The teachers’ use of exploratory talk and class discussion while implementing the strategy are illustrated in figure 4.2 below.

![Figure 4.2: Teachers’ use of exploratory talk and class discussion as observed through classroom observations](image)

- **Teachers**
  - 4: majority of learners engage in exploratory talk
  - 3: learners participate in class discussion
  - 2: learners provide short answers
  - 1: no class discussion

*Figure 4.2: Teachers’ use of exploratory talk and class discussion as observed through classroom observations*

#### Implementation

The classroom observations revealed that while Teachers C, E, F and G successfully used open-ended questions which allowed the learners to engage in discussion, the other teachers relied on closed-ended questions and short answers from
their learners. In particular, Teachers E and F encouraged the learners to come up with their own ideas and thoughts and to express them clearly to the class. It was evident from the classroom observations that teachers A, B, D, H and I maintained control of class discussion, allowing limited opportunity for the learners to engage with the teacher or their peers. None of the teachers successfully implemented exploratory talk amongst their learners.

Teachers C and E used competition between groups of learners in their class to generate discussion and questions. The learners had to determine which group could fit the most drops of water on a five cent coin, which encouraged group members to ask questions such as why and how other groups were getting more or less than them. This competition also facilitated discussions about variables and control factors. In comparison, teachers A, B, H and I spent little time on this section of the strategy, and moved quickly onto defining the investigable question for the lesson.

**Teachers’ Perspectives**

During the final interviews, the teachers stated that the purpose of class discussion is to allow learners to discuss their thoughts and questions about the stimulus, and that the ultimate goal was to create a list of questions from them. The data generated from the teacher portfolios also indicated a strong focus on class discussion, but without indicating an understanding of exploratory talk as defined by Webb (2008).

Many of the teachers were surprised by the comments made and questions asked by their learners. Teachers D and F stated that their learners were more creative and intuitive than what they had previously thought, whereas others discovered that their learners had many ideas and thoughts which were not scientifically accurate (teachers A, B, and H). Teachers A, B, H and I also stated that for many of their learners the class discussion was a challenge as they did not have sufficient background knowledge or understanding to participate.

The teachers all stated in their portfolios essays that they believed that a creative stimulus was essential to promoting class discussion. Teachers’ B, I and H commented that they were surprised by how lively and interactive their class discussions were when
they used an effective stimulus to introduce the topic. However, Teacher A expressed concern that discipline could not be maintained due to the high levels of enthusiasm and excitement generated and preferred to limit his learners’ interaction in order to keep them focused.

### 3.3 Designing an Investigable Question

Data revealing the teachers’ approaches towards designing an investigable question were generated via the analysis of the classroom observations and learner science notebooks and illustrated in figure 4.3.

![Teachers' approaches towards designing an investigable question as inferred from the classroom observations and their learners' science notebooks](image)

- 4: teacher guides learners in choosing their own question
- 3: teacher leads the class to choose a predetermined question through class discussion
- 2: teacher provides class with a question with no discussion
- 1: no question

*Figure 4.3 Teachers’ approaches towards designing an investigable question as inferred from the classroom observations and their learners’ science notebooks*
Implementation

Results from the classroom observations indicated that the majority of the teachers struggled with giving the learners time to develop their own questions, and often took back control after a short period of time because it appeared as though the learners could not come up with their own questions. Only teachers E and D allowed their learners to develop their own questions, with teacher C guiding the whole class towards a common question, and the other teachers providing the class with a question to investigate. However, an analysis of investigations subsequent to the classroom observations in their learners’ science notebooks revealed that teachers B, F and G improved as they progressed towards guiding the class as a whole towards an investigable question during the second time the strategy was implemented.

Teachers Perspectives

Data from the teachers’ portfolios and the final interviews indicated that all of the participating teachers agreed that their purpose during the investigable question phase of the strategy was to facilitate groups of learners in choosing which question each group of learners wanted to investigate. The teachers commented that this was very different to their normal way of teaching science, as it was the learners who had to formulate their own investigable and researchable questions. Teachers B, F, G and H commented that this did make his learners more interested and enthusiastic because they were finding out answers to questions which they had chosen themselves.

Teachers C, E, F and G especially appreciated the idea of the learners coming up with their own questions because it provided an opportunity where the learners had to think for themselves. Most of the teachers commented on how their learners are ‘lazy when it comes to thinking’, and that they enjoyed the idea that their learners must do the thinking and develop their own questions. Most of the teachers (A, C, D, E, G, H) also commented that when a lesson is directed by the learners’ questions, the learners were more eager to participate and less likely to ‘fool around’. The majority of the teachers also expressed their opinions that while they considered it important to encourage
learners to think critically and creatively, they often struggled with what teaching and learning methods to use to achieve this.

Teachers A, B, H and I commented that the learners had tremendous difficulty in forming their own questions due to academic difficulties and language barriers. Teachers B and H also commented that the learners were not academically prepared for the ISLS because they did not have the necessary skills such as the ability to formulate their own questions and to design their own experiments. However, Teachers B and H, and also D and F, also commented that their learners’ became more confident in their ability to formulate questions and improved the second time the strategy was implemented.

The majority of the teachers commented that their learners struggled initially to think of investigable questions, as most of the questions posed were researchable and not able to be investigated in the classroom. However, Teacher H stipulated that once his learners understood the difference between an investigable and researchable question, they were more capable of asking either kind of question. All the teachers noted that they had never discussed this differentiation between questions with their learners before. In particular, teacher H stated that for the first time, his learners started to understand the purpose of a science investigation. He believed that this understanding enabled his learners to start asking the right questions, something which they had not been able to do in the past.

3.4 Planning an investigation

Data revealing the teachers’ approaches towards planning an investigation were generated via the analysis of the classroom observations and learner science notebooks and illustrated in figure 4.4 below.
Chapter 4: Results

The classroom observations and learners’ science notebooks indicated that teachers A, B, H and I were reluctant to release control and permit their groups of learners to operate with freedom and autonomy. Observations suggested that they were not able to allow their learners to come up with their own ideas or design their own investigations. However, it was also noted that despite these teachers attempt to control the

Figure 4.4 Teachers’ approaches to planning an investigation as inferred from classroom observations and their learners’ science notebooks

Implementation
investigation, some learners still chose to act autonomously. Teacher I developed a ‘Science Investigation Worksheet’ which guided the learners through the investigation process step by step.

In comparison, the classroom observations of teachers C, E and G revealed the learners excitement when faced with a task which they have to do themselves. The challenge of planning their own investigation seemed to inspire enthusiasm and interest in developing their own ideas and testing to see what would happen. Teachers C, E and G stated that, as the learners were exposed to the strategy, they became more confident in their own abilities to plan an investigation. The analysis of their learners’ science notebooks revealed that this improvement was also evident with the Teachers D, F and H who progressed to allow groups of learners to plan their own investigations in their second and third investigations using the strategy following the classroom observations. Teacher E provided the most opportunities for his learners to make their own decisions and plan their own observations. The classroom observations also revealed that his learners were used to working autonomously while in groups.

The importance of writing down the prediction, or ‘what I think’, step was illustrated during Teacher A’s lesson on gravity. His learners were not required to predict which of the provided balls would fall the fastest, and therefore did not consider what they thought would happen. The result was that his learners were not surprised or intrigued by what happened in the investigation, and did not appreciate the relevance of all the balls falling at the same speed, irrespective of mass and size. In comparison, teachers C, F and H commented that they had never before asked learners to predict what they thought would happen in an investigation, and were surprised by the effect it had on their learners’ positive response to the investigation. The teachers reported that the process of predicting encouraged the learners to think critically and also promoted their interest and enthusiasm.

*Teachers’ Perspectives*

The teachers’ lesson plans submitted in their final portfolio indicated that they understood that their learners should participate actively in this process by designing and recording their own investigations. They expressed an understanding that the role of the
teacher was to facilitate a discussion regarding variables and control factors, but to allow the learners to decide what they wanted to do. In particular, the teachers stated that they appreciated the formal structure of the strategy (as illustrated in figure 2.1) because it provided them with specific points at which to introduce various aspects of investigation, such as this discussion about variables.

The majority of teachers enjoyed the use of terms such as ‘What I want to know’, ‘what I did’ and ‘what I found out’ as opposed to more scientific terms as many of their learners struggle with the language of instruction and therefore find these simplified terms easier to understand. In particular, Teacher H commented that the use of these terms helped his learners to understand the purpose of scientific investigation for the first time. Once they had grasped this understanding, they were then able to design and implement their own investigations. This approach to planning an investigation also helped the learners to think and plan logically without ‘getting lost along the way’.

The participating teachers expressed that the greatest benefit of allowing the learners to plan their own investigations was that it promoted the development of problem solving skills. The teachers recognised that it was important to equip learners with decision-making skills through the learning process and appreciated the strategy’s focus on the learners making their own decisions when designing their investigations. In particular, Teacher G commented that the strategy helped learners to develop their problem-solving skills by allowing the learners to make their own choices and decisions about how to investigate their chosen question. Teacher F used the planning and investigation model to encourage her learners to ‘think critically and independently’. Learners were required to state what they thought would happen and why. Teacher F stated that her learners seemed excited when they realised that they would not be given the answers but would have to work them out for themselves. Teachers C, E, F and G all commented on the creativity of their learners and how the strategy provided them with opportunities to ‘think out of the box’.

However, in their final interviews, all nine teachers spoke of being restricted by time pressure. This was because they were expected to keep up with the other classes in
their grades in order that they prepare for examinations. Many of the teachers stated that they had restricted their learners’ freedom to plan their own investigation because they felt that it would have taken too much time.

### 3.5 Doing an investigation

Data revealing the teachers’ approaches towards doing an investigation were generated via the analysis of the classroom observations and learner science notebooks and illustrated in figure 4.5 below.

![Bar Chart](image)

**Teachers**

- Classroom Observation
- Learner Science Notebooks

- 4: teacher allows groups of learners to do their own investigations
- 3: teacher guides learners in doing the investigation
- 2: teacher demonstrates investigation to class using selected learners
- 1: no investigation

*Figure 4.5 Teachers’ approaches to doing an investigation as inferred from classroom observations and from their learners’ science notebooks*
Chapter 4: Results

Implementation

From the classroom observations it seemed as though this component of the strategy was the most popular with the teachers as all nine allowed at least some degree of participation from their learners. Teachers B, H and I demonstrated an experiment to the whole class, allowing selected learners to participate at certain stages during the investigation. The final interviews revealed that this approach was largely due to lack of resources, a desire to keep control over discipline and a lack of confidence in the learners’ ability to perform the experiment on their own. Teacher B dealt with learners speaking different languages, and therefore believed it easier to demonstrate the investigation to the class as a whole, as opposed to allowing groups to work on their own. Teachers H and I mentioned difficulties due to large classes in terms of discipline, limited understanding of what science investigation involved and not having sufficient resources for all the learners. However, teacher H found that when doing the strategy for the second and third time, he was more confident in allowing the learners to work in groups as they had gained a better understanding of what was expected of them.

The classroom observations for teachers C, E, F and G revealed how their learners enjoyed doing the investigations by themselves, and were often surprised by how their predictions differed with what they discovered. These teachers believed that their classes experienced greater enthusiasm and interest in doing the investigation when they were ‘left alone to work things out for themselves’.

Teachers’ Perspectives

The portfolio lesson plans and essays indicated that the teachers understood that one of the main aims of the ISLS was to develop “young scientists who can do activities and discover facts through observation and participation and have the ability to record all scientific material accurately” as stated by Teacher C, and that the ISLS aims to achieve this by allowing active participation from the learners when doing the investigation. In his final interview, Teacher H commented that the ISLS ‘is a far more flexible approach to investigations, which allows the learners to feel confident about their questioning and thought processes’.
Many of the teachers commented that they normally avoid group-work situations as the learners’ use these times as opportunities to ‘mess around and make jokes’ (Teacher A). However, the same teachers stated that when their learners were doing investigations, which they had to plan themselves in order to answer their own questions, they were far more focused and interested in doing the investigation because they knew that their teacher was not going to give them the answer.

### 3.6 Teachers’ use of the learners’ science notebooks

Data revealing the teachers’ approaches to using the learner’s science notebooks were generated via the analysis of the classroom observations and learner science notebooks and illustrated in figure 4.6 below.

![Figure 4.6](image)

**Figure 4.6** Teachers’ implementation of the learners’ science notebooks as inferred from the classroom observations and their learners’ science notebooks.
Implementation

While the teachers’ portfolios and final interviews indicated that they had an excellent understanding of the purpose of the learners science notebooks, the notebooks themselves revealed that, in practice, the teachers’ did not use the notebooks as intended. During the classroom observations, most of the teachers verbally encouraged the learners to write autonomously in their notebooks, however only learners’ from the classes of teachers D, E and G continued to produce original and comprehensive work throughout the intervention period as revealed in their notebooks. The classroom observations of, and later the learners’ notebooks from, teachers A and I revealed that the teacher maintained control of the learning process and guided the learners’ through what they should write and do with their notebooks. Teachers B, C, F and H allowed the groups in their classes to freely write up their plans and observations for each investigation, but provided their classes with common questions and results as revealed in their learners’ notebooks.

Teachers Perspectives

The final interviews revealed that the participating teachers understood that the purpose of the science notebooks was to give the learners an opportunity to write freely and creatively. They stated that they understood that their role was to guide the learners to use the headings (date and time, prediction, procedure, conclusions and line of learning), but that the learners be encouraged to write their own thoughts, ideas and discoveries. Most of the teachers commented that their learners enjoyed writing in their notebooks because they did not have “the consequences of getting low marks” (Teacher G). However, other teachers commented that their learners struggled to know what to write without direction from their teacher.

3.7 Line of learning and further research

Data revealing the teachers’ approaches towards the line of learning were generated via the analysis of the classroom observations and learner science notebooks and illustrated in figure 4.7 below.
Chapter 4: Results

Implementation

The majority of the teachers provided their classes with extra information about topics relating to the investigations in the form of hand outs. This method was largely due to limited resources such as access to books and computers. The teachers also felt limited by the time they had available for teaching science and could not afford extra lessons for the learners to do further research. Teachers’ A, B, H and I emphasised that their learners did not have access to adequate resources for research such as the internet outside of lesson times, and thus their learners were dependant on time in class to do further research.
Despite providing hand-outs for the majority of her class, teacher F also had a computer connected to the internet in her classroom for learners who finished their work before the rest of their classmates to do further research on the topic. Teachers D, E and G provided opportunities for their learners to do extra research for homework. Teacher D gave the learners freedom in choosing topics, while teachers E and G provided the learners with specific research topics relating to the investigations completed in class.

_Teachers’ Perspectives_

The teachers who used the strategy to incorporate extra research into their lessons stated that they appreciated the idea of a line of learning as it provided an opportunity to introduce research opportunities. Teacher G commented in the final interviews that he usually struggles with how to incorporate research into his normal teaching process, and enjoyed the structure of the ISLS (figure 2.2) because it provided an opportunity for research to occur within the learning process. He also commented that after initially giving the learners freedom to do their own research, he later guided the class towards similar research topics because he found that time and resource limitations required that he complete the syllabus in time for examinations.

All of the teachers enjoyed the concept of the learners’ researching their own questions and ideas, and commented that the strategy enables them “to think further than the investigations and also to link relevant issues and sustainable development to their classroom investigations” (Teacher E). Teachers D, E, G and F also noted that their learners were more motivated to do extra research when they were trying to find out why something happened in their own investigations which they did not understand. Teacher H commented that the line of learning promotes thinking because “it encourages the learners to look beyond what happens in class and to ask why and how”.

### 3.8 Argumentation and presentation

Data revealing the teachers’ approaches towards planning an investigation were generated via the analysis of the classroom observations and learner science notebooks and illustrated in figure 4.8 below.
Figure 4.8  Teachers’ implementation of argumentation and presentation as inferred from the classroom observations and their learners’ science notebooks

Implementation

The science notebooks and classroom observations indicated that only teacher D provided an opportunity for her learners to present their findings, and that their presentations were not based on the argumentation model associated with the ISLS. The learners’ presentations consisted of describing what they did in their investigations and reading information they had found on the internet, and did not follow a process of argumentation. It was clear that many learners did not have a clear understanding of what they presented as they merely read what they had found on the internet.
Chapter 4: Results

All other participating teachers indicated that their reasons for not attempting this component of the strategy were due to limited confidence in what was specifically expected in terms of argumentation and pressure to keep up with other classes in the grade who were not implementing the ISLS. These reasons were given by eight of the nine teachers for leaving out this step in the process.

*Teachers’ Perspectives*

The argumentation and presentation component of the strategy seemed to be the most difficult for the teachers’ in terms of both their understandings and the actual implementation of argumentation and presentation. The teachers’ exhibited limited understanding of what was specifically required for argumentation as indicated in their essays submitted in their teacher portfolios. As noted earlier, eight of the teachers never implemented this step of the strategy in their classrooms due to time limitations.

3.9  **Incorporation of sustainable development topics**

Data revealing the teachers’ use of the strategy to introduce a link to sustainable development were generated via the analysis of the classroom observations and learner science notebooks and illustrated in figure 4.9 below.
Chapter 4: Results

Figure 4.9  Teachers’ use of the ISLS to incorporate issues relating to sustainable development into the scientific topic being taught as inferred from the classroom observations and their learners’ science notebooks

Implementation

Teacher I was the only teacher to not introduce links to sustainable development. This was because he did not feel confident in his knowledge of sustainable development to do so. Teachers A and H did not use any specific step in the strategy to introduce a link to sustainable development, but rather mentioned the link at the end of the lesson.

Teachers B and D used the stimulus to introduce the link to sustainable development and carried this theme throughout the investigation, and used the link as a topic for further research after the line of learning had been drawn. Teacher B associated recycling with a lesson on materials and matter and teacher D related her lesson on
ecosystems to penguins and oil spills, and her lesson on food and energy sources to poverty and malnourishment.

Teachers D and E were the only two to encourage their learners to further investigate their own ideas relating to sustainable development. Teachers C, F and G all used the line of learning aspect of the strategy to introduce a link to sustainable development and provided their class with the relevant information. These teachers’ reasons for not allowing their learners to further investigate their researchable questions were due to time and resource limitations.

**Teachers’ Perspectives**

The teachers’ portfolio essays all acknowledged the importance of educating children to be adults in our future world and that, therefore, they need to be aware of environmental issues. In addition, they recognized that their learners need to be able to think critically and creatively if they are going to be able to solve complex problems such as those relating to the environment.

Teachers B, D, E and G commented that they found the strategy useful in helping them to integrate issues relating to sustainable development into the topic they were teaching. They stated that they had not thought of relating various learning topics to sustainable development before, but once given the challenge, found it easy to do and found that their learners responded well to the relevant application of what they were learning. In particular, Teacher A mentioned that he had initially doubted his ability to find links to sustainable development, but once he started looking on the internet was surprised by how much information he could find. He connected his learners’ investigations on gravity to an article about a gravity-lamp which uses gravity to create light.

### 3.10 Degree of learner-orientated learning

Data revealing the teachers’ approaches towards learner-orientated learning were generated via the analysis of the classroom observations and learner science notebooks and illustrated in figure 4.10 below.
Chapter 4: Results

Figure 4.10 Teachers’ approaches to learner-orientated learning as inferred from the classroom observations and their learners’ science notebooks

Implementation

Classroom observations revealed that, for the most part, teachers A, B, H and I maintained control throughout the investigation process, giving their learners very little, if any, chance to make their own decisions. Teacher A allowed the learners opportunities to make some decisions during the ‘doing the investigation’ phase during the classroom observations, but the notebooks revealed that during further investigations, they were given instructions to follow. In comparison, during the classroom observations, teacher H maintained control of all decisions, but his class’s
notebooks indicated that during subsequent investigations, the learners were able to make their own decisions when planning and doing their investigations.

Teachers C, D, F and G all allowed their learners to make decisions during selected stages of the strategy, specifically the phases that involved planning and doing the investigation. However, these teachers provided their learners less autonomy when designing the investigable questions and writing in their science notebooks.

During the classroom observations teacher E allowed his learners the opportunity to make all their own decisions regarding the investigation. It was noted during the observations that they responded as though this was not very different from how they were normally taught and they appeared to have the confidence and ability to work independently in their groups.

The classroom observations data suggested that there is a directly proportional relationship between the degree of teacher control and the response of the learners. When the teachers gave the decision making roles to the learners, they were visibly more enthused and excited about the learning process. They seemed eager to tackle the challenge, and appeared to really enjoy the suspense of not knowing what would happen and that they would have to discover it for themselves. However, as soon as the teachers’ took back control of the learning process, the learners seem to lose interest and appear bored and distracted at times.

*Teachers’ Perspectives*

During the final interviews and in their portfolio essays, the teachers acknowledged the role of the learner in the strategy, and that their role as a teacher was more of a facilitator. However, despite this acknowledgment, most of the teachers’ perceptions of learner-orientated learning differed from that proposed by the strategy. Only teachers E and G understood learner-orientated learning as giving the learners autonomy and the opportunity to make their own decisions in the learning process. The other teachers’ associated the term learner-orientated with learner participation and did not recognise the necessity for the learners to make their own decisions.
Chapter 4: Results

Teacher A was critical of the concept of learner-centred learning, as he considered it to be based on the false assumption that learners actually want to learn. From his perspective, learners are generally not interested in learning and thus the teacher faces the challenge of trying to encourage learners learn, read and write while trying to maintain discipline and order in their classrooms. From his experience, learner-orientated learning and methods such as group work are often more disruptive than beneficial.

However, all of the teachers did comment that the strategy helped them to teach in a more learner-centred and discovery based way, which was something they all struggled with previously. The teachers were all aware of the National Curriculum Statement’s focus on learner-orientated learning, but stressed that they battled to find effective ways of teaching in a more learner-orientated way.

In the final interviews, all of the nine teachers emphasised that the greatest benefit of the strategy was its ability to include the learners and allow them to participate at every stage of the learning process. Teachers C, E, F, G and H all commented that the learners became more interested and active when they realised that their teacher was not going to tell them what to do. In particular, the teachers found that the learners really enjoyed the strategy, specifically planning and doing the experiment themselves. They enjoyed asking their own questions, and then finding out their own way to discover the answers to their questions.

3.11 Teachers’ overall implementation of the strategy

In addition to the segmented analysis of the strategy, each teacher’s personal level of success for the overall implementation of the strategy was also analysed. This was achieved by adding together the score each teacher received for each of the ten components of the assessment schedule and converting the final total into a percentage. These data revealed a clear distinction between those teachers scoring above 50% and those scoring below as illustrated in figure 4.11.
Figure 4.11 The degree to which each teacher implemented the ISLS as indicated by their total scores gained for the assessment schedule’s ten components

Teachers D, E, G, C and F were classified as ‘strong implementers’ and teachers H, B, A and I were classified as ‘weak implementers’. This was important for the statistical analysis of the learners’ pre and post-tests because it allowed for a comparison between these two groups.

4. LEARNERS’ TESTS

As previously discussed in chapter three, the learners’ tests (Appendix B) comprised of a variety of questions. These questions were divided into two sections based on whether the questions assessed a) the learners’ perspectives concerning environmental issues or b) the learners’ understandings and abilities relating to scientific investigation. A pre-post test design was used and analysed in an attempt to ascertain if the strategy had any effect on the learners’ perspectives, understandings and/or abilities relating to the categories within these two sections (Table 4.1.)
Table 4.1  Division of learners’ test questions into categories

<table>
<thead>
<tr>
<th>Section 1</th>
<th>Environmental issues: learners’ perspectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Categories</td>
<td>Recognition of environmental problems</td>
</tr>
<tr>
<td></td>
<td>Human actions as a dominant cause of environmental problems</td>
</tr>
<tr>
<td></td>
<td>Personal responsibility towards the environment</td>
</tr>
<tr>
<td></td>
<td>Importance of learning about how to protect the environment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section 2</th>
<th>Science Investigation: understanding and abilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Categories</td>
<td>The learners’ understanding of graphical representation of data (graphs)</td>
</tr>
<tr>
<td></td>
<td>The learners’ understanding of variables (variables)</td>
</tr>
<tr>
<td></td>
<td>The learners’ understanding of the purpose and role of inquiry-based investigation (investigation)</td>
</tr>
<tr>
<td></td>
<td>The learners’ ability to formulate their own investigable question (question)</td>
</tr>
</tbody>
</table>

Before commencing the testing procedure, each learner was given a student number by their teacher in order to provide a degree of anonymity and consistency. The learners were instructed to use the same student number when completing the post-test to allow a more effective statistical analysis to be performed on the pre and post-test data. Only those learners who completed both the pre- and post-tests were included in the analyses, resulting in a total of 208 learners’ tests being analysed.

4.1  Learners’ perspectives of environmental issues

Each of the questions 1, 2.3, 3.2 and 4.3 of the learners’ test (Appendix B) required the learners to respond to a group of statements indicating their view of a particular environmental issue. For example, they were asked whether they strongly agreed, agreed, disagreed or strongly disagreed with statements such as ‘human actions are causing serious damage to the environment’, ‘it is due to human actions that the earth is getting warmer’ and ‘it is important that we learn about new forms of energy which are clean and don’t produce pollution’. During the data analysis phase, each of these statements was re-classified into one of the four possible categories illustrated in table 4.1 above, depending on whether the statement assessed:
Chapter 4: Results

the learners’ recognition of environmental problems,
the learners’ views that human actions are a dominant cause of environmental problems,
the learners’ views that we each have a personal responsibility towards the environment, or
the learners’ views concerning the importance of learning about how to protect the environment.

Within each of these four categories, the number of strongly agree, agree, disagree and strongly disagree responses were added together and converted into a percentage to indicate the proportion of learners who shared common perspectives regarding each of the four categories. The initial analysis involved a comparison between the perspectives held by the learners from the ‘strong implementer’ group compared with those in the ‘weak implementer’ group. However, this initial analysis showed virtually no difference in views and was considered to be a futile comparison. Therefore, figure 4.12 provides a graphical representation of the perspectives held by all 208 learners as indicated on their pre-tests.

![Figure 4.12 Learners’ perspectives concerning environmental issues as indicated in the learners’ pre-test analysis](image)

**Views on environmental issues**
According to the data generated via the learners’ tests, they all either agreed or strongly agreed that there are serious environmental problems and that it is important that we learn about ways to protect the environment. Ninety-seven percent of learners either strongly agreed or agreed that human actions were a dominant cause of environmental problems and 83% agreed or strongly agreed that each person has a responsibility towards caring for the environment.

Results from the post-test questions, showed almost no change in the learners’ awareness and attitudes concerning environmental issues. For this reason, no further analysis of the post-test results was done.

4.2 Statistical analysis of the science investigation questions

The learners tests were divided into and analysed as two groups, according to the teachers’ degree of successful implementation of the strategy (figure 4.12). As previously indicated, the learners from teachers D, E, G, C and F were placed in the ‘strong implementers’ group, while the learners from teachers H, B, A and I were placed in the ‘weak implementers’ group. This division allowed for statistical comparisons to be made between the two groups of in terms of the corresponding learners’ performance in the pre-post tests, specifically between the four categories as previously illustrated in Table 4.1

Student’s t-test analysis

After dividing the learners’ tests into the two groups described above, Student’s t-test (Donnelly & Trochim, 2006) was used to analyse whether the two groups were statistically different from each other before and after the implementation of the strategy. A t-test analysis is appropriate for comparing the means of two groups, and especially appropriate as the analysis of a pre-post-test research design involving two distinct groups. Where there is a difference between the two groups, a probability value (p) less than or equal to 0.05 (p \leq 0.05) indicates that there is a statistically significant difference in the results (95% confidence level). Similarly, when p \leq 0.01, there is a 99% level of confidence that the difference between the two groups is statistically significant.
Chapter 4: Results

significant. A large probability value \( p > 0.05 \) indicates that the difference indicated between the two groups can be attributed to chance (Gravetter & Wallnau, 2008).

When the differences between two groups are shown to be statistically significant \( p \leq 0.05 \), an effect size can be calculated to determine the practical significance of the reported differences (Becker, 2000; Gravetter & Wallnau, 2008). While \( p < 0.05 \) indicates a statistically significant difference based on a treatment, it does not measure the magnitude of the effect of the treatment. Cohen’s \( d \) is an index that measures the magnitude of the effect (effect size) of a particular treatment by calculating the difference between the means of two groups, divided by the standard deviation of either group. The practical significance of the difference in question is determined according to the following values:

- 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 \( d > 0.8 \).

In other words, 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. Cohen's \( d \) is also frequently used in estimating sample sizes, where a lower Cohen's \( d \) value indicates a necessity of larger sample sizes and vice versa (Bekker, 2000, Gravetter & Wallnau, 2008).

*Pre-test analysis*

The t-test analysis of the learners’ pre-test scores for the two pre-defined groups (Table 4.2) illustrated differences between the strong and weak implementers with reference to their abilities and understandings at the starting point before the intervention period. These differences existed for all four of the categories discussed above and for the pre-test as a whole. A summary of the results are illustrated in Table 4.3.
<table>
<thead>
<tr>
<th>Category</th>
<th>Statistical significance of difference (p value)</th>
<th>Practical significance of difference (Cohen’s d)</th>
<th>Mean difference (Δ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphs</td>
<td>p = 0.000</td>
<td>d = 0.501</td>
<td>Δ = 13.79</td>
</tr>
<tr>
<td>Variables</td>
<td>P = 0.633</td>
<td>n/a</td>
<td>Δ = 2.00</td>
</tr>
<tr>
<td>Investigation</td>
<td>p = 0.005</td>
<td>d = 0.39</td>
<td>Δ = 8.36</td>
</tr>
<tr>
<td>Question</td>
<td>p = 0.633</td>
<td>n/a</td>
<td>Δ = -1.57</td>
</tr>
<tr>
<td>Total</td>
<td>p = 0.012</td>
<td>d = 0.35</td>
<td>Δ = 5.65</td>
</tr>
</tbody>
</table>
### Table 4.3: Results of Student’s t-test analysis of the learners’ pre-tests for the Implementer and Non-implementer groups

<table>
<thead>
<tr>
<th>Category</th>
<th>Descriptive Statistics</th>
<th>Inferential Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Imp (n =118)</td>
<td>Non-Imp (n = 90)</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>Graphs</td>
<td>44.35</td>
<td>30.21</td>
</tr>
<tr>
<td>Variables</td>
<td>53.11</td>
<td>31.50</td>
</tr>
<tr>
<td>Investigation</td>
<td>71.69</td>
<td>22.08</td>
</tr>
<tr>
<td>Question</td>
<td>13.98</td>
<td>28.41</td>
</tr>
<tr>
<td>Total</td>
<td>45.78</td>
<td>18.10</td>
</tr>
</tbody>
</table>
There was no statistically significant difference between the two groups’ of learners understanding of variables and ability to formulate an investigable question \((p \geq 0.05)\), which suggests that the differences can be attributed to chance. There was a statistically significant difference between the learners understanding and application of graphical representation and their understanding of what constitutes an investigable question at the 99% level of confidence \((p \leq 0.01)\). In addition, the analysis of the overall total from the pre-tests indicated that there was a statistically significant difference between the two groups at the beginning of the implementation of the strategy \((p \leq 0.05)\). Cohen’s \(d\) scores indicated that each of these statistical differences had small practical significances, with the exception of the graphs category when a moderate significance was recorded \((d = 0.501)\).

The difference between the two groups in the t-test analysis is reflected as the mean difference \((\Delta)\). A positive score implies that the strong implementers group of learners achieved better than the weak implementers did, while a negative score indicates the converse. In both cases where the difference between the abilities of the two groups was shown to be statistically significant (graphs and investigation) the mean difference indicated that the strong implementer group of learners was stronger than the weak implementer group. The results for the total pre-test scores also indicated that as a whole the strong implementers group was academically stronger than the weak implementers group \((\Delta = 5.65)\) at the beginning of the implementation phase of the strategy.

**Post-test analysis**

The t-test analysis of the post-test scores for the two pre-defined groups (Table 4.4) revealed statistically significant differences in improvements between the two groups for all four of the categories and for the post-test as a whole, as presented in Table 4.5.
<table>
<thead>
<tr>
<th>Category</th>
<th>Descriptive Statistics</th>
<th>Inferential Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Imp (n =118)</td>
<td>Non-Imp (n = 90)</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>Graphs</td>
<td>56.78</td>
<td>28.10</td>
</tr>
<tr>
<td>Variables</td>
<td>54.80</td>
<td>30.36</td>
</tr>
<tr>
<td>Investigation</td>
<td>72.71</td>
<td>20.86</td>
</tr>
<tr>
<td>Question</td>
<td>15.25</td>
<td>26.56</td>
</tr>
<tr>
<td>Total</td>
<td>49.89</td>
<td>15.93</td>
</tr>
</tbody>
</table>
**Table 4.5** Summary of Student’s t-test results for the learners’ post-test scores analysis

<table>
<thead>
<tr>
<th>Category</th>
<th>Statistical significance of difference (p value)</th>
<th>Practical significance of difference (Cohen’s d)</th>
<th>Mean difference (Δ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphs</td>
<td>p = 0.000</td>
<td>d = 0.93</td>
<td>Δ = 24.74</td>
</tr>
<tr>
<td>Variables</td>
<td>P = 0.001</td>
<td>d = 0.48</td>
<td>Δ = 14.06</td>
</tr>
<tr>
<td>Investigation</td>
<td>p = 0.000</td>
<td>d = 0.56</td>
<td>Δ = 13.16</td>
</tr>
<tr>
<td>Question</td>
<td>p = 0.014</td>
<td>d = 0.35</td>
<td>Δ = 8.03</td>
</tr>
<tr>
<td>Total</td>
<td>p = 0.000</td>
<td>d = 0.96</td>
<td>Δ = 15.00</td>
</tr>
</tbody>
</table>

In each of the categories listed in table 4.5, including the overall score for the post-test, the strong implementers group improved to a greater degree than the weak implementer group. However, as the t-test analysis of the pre-test’s indicated that there was a statistically significant difference between the two groups of learners at the start of the implementation of the strategy, the t-test analysis of the post-test scores was not deemed sufficient to obtain an accurate representation of the differences in improvement. Analysis of Covariance (ANCOVA) techniques were applied, as it was considered necessary to account for the fact that the two groups were not equal from an academic perspective, as indicated by the variations in the initial positioning of the learners in terms of the learners’ test scores.

**ANCOVA post-test analysis**

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 (Donnelly & Trochim, 2006; Gravetter & Wallnau, 2008). In this study, the covariates were the initial scores of the participants. In other words, due of ANCOVA’s consideration of the difference in abilities of the two groups of learners at the beginning of the strategy implementation, the result of the implementation alone could be statistically evaluated between the strong implementers and weak implementers.
groups. Table 4.6 illustrates the results of the ANCOVA analysis of the data generated by the learners’ post-tests. In table 4.6 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, and is also used to calculate the probability value. As $p \leq 0.05$ in all cases, Cohen’s $d$ was calculated in order to gauge the effect size of the practical significance of the differences. The results of the statistical analysis using ANCOVA are summarised in table 4.7.

<table>
<thead>
<tr>
<th>Category</th>
<th>Statistical significance of difference (p value)</th>
<th>Practical significance of difference (Cohen’s d)</th>
<th>Mean difference (Δ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphs</td>
<td>$p = 0.000 \ (p \leq 0.01)$</td>
<td>$d = 0.79 \ (0.5 &lt; d &lt; 0.8)$</td>
<td>$\Delta = 20.17$</td>
</tr>
<tr>
<td>Variables</td>
<td>$P = 0.001 \ (p \leq 0.01)$</td>
<td>$d = 0.47 \ (0.2 &lt; d &lt; 0.5)$</td>
<td>$\Delta = 13.79$</td>
</tr>
<tr>
<td>Investigation</td>
<td>$p = 0.001 \ (p \leq 0.01)$</td>
<td>$d = 0.48 \ (0.2 &lt; d &lt; 0.5)$</td>
<td>$\Delta = 11.24$</td>
</tr>
<tr>
<td>Question</td>
<td>$p = 0.014 \ (p \leq 0.05)$</td>
<td>$d = 0.35 \ (0.2 &lt; d &lt; 0.5)$</td>
<td>$\Delta = 8.05$</td>
</tr>
<tr>
<td>Total</td>
<td>$p = 0.000 \ (p \leq 0.01)$</td>
<td>$d = 0.88 \ (d &gt; 0.8)$</td>
<td>$\Delta = 12.87$</td>
</tr>
</tbody>
</table>
Table 4.7  Results from the ANCOVA analysis of the learners’ post-tests for the Implementer and Non-implementer groups

<table>
<thead>
<tr>
<th>Category</th>
<th>Descriptive Statistics</th>
<th>Inferential Statistics</th>
<th>Practical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (n =118)</td>
<td>Non-Imp (n = 90)</td>
<td>Mean Diff.</td>
</tr>
<tr>
<td>Graphs</td>
<td>54.80 25.35</td>
<td>34.63 25.45</td>
<td>20.17</td>
</tr>
<tr>
<td>Variables</td>
<td>54.69 29.23</td>
<td>40.89 29.24</td>
<td>13.79</td>
</tr>
<tr>
<td>Investigation</td>
<td>71.88 23.27</td>
<td>60.64 23.33</td>
<td>11.24</td>
</tr>
<tr>
<td>Question</td>
<td>15.26 23.20</td>
<td>7.21 23.20</td>
<td>8.05</td>
</tr>
<tr>
<td>Total</td>
<td>48.97 14.56</td>
<td>36.09 14.59</td>
<td>12.87</td>
</tr>
</tbody>
</table>
Chapter 4: Results

ANCOVA analysis of the post-test data indicate that the strong implementer’s learner group had achieved greater improvements than the weak implementers overall and in all of the categories, and that these differences were statistically significant. The values obtained for Cohen’s d also illustrated that, as a whole, the overall variation in improvement between the strong implementers and weak implementers had a highly significant practical relevance, indicating that the effect-size of the strategy intervention was statistically relevant. This difference in improvement was especially relevant when comparing the learners’ ability to understand and apply graphical representation. The differences in improvements for each of the five categories for the two learner groups have been graphed in figures 4.13 below.

![Graph showing differences in improvements between pre- and post-test scores of the strong implementer and the weak implementer groups for each of the 4 categories of science investigation questions, and the total scores](image)

**Figure 4.13** Differences in improvements between pre- and post-test scores of the strong implementer and the weak implementer groups for each of the 4 categories of science investigation questions, and the total scores
While the total score for the post-test indicated an overall improvement for both groups of learners, Figure 4.13 indicates that for each category the strong implementers showed a statistically significantly greater degree of improvement. The greatest difference in improvement occurred with the learners’ understanding of graphs, followed by their understanding of variables and investigation respectively, and lastly their ability to formulate an investigable question. The data also indicated that both groups experienced the least improvement in their ability to formulate an investigable question.

5. LEARNERS’ SCIENCE NOTEBOOKS

The learners’ entries in their science notebooks were analysed according to the Science Notebook Checklist (Appendix G) and converted into a percentage. The data generated from the learners science notebooks were analysed and yielded information regarding the construction of an investigable question, designing an investigation, collecting and recording data, the use of scientific drawings and drawing conclusions (Figure 4.14). As there was no evidence of the learners’ use of the science notebooks approach previous to this study, a comparison between the different classes or between the Implementer and Non-implementer groups could not be made to determine progress or improvements. Therefore, the learners’ science notebooks were analysed to provide insight into the learners’ level of conceptual and procedural understandings when conducting scientific investigations (Villanueva, 2010).
5.1 Constructing an investigable question

The analysis of the learners’ science notebooks indicated that 57% of the learners copied their teacher’s question during the scientific investigations conducted in the classrooms. The remaining learners wrote their own questions, but these were either inaccurate (12%) or accurate but incomplete (31%). This was largely due to the questions written not being investigable such as “What do I want to know about heat?” or incomplete such as “How many drops can fit on a coin?”

5.2 Designing and implementing an investigation

Of the 273 notebooks analysed, all of the learners demonstrated evidence of an experimental procedure. Most of the learners’ designed and wrote their own plan in answering the question, with only 23% copying the teacher’s information. Of the 77% who wrote their own plans, 61% were accurate but incomplete and could not be replicated. The most common mistakes noted were the omission of important steps in the plan and little consideration for the fairness of the test. Many of the investigation
designs were extremely brief with little or no referral to variables of control factors. However, 16% of the learners demonstrated that they were able to create and write down a complete and replicable procedure.

### 5.3 Collecting and recording data

Data from the 273 notebooks indicated that all learners were exposed to the process of collecting and recording data. Most of the learners’ were given the opportunity to record data by themselves, with only 23% copying the teacher’s information. Only 21% of the learners were able to accurately record complete data sets, with 53% recording accurate, but incomplete data. These data sets were considered incomplete due to key measurements being omitted and incomplete tables and graphs being presented.

### 5.4 Scientific drawings

Results from the analysis of the scientific drawings yielded the widest range of data with 37% having no drawings and only 11% of learners generating original drawings which were sufficiently labelled and provided accurate details regarding their observations. Eight percent of the learners produced drawings which either lacked relevant detail, had limited or inaccurate labels or which were irrelevant to the investigation. The largest group, 44%, generated their own drawings which were considered incomplete due to the absence of relevant detail in the labels provided.

### 5.5 Drawing conclusions

Analyses of the science notebooks indicated that the learners struggled with drawing their own conclusions with 13% having no indication of any conclusions and only 31% providing conclusions in their own words. An overwhelming majority (56%) merely copied the teacher’s conclusions, and it was noted that even these conclusions were lacking relevant detail and information. Most of the conclusions mere restated the result of the investigation with no explanation as to why they thought they achieved those results.
6. CHAPTER SUMMARY

This chapter focused on the qualitative and quantitative data generated in this study. Data generated from the exploratory interviews provided descriptions of the teachers’ understandings and previous experiences relating to sustainable development and ESD. A comprehensive discussion of the implementation of the ISLS provided insight into both the teachers’ implementation of the strategy in their classrooms and their theoretical perspectives concerning their views of the ISLS and their experiences with implementing the strategy.

A quantitative analysis of the learners’ pre- and post-tests illustrated changes in their understandings and abilities relating to scientific investigation as a result of the implementation of the strategy, as well as illustrating the learners’ perspectives of environmental issues. Student’s t-test analysis of the pre- and post-tests revealed statistically significant differences in improvements between the strong and weak implementer groups, indicating that the strong implementer’s learners improved to a greater degree than weak implementer group in all four categories and for their overall test scores. Furthermore, the ANCOVA results indicated that these differences in improvements between the two groups could be attributed to the use of the strategy by the teachers within the strong implementer’s group. This result was especially evident when comparing the learners’ ability to understand and apply graphical representation.

Finally, the data gleaned from the learners’ notebooks regarding their approach towards scientific investigations in their classrooms were presented. These results indicated that while the majority of learners were able to design their own investigation, collect data and represent their procedures or findings through adequate scientific drawings, a large majority of the learners struggled to construct their own investigable question and to draw their own conclusions.
CHAPTER FIVE
DISCUSSION OF RESULTS

1. INTRODUCTION

This chapter discusses the qualitative and quantitative data presented in chapter four. The findings from the teachers’ exploratory interviews are discussed in order to provide a greater understanding of exposure to, understandings of, and experience with, teaching ESD. An extensive evaluation of the participating teachers’ ability to implement the Integrated Strategy for Scientific Literacy follows, concentrating on the Strategy Assessment Schedule’s ten components described in chapter three (Table 3.4). Finally, the learners’ engagement in the strategy is discussed through an evaluation of the statistical analysis of their pre- and post-test scores, and the results generated from their science notebooks.

2. EXPLORATORY INTERVIEWS

Prior to the Integrated Scientific Literacy Strategy (ISLS) training workshop, each teacher participated in an exploratory interview concerning their experiences with teaching ESD. The Exploratory Interview Questions protocol was used to examine, a) their general awareness concerning ESD issues; b) their perspectives concerning their learners’ responses to ESD related topics; and c) challenges and obstacles faced when teaching ESD related topics.

2.1 Awareness and knowledge of ESD

The results from the exploratory interviews revealed that the participating teachers were aware of the concept of sustainable development, with specific reference to its focus on the preservation of the natural environment, global warming and the use of non-renewable energy sources. However, while most of the teachers were familiar with the term sustainable development, only one third had heard of the concept of ESD. This finding is consistent with Winter’s (2009) observation, which he explains is due to
Chapter 5: Discussion of Results

the lack of mention of ESD within the Department of Education’s National Curriculum Statement (NCS).

Exploratory discussions about ESD revealed that only three of the teachers indicated an awareness of the human component within sustainable development, and none of the teachers revealed an understanding of ESD’s focus on poverty alleviation and the need for the provision of basic needs for all people. According to Winter (2009), this could be due to the National Curriculum Statement’s focus on the environmental aspects of topics such as climate change and the sustainable use of the earth’s resources, with only brief mention of the human component. The perceived absence of the human component in the teachers’ understandings of ESD highlights the problems of confusion between environmental education and ESD (Le Grange, 2010), insufficient teacher knowledge and understanding (Winter, 2009), and reiterates Corney’s (2006) observation that teachers struggle to relate to the complexity of ESD. Chatzifotiou (2006) suggests that due to the limited knowledge and information that teachers seem to possess in terms of their practices and new developments, the concept of environmental education is a lot easier to comprehend than ESD as they are already familiar with the terms ‘environment’ and ‘education’ and can therefore continue teaching using similar content and methods that they are already using.

Heimlich (2007) and McKeown (2010) maintain that human development is central to the ESD concept, distinguishing it from environmental education which focuses predominantly on the preservation and conservation of the environment. Similarly, Venkataraman (2010) establishes that the main difference between environmental education and ESD is ESD’s broader context, encompassing socio-cultural and political issues such as equity, poverty, democracy and quality of life for societies. McKeown (2002) emphasises that ESD should encompass issues relating to interactions between human development and the environment, and that in order for an effective framework for teaching ESD to be developed teachers need to be equipped to help learners identify and think about the complex relationships existing between society, the environment and the economy.
2.2 Teaching ESD: Approaches and challenges faced

During the exploratory interviews, the teachers articulated dissatisfaction with their learners’ apathetic attitudes towards the natural environment and frustration that they did not seem to be able to change the way their learners valued the natural environment. They also expressed a desire to teach in such a way that they might impact their learners at a values level, but did not feel confident that they knew how to achieve this goal.

The participating teachers’ chose the use of supplemental media such as DVD’s, and group discussions to teach topics relating to the environment, and did not indicate the use of inquiry as an instructional method. For Fensham (2008) and Barrow (2010), learner-centred scientific inquiry provides an avenue for developing natural curiosity and appreciation for the natural world. However, it seems that the teachers have an insufficient knowledge base concerning science and investigation. This suggestion is based on the teachers’ observed hesitancy and reluctance to use learner-orientated inquiry. While recent educational theory has embraced and promoted the logic of group or co-operative work in school classrooms (Coetzee, Van Niekerk, & Wydeman, 2008; Nieman, & Monyai, 2006), the findings from literature and this study suggested that this is still an approach which many teachers struggle to implement, and who, therefore, prefer to avoid. This notion is consistent with Villanueva & Webb’s (2008) previous conclusions, and is probably due to the highly interactive and unpredictable nature of investigations (Yore, et al., 2007).

Despite the NCS’s call for teachers to act as mediators (Department of Education, 2002), the findings from the exploratory interviews revealed that the participating teachers were still reliant on teacher-dominated and content-based teaching approaches. These reflect concerns that there is not a cadre of capable and knowledgeable teachers within South African primary science education (Christie et al., 2007). Makgato and Mji (2006) note that the progression of South African education towards critical and creative thinking rests partly on teachers being inspired and motivated to change their normal teaching practices, and Lotz-Sisitka (2006, 2008) emphasises the importance of training South African teachers to teach ESD in such a way that critical and creative thinking are promoted. However, the training of teachers to effectively teach the knowledge and skills of ESD remains a challenge (Fensham, 2008; Le Grange, 2010; Winter, 2009).
3. TEACHERS’ IMPLEMENTATION OF THE STRATEGY

Following the training workshop on the Integrated Scientific Literacy Strategy (ISLS) and ESD the teachers were tasked with implementing the strategy in their Natural Science lessons during the intervention period of this study. The following discussion seeks to interpret and explain the results generated by the ten point assessment schedule as presented in chapter four.

3.1 Use of a stimulus

Webb (2008, 2009) suggests that learner interest and enthusiasm can be readily obtained when a lesson is introduced with a counter-intuitive observation (discrepant event), or through stories or readings use to spark interest and provide information. The use of a stimulus to begin lessons or investigations was proposed to the participating teachers in this study to promote learners’ interest and enthusiasm, to elicit their prior knowledge, and to provide them with information.

Similar to the experience described by Marks and Eilks (2009), the teachers all found that the use of a stimulus inspired noticeable interest and enthusiasm, and provoked questions and discussion amongst the class. In contrast to Villanueva’s (2010) observation that teachers found discrepant events too challenging to use, most of the teachers successfully employed this method. The teachers stated during their interviews that the use of a discrepant event aroused curiosity in their learners because they were eager to find out why the unexpected had occurred, making the following discussion or investigation more relevant and meaningful to them (Marks & Eilks, 2009).

However, despite training on the use of a reading stimulus as a tool to expand learners’ science thinking, conceptual development, and their abilities to read and write (Powell & Aram, 2007), only one of the teachers used a reading stimulus during the study period. This particular stimulus was read aloud by the teacher who did not provide opportunity for her learners to engage in read-aloud, shared, guided or independent reading as proposed by England and Webb (2008), which she attributed to a lack of resources and her learners’ weak reading skills. Nevertheless, the stimulus still appeared to be effective as it provided the learners with ideas about the topic, encouraged them to
tackle unfamiliar content and promoted class discussion and questions about the issue on hand (England & Webb, 2008).

### 3.2 Exploratory talk and class discussion

As noted in chapter four, although the teachers attempted to promote class discussion, exploratory talk as defined by Mercer, Wegerif & Dawes (1999) was not satisfactorily achieved. This finding supports Taylor and Vinjevold’s (1999) concern around the lack of meaningful class discussions in South African classrooms. Classroom observations from this study revealed that while the teachers did use a stimulus to generate general class discussion, the learners were generally not encouraged or guided to engage in critical and constructive attempts to challenge each other’s ideas as also noted by Webb (2008). The teachers’ seemed satisfied with general class discussion and did not attempt to create meaningful opportunities for groups of learners to discuss and challenge opposing ideas. The inability of the teachers to effectively promote discussion may be due to limited exposure to, and narrow understandings of, the role of discussion and the role and possibilities of exploratory talk (Webb, 2008).

In addition, the classroom observations and teacher portfolios also revealed some of the teachers’ preference for maintaining control over the discussion process through their use of an Initiation-Response-Feedback approach (Dillon, 1994; Sinclair & Coulthard, 1975). In their final interviews these teachers expressed their fear of losing focus, control and discipline during their lessons. Barnes and Todd (1995) express a concern that without the freedom to discuss and explore learning topics, learners are left with a vague understanding of the purpose of their learning experience, and often remain perplexed, unfocused, and therefore, unproductive. In addition, Lemke (1990) maintains that Initiation-Response-Feedback cycles promote the idea that scientific knowledge is fixed and unquestionable, and do not promote constructivist learning.

In contrast, the use of exploratory talk promotes the construction of knowledge by encouraging learners to critically challenge each other’s ideas, justify their own thoughts and opinions, and offer alternative ideas for consideration (Webb, 2008). The teachers’ who did try to engage their learners in a more conversational form of class discussion, commented that as their learners acquired a deeper understanding of the purpose of
scientific investigation, and that they gained confidence and were more enthusiastic and motivated when participating in discussions and practical investigations. In agreement with Villaneuva’s (2010) findings, the teachers’ final interviews revealed that their classes engaged in increased classroom discussion during their second and third attempts at implementing the strategy, often because the teachers themselves were more confident in providing their learners with opportunities to share their own ideas. The teachers suggested that with time and increased exposure to the strategy, their learners could become more adept at engaging in class discussion.

3.3 Designing an investigable question

The idea that the learners design their own investigable question, which they would then investigate, seemed to be a completely new concept for the teachers, and one with which they struggled. None of the teachers’ had tried this approach before, and most struggled to relinquish control. The ISLS proposes that the teachers’ use the stimulus to generate class discussion around the lesson’s topic. From this class discussion, the learners start to develop a list of questions, which are separated into those which can be investigated (investigable) and those which need to be researched (researchable). The teacher facilitates the class discussion around the various discussion, and subtly ‘leads’ the class into choosing one question, which they will then investigate. If implemented correctly, the learners are actively engaged in the process of deciding which question they want to investigate, which encourages a sense of ownership over the learning process (Webb, 2008). While the teachers did facilitate class discussion where learners were able to suggest questions, when the time came to choose a question, the teachers shut down the discussion process and provided the class with a pre-determined investigable question, which the teacher had planned for the lesson. The teachers were more comfortable with providing their classes with an investigable question which they had previously chosen, suggesting that teachers will revert to their old ways of teaching when they lack experience, confidence or knowledge of a particular teaching method (Hiebert et al., 2003; Thomas & Pederson, 2003).

However, despite the teachers’ apprehension, they did acknowledge that this approach where learners design their own investigable questions could be an excellent
example of how teachers could change their normal teaching habits in order to promote critical and creative thinking (Makgato & Mji, 2006). Despite providing a pre-determined question for the investigation at the end of the discussion, the teachers still expressed significant appreciation for the discussion aspect of this step in the strategy, as they witnessed their learners thinking for themselves, developing their own lists of questions and participating with greater enthusiasm. In particular, some of the teachers suggested that, with time, the learners who initially struggle to develop their own thoughts can gain confidence in their own abilities as they are guided and encouraged to think of their own ideas and questions. In addition, some of the teachers commented that after exposing their learners to the differentiation between investigable and researchable questions, their learners displayed an improved understanding of scientific investigation, and began to think critically about the questions they were asking.

3.4 Planning an investigation

Many researchers argue that imitating authentic scientific investigations helps to lead teachers away from the unsophisticated notion of science as a process in which learners simply gain knowledge and learn process skills towards a richer understanding of science, scientific concepts, reasoning and critical thinking (Bybee, 1997; Miller & Calfee, 2004; Mintz & Calhoun, 2004). The ISLS proposes that by planning their own investigations, groups of learners are required to think about how to choose and design the right steps so that their investigations will provide an answer for the investigable question posed (Huber, 2008; Webb, 2008c). As opposed to following a set of instructions on a worksheet, the learners were required to make their own choices, thereby creating opportunities for them to focus on problem-solving in small groups (Daniels’ et al., 2001, Daniels & Perry, 2003; Paris & Combs’s, 2006).

In particular, the teachers expressed appreciation for how the strategy helped them to explain the role and use of variables to their learners, and provided them with opportunity to enable their learners to apply this knowledge to their investigation. The task of planning their own investigations required the learners to identify and apply the concepts of dependent and independent variables, and to design a means of controlling the various variables (Webb, 2008a). In comparison to following step-by-step
instructions, the learners had to engage in both the procedural and conceptual aspects of the investigation (Gott & Duggan, 1995). The learners had to utilise their procedural understandings by choosing what, when and how to measure during their investigations; and applied conceptual understandings when using theory to interpret and explain their results (Webb, 2008a). The teachers commented that by allowing the learners to work independently and make their own decisions and choices, the learners were required to engage in critical thinking because they had to think of, and then find a way, to investigate the unknown (Huber, 2008). This observation confirms Webb’s aspirations for the strategy to promote “critical reflection necessary for the development of high-order cognitive skills” (Webb, 2008c, p. 161).

Lotz-Sisitka (2006), McKeown (2002) and Venkataraman (2010) emphasise the importance of skills such as critical thinking and problem solving within ESD. In addition to the above, Lotz-Sisitka (2006), Bonnet (2006) and Higgs (2002), urge educators to embrace participatory and democratic teaching approaches, which encourage greater personal engagement from the learners, and therefore, a fuller understanding of the issues being taught. The participating teachers’ noted in their portfolios and interviews that the opportunity given to their learners to plan their own investigations significantly increased their fervour for and participation in their science lessons. The challenge of the unknown, and the realisation that their teacher was not going to provide them with an answer, seemed to inspire enthusiasm and creativity when planning their own investigations. The reflective interviews also indicated that the strategy’s use of terms such as “What I want to know” and “What I found out” in place of more difficult scientific terminology, increased the accessibility of the planning process to a greater number of children because they could understand what was required. Two teachers commented that these phrases were especially helpful for their learners who struggled with having to learn in their second language, allowing them to participate more often than they usually did.

In particular, the role of the ‘What I think’ (prediction) step seemed to generate interest because the learners wanted to find out if they were right. The process of making a prediction also seemed to encouraged critical thinking as the learners had to think about what they thought would happen based on their current knowledge about the
topic, and helped them develop more accurate understandings of the purpose of scientific investigation.

As with the investigable question, the concept of allowing the learners to design their own investigations differed to the teachers’ usual teaching methods. For this reason, the teachers appreciated the formal structure of the strategy’s demarcated phases as it helped them to implement this new approach to learning in a structured fashion. However, the teachers also found each phase of the strategy to be very time consuming, and repeatedly discussed the tension they felt between implementing each phase properly and the time pressure they were under to move on and prepare for exams.

3.5 Doing an investigation

Huber (2008) maintains that while textbooks and worksheets can be helpful in helping learners to succeed in hands-on activities, they restrict opportunities for learning through inquiry and the chance to experience ‘real’ science. As opposed to step-by-step instructions, inquiry-based learning encourages learners to problem solve, learn to think like scientists and experience ownership of the activity and learning process (Huber, 2008).

Classroom observations and the examination of the learners’ science notebooks revealed that during this phase of conducting the investigation, the teachers provided their learners with the greatest degree of participation and ownership over the learning process. It was also during this phase that the learners exhibited the greatest motivation and enthusiasm when given the freedom to work autonomously in their groups (Daniels’ et al., 2001, Daniels & Perry, 2003; Paris & Combs’s, 2006). The learners seemed to enjoy the opportunity to ‘work things out for themselves’ and the teachers commented on their creativity and innovation when faced with the task of doing their investigations by themselves. As such, the findings of this study affirmed previous observations that autonomous participation encourages learners to think creatively and to develop democratic decision making processes (Daniels, et al., 2001).

Qualitative data from the classroom observations in this study revealed that while working on their investigations in groups, the learners engaged in exploratory talk by challenging and questioning each other’s ideas, defending their own ideas and by
offering alternative suggestions (Webb, 2008). The groups of learners were required to ‘figure things out for themselves’, providing opportunity for cooperative engagement in the construction of knowledge (Daniels, et al., 2001). This observation was further corroborated by the teachers’ interviews, which suggested that the use of open-ended investigations encouraged their learners to extract meaning from their own findings, enabling them to form more comprehensive understandings of the purpose of their investigations (Millar, 1996; Webb 2009). This process in turn, helped to guide the learners towards a greater understanding of how science produces new knowledge because they were experiencing the process for themselves (Cobern et al., 2010; Huber, 2008; Hume & Coll, 2010).

3.6 Teachers’ use of the learners’ science notebooks

The purpose of the science notebooks in the strategy is to provide opportunity for learners to freely record their questions, predications, observations and conclusions in their own manner and without the pressure of their work being marked (Nesbit, 2007). Teachers are urged to use reading and writing as tools to expand their learners’ science thinking and conceptual development within the context of inquiry-based learning experiences (Powell & Aram, 2007). However, despite the training provided and the teacher portfolios indicating that the teachers had a clear understanding of the role and purpose of the science notebooks, the results generated indicated that most of the teachers did not allow their learners to use the books as intended. These teachers maintained control over the learning process by providing learners with an investigable question, guiding learners through what they should write for the investigation procedure and marking their books. These results suggest that, as Thomas and Pederson (2003) predict, despite training in new teaching methods, many teachers will resort to teaching the way they have been taught because that is where most of their confidence in their teaching abilities lies.

The final interviews suggested that some of the teachers maintained control over the Science Notebooks because their learners appeared to struggle to know what to write. They said that their learners were not used to the freedom to write their own thoughts and ideas, and did not have the confidence in their abilities to do so. This
Chapter 5: Discussion of Results

confirms Webb’s (2009) previous observation that many learners remain dependent on their teachers to provide them with an investigable question, the procedural steps to an investigation, and how to communicate data collected and the conclusions they have drawn.

Many science teachers are not familiar with the use of open-ended inquiry approaches, meaning that learners are seldom exposed to such an approach to learning. Webb (2009) reiterates Chiappetta’s (1997) advice that it is important for teachers to be given support and guidance in how to engage their learners in approaches such as the science notebook approach, so that they do ask questions, describe objects and events, test their ideas with what is known, and communicate what they have learnt. Fulton and Campbell (2003) encourage learners to use science notebooks to freely write, discuss and reflect on their investigation, providing opportunity for them to focus on the extent to which they understand the content. In addition, Hand et al., (2004) suggest that the use of the science notebooks approach may also enable the learners to make meaningful connections with their prior experiences and knowledge.

3.7 Line of learning and further research

The line of learning, which follows the learners’ conclusions to their investigation, aims to promote the learners’ ability to develop a deeper understanding about the topic or concept investigated by highlighting researchable questions which cannot be answered through investigations. Consistent with Powell and Aram’s (2007) recommendations, the teachers’ reflective interviews from this study indicated that by allowing their learners the chance to construct their own ideas and questions they appeared more motivated to pro-actively engage in further research. In addition, the teachers suggested that the process of open-ended inquiry stimulated their learners’ curiosity about natural phenomenon, encouraging them to think critically and creatively about their own experiences and investigations. The knowledge that their teacher was not going to provide all the answers seemed to motivate them to find out the answers to their own questions, specifically when asking why the unexpected occurred.

However, despite acknowledging the value of the line of learning in encouraging their learners to think beyond the classroom, the notebooks and reflective
interviews indicated that most of the teachers did not follow through with the research process as proposed by the ISLS. The ISLS encourages teachers to provide opportunity for their learners to further research their own research questions which they have asked in response to their investigation. The learners should actively engage in the research process by choosing where to look for information, which information is relevant and how to present this information. However, the for the most part, the teachers provided a prescribed research question, and often provided the learners with research they had already located themselves. This approach was largely due to resource and time constraints. The teachers expressed frustration with the limited resources available for their learners, such as books and computers, and resorted to photostatting hand-outs with the relevant information. The result was that instead of groups of learners researching their own questions, the whole class was provided with information regarding one specific question chosen by the teacher.

In addition to limited resources, the teachers felt extremely constrained by time. The teachers expressed that, while beneficial, the strategy was a very time consuming process, which they were not able to implement fully because they were under pressure to keep up with other classes in their grades and to prepare for examinations. This experience suggests that despite the National Curriculum’s aspirations for more learner-orientated approaches (Department of Education, 2002), many teachers are avoiding these approaches due to the pressure to finish the curriculum and to prepare for examinations.

3.8 Argumentation and presentation

Similar to the line of learning, the teachers did not successfully implement the argumentation phase of the strategy. Only one of the teachers introduced this phase, and despite discussing Toumlin’s (1985) model of argumentation during the training workshop, the learners’ presentations were considered incomplete as they were focused on presenting information to the class and did not include their claims, warrants or backings. The other teachers all stated that they did not introduce this phase of the strategy because they had run out of time.
The final interviews also suggested that the teachers’ conceptualisation of argumentation was limited and that they did not feel confident in their abilities to correctly implement the argumentation phase. Biographical information provided by the teachers’ prior to the training workshops suggested that their limited understanding could be due to the teachers’ generalist primary school training (Fensham, 2008, Pearson et al., 2010) and an insufficient science background (Villanueva & Webb, 2008). Therefore, it seemed as though the teachers’ limited knowledge and experience restricted their learners’ exposure to the strategy’s approach towards argumentation and presentation.

3.9 Integration of sustainable development topics

McKeown (2002) maintains that an essential priority of ESD is to re-orient basic and secondary education to address issues of sustainability. The UNESCO (2004) statement advocates that the principles, values and practices of sustainable development should be integrated into all aspects of education and learning (Lotz-Sisitka, 2006). As such, the ninth component of this study’s assessment schedule, focused on the use of the ISLS as a tool to integrate sustainability into the Natural Sciences learning area.

The results generated using the Strategy Implementation Rubric suggest that the strategy could provide an effective tool for integrating issues of sustainability into science lessons, specifically through the use of the stimulus and the line of learning concept. Some of the teachers used topics relating to sustainability as their stimulus to generate curiosity and interest, while others used the line of learning to link the science investigation to issues relating to sustainable development. During their final interviews, the teachers expressed confidence in their abilities to use the strategy for this purpose, and also found that their learners responded well to the relevant application of what they had learnt in the ‘real’ world (Marks & Eilks, 2009). Their reflective interviews also revealed that this integration of sustainable development topics into their science lessons was new to the teachers, and not something that they were currently focusing on in their science lessons.

In addition to increased knowledge, McKeown (2002, 2010) maintains that ESD should provide learners with practical skills that will enable them to continue learning
after they leave school and to live sustainable lives. Table 5.1 summarises previous discussion of the findings by suggesting how the use the ISLS can integrate some of the skills required for inquiry-based investigation with those required for ESD, as described in chapter two.

*Table 5.1 Suggested integration of inquiry-based skills and ESD through the use of the ISLS*

<table>
<thead>
<tr>
<th>Component of the ISLS</th>
<th>Inquiry-based skills promoted by the ISLS</th>
<th>Links to skills required for effective ESD to be achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulus event</td>
<td>Stimulates discussion and interest</td>
<td>Curiosity and creativity</td>
</tr>
<tr>
<td></td>
<td>Links education to everyday experiences</td>
<td>Link to ESD problems faced in their life experiences</td>
</tr>
<tr>
<td>Investigable question</td>
<td>Open-ended questions</td>
<td>Identification of problems</td>
</tr>
<tr>
<td></td>
<td>Discovery and exploration</td>
<td>Critical thinking</td>
</tr>
<tr>
<td></td>
<td>Open-ended discovery and investigation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inquiry Investigation</td>
<td>Constructing new knowledge</td>
<td>Learner participation</td>
</tr>
<tr>
<td></td>
<td>Group work</td>
<td>Democratic decision making</td>
</tr>
<tr>
<td></td>
<td>Science notebooks</td>
<td>Conceptual development</td>
</tr>
<tr>
<td></td>
<td>Literacy skills – reading, writing</td>
<td>Literacy skills</td>
</tr>
<tr>
<td>LOL and further research</td>
<td>Constructing new knowledge</td>
<td>Critical thinking skills</td>
</tr>
<tr>
<td></td>
<td>Discovery and exploration</td>
<td>Research skills</td>
</tr>
<tr>
<td>Argumentation</td>
<td>Evaluate information</td>
<td>Critical thinking skills</td>
</tr>
<tr>
<td></td>
<td>Present and argue conclusions</td>
<td>Communication skills</td>
</tr>
</tbody>
</table>
3.10 Learner-orientated learning

According to South Africa’s National Education Standards (National Research Council, 1996) definition of ‘full enquiry’, the ISLS is an example of an inquiry-based process because it encourages learners to pose a productive question, design an investigation to answer the question, conduct the investigation and collect relevant data, interpret and document their findings, and finally, provides an opportunity for them to present their findings and conclusions (Huber, 2008). In chapter two of this study, the importance of learner-centred learning to scientific inquiry was emphasised in Barrow’s (2010) view of classroom inquiry in Table 2.2. Barrow (2010) expresses his “essential features” (p. 13) of scientific inquiry along a continuum ranging between learner self-direction (inquiry achieved) and direction provided by the teacher (inquiry stifled). A comparison between the ISLS and Barrow (2010), indicates that, the ISLS can be considered to promote maximum amount of learner self-direction, by creating opportunities for the learners to plan and construct their own investigations by posing their own questions, collecting and analysing evidence and preparing and presenting their own arguments to communicate their explanations (Barrow, 2010).

While the teachers’ indicated an appreciation of the strategy’s ability to help them teach in a more discovery and learner-centred way, it has been noted earlier that some of the teachers struggled to relinquish control during certain phases of the strategy. The final interviews revealed that the two predominant reasons for their struggle were that:

a) although the teachers associated learner-oriented teaching methods with active participation (such as doing investigations themselves), they did not recognise the role of learner autonomy in making decisions as proposed by Bansberg (2003) and Carter (2010), and

b) their concern that they would not be able to maintain focus and discipline if they allowed their learners too much freedom to work autonomously in groups (Dillon, 1994).

These views were corroborated by the analysis of the classroom observations and the learners’ science notebooks, which indicated that the teachers were most successful during the ‘doing’ phase of the strategy as they allowed their learners the
opportunity to personally engage in the investigation. However, during the phases requiring important decisions such as designing an investigable question, most of the teachers assumed control over the learning process. Yet, despite their insufficient use of a genuine learner-oriented approach throughout the use of the strategy, the teachers’ still experienced increased enthusiasm and motivation from their learners as predicted by Carter, (2010), Daniels, et al. (2001) and Paris and Combs (2006). The Department of Education’s (2002) National Curriculum Statement was founded on the concept of Outcomes-Based Education, which encourages “a learner-centred and activity-based approach to education” (2002, p.1). However, despite almost a decade since it was implemented into the South African schooling system, the findings from this study revealed that most of the teachers still struggle with effective learner-orientated strategies, and commonly revert back to familiar educator-dominated modes of teaching (Hiebert et al., 2003; Thomas & Pederson, 2003).

The reluctance to use learner-orientated approaches seemed to be especially true for the teachers who had been teaching for an extended period of time (ten years or more), or for the older teachers. A review of the teachers’ biographical information indicated that the teachers who were most pro-active in engaging learner-orientated methods were either those who had only been teaching for a few years (3-5 years) or who were younger than the others (Appendix H). In comparison, the teachers who had been teaching for ten years or more, and who were older, were those who struggled to transition away from an educator-dominated approach to teaching. In their reflective interviews, these teachers indicated that they believed they should be in control of the learning process, as some of their learners are not naturally motivated or capable of learning without supervision and therefore learn best when receiving constant direction and support from their teachers. This reluctance could be due to the way in which they were taught at school, and how they were taught to teach. These teachers were educated and raised during the modern era, where there was a definite right and wrong way to do things and thus may struggle to adopt the more different and flexible teaching approaches associated with more recent, contemporary teaching theories. In comparison, the younger teachers, and those who had been teaching for shorter periods of time, could have been exposed to more contemporary approaches to teaching, and were therefore
not as entrenched in their ways as the older, more experienced teachers. They have also had greater exposure to the postmodern era, and due to their younger ages, could be more willing to embrace change and new ideas, especially considering recent research which indicates that learner-orientated learning leads to optimum learning, because learners are more engaged and focused on problem-solving (Daniels et al., 2001; Paris & Combs, 2006; Wood, 2008).

### 3.11 Summary

A final synopsis of the dominant advantages and disadvantages experienced by the teachers during the implementation of the strategy is provided in Table 5.2.
**Table 5.2** Summary of the most common advantages and disadvantages experienced by the teachers while implementing the ISLS in their classrooms

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of the stimulus to generate interest and discussion</td>
<td>The teachers struggled to let go of their control over the learning process and allow the learners a greater degree of autonomy and participation during the decision making phases of the strategy</td>
</tr>
<tr>
<td>Learners are interested and enthusiastic because they are discovering things for themselves</td>
<td>The strategy is a lengthy process and teachers are under great time pressure to keep up with the other classes and to prepare for exams</td>
</tr>
<tr>
<td>Helpful to engage learners in effective group-work and participation</td>
<td>Teachers’ fear of discipline problems during group work</td>
</tr>
<tr>
<td>Promotes reading and writing</td>
<td>Learners struggled to formulate their own questions</td>
</tr>
<tr>
<td>Learners develop a greater understanding of scientific investigations, and improve skills such as formulating questions and analysing graphical representations</td>
<td>Learners struggled to know what to write in their science notebooks</td>
</tr>
<tr>
<td>Learners develop problem-solving and decision making skills when planning investigations</td>
<td>Limited resources for small group investigations and for further research</td>
</tr>
<tr>
<td>Use of the prediction and investigable questions to encourage learners to think critically</td>
<td>Provides specific opportunities to link scientific concepts to issues relating to sustainable development</td>
</tr>
</tbody>
</table>

4. **LEARNERS’ TESTS**

The learners’ test was designed to assess, a) the learners’ perspectives concerning environmental issues and b) their understandings and abilities relating to scientific investigation. A pre-post test design was used and statistically analysed in an attempt to ascertain if their teachers’ implementation of the strategy had any effect on their perspectives, understandings and/or abilities.

4.1 **Learners’ perspectives of environmental issues**

The majority of the participating learners acknowledged each person’s responsibility towards caring for the environment and the importance of learning about how to protect the environment. The findings from the learners’ tests also suggested that the learners were aware of environmental problems and the role that human actions play...
in causing and aggravating these problems. These findings suggest that the National Curriculum’s inclusion of environmental topics through learning areas such as the Natural Sciences is providing learners with relevant knowledge and exposure to environmental issues (Department of Education, 2002).

These findings seemed in sharp contrast with the teachers’ opinions expressed during their exploratory interviews, where they expressed concern for their learners’ apparent lack of interest and value in the natural environment. Therefore, while it seems as though the learners know the ‘correct answers’ for tests and worksheets, from the teachers perspectives, this knowledge does not affect their values, attitudes and behaviour towards the natural environment. Findings from the exploratory interviews revealed the teachers’ frustration that the knowledge taught is not influencing values or leading to changed behaviour, a concern expressed by Lotz-Sisitka (2006, 2007) who emphasises the need for ESD to impact both values and behaviour.

In response to their frustration with their learners’ apparent apathy towards the natural environment, the teachers expressed a desire to be able to teach in such a way that the knowledge gained might lead to a change in their learners’ behaviour. They expressed a desire to be able to reach the level of values, but concurrently stated that they did not have confidence in their current teaching methods to achieve these aims, and were unsure of what changes to make or approaches to follow in order to try and achieve these aims. For Lotz-Sisitka (2006), unless ESD is based on participatory approaches, requiring critical thinking and personal engagement with knowledge, ESD may become yet another ideology which fails to lead to any genuine change or solution.

**4.2 Learners’ understandings of scientific investigations**

An overall analysis of the teachers degree of successful implementation of the strategy, indicated a divide between those teachers who successfully implemented the strategy, and those who did not (figure 4.12). A statistical comparison between the learners’ tests for each group was done in an attempt to discover if the successful implementation of the strategy had an impact on the learners’ scientific abilities. The learners from teachers D, E, G, C and F were placed in the ‘strong implementers’ group,
while the learners from teachers H, B, A and I were placed in the ‘weak implementers’ group.

The questions in the learners’ tests were grouped into four categories:

- the learners’ understanding of graphical representation of data (Graphs)
- the learners’ understanding of variables (Variables)
- the learners’ understanding of inquiry-based investigation (Investigation)
- the learners’ ability to formulate their own investigable question (Question)

**Pre-test analysis**

An initial comparison between the strong implementer and weak implementer groups of teachers revealed the following differences which were deemed relevant to this study:

The strong implementer group of teachers all taught in schools in the more affluent suburbs of Port Elizabeth, compared to the weak implementer group who taught in schools populated by children from the poorer inner-city and township areas.

The strong implementer’s classes were between 25 and 30 learners, whereas the weak implementer’s classes were larger than 30 children.

The strong implementers had greater access to resources such as libraries, computers and laboratory equipment compared with the weak implementer group.

In particular, the teacher who achieved the greatest success and whose learners responded best to the strategy came from the school in the most affluent suburb of Port Elizabeth, the smallest classes and the greatest access to resources (Appendix H). These learners seemed to be the most confident and capable in terms of working in autonomous groups, developing their own questions and innovative investigations, and recording their work independently in their science notebooks.

Student’s t-test analysis of the pre-tests indicated a small statistically and practically significant difference between the strong implementer and weak implementer groups. This result indicated that at the start of the implementation phase the strong implementer’s group of learners were slightly stronger academically, specifically in
terms of their understandings of graphical representation and scientific investigations. The final reflective interviews suggested that this difference in abilities could be due to the learners from the poorer areas inferior education during their early schooling years (Cronje, 2010; Roodt, 2010). Research has shown that within South African education, many learners from poorer communities struggle with science because their science teachers often have limited scientific knowledge and background, leading to a substandard science education during their earlier schooling years (Villanueva, 2010; Webb & Glover, 2004). This may have affected this group’s ability to understand what scientific investigations are about and their confidence in their ability to work on their own. However, there were also wide ranges of academic abilities within classes as well as between schools, as evidenced by the large standard deviation values in the pre- and post-test data. Because of the mean difference in pre-test scores between schools, Analysis of Covariance techniques (ANCOVA) were applied when analysing the post-test scores.

*Post-test analysis*

As noted above, ANCOVA analysis of the post-test scores was done in order to assess if the implementation of the ISLS had any effect on the learners understandings and/or abilities concerning scientific investigations. The results revealed that while both groups experienced improvements in all categories, the strong implementers’ group achieved a greater degree of improvement compared with the weak implementers’ group. This difference indicated that the strong implementation of the strategy by the teachers had a statistically significant influence on their learners’ abilities to understand scientific investigation, i.e. the learners’ whose teachers implemented the strategy most successfully, achieved a greater degree of improvement in terms of their understandings of graphical representation, variables and the role of inquiry investigation, and also in their abilities to formulate their own investigable question.

Figure 4.13 in the results chapter indicated that both groups experienced the greatest degree of improvement in their understanding of inquiry-based investigation. This result is significant when comparing it with the findings gained from the teachers’ implementation of the strategy, as the teachers achieved their greatest success during the ‘doing an investigation’ phase of the strategy. This comparison suggests that the learners
experienced the most improvement in their understanding of investigations because their teachers allowed them the greatest degree of autonomy when conducting their own investigations, suggesting that learners may achieve optimal learning when they are pro-actively participating in the learning process (Daniels & Perry, 2003; Meece, 2003; Paris & Combs, 2006; Wood, 2008). For Meece (2003) and Wood (2008), this is because learners learn best when given opportunities to make their own decisions and to develop their own solutions.

The ANCOVA results also indicated statistically significant improvements in the learners’ understandings of graphs and variables (Figure 4.13). The teachers’ reflective interviews suggested that the use of the prediction step in planning the investigations helped the teachers to explain the purpose and use of variables to their learners, something with which they had previously struggled and avoided. In addition to an improved understanding of variables, Figure 4.14 revealed that the majority of learners engaged in collecting and recording their own data in their science notebooks. While the science notebooks analysis did indicate that most of the learners struggled to generate accurate and complete information, the post-test analysis revealed an overall improvement in the learners’ understandings of, and ability to apply, graphical representation of information. This suggests that the experience of having to choose and decide how to collect and record their own data helped the learners to gain a better understanding of graphical representations of information. For the most part, these activated took place during the ‘doing phase’ of the strategy when groups of learners had the greatest degree of autonomy, once again suggesting that learner participation and engagement in their learning process is beneficial to their learning experience (Daniels & Perry, 2003; Meece, 2003; Paris & Combs, 2006; Wood, 2008).

For both groups, the area where the least amount of improvement was gained was their ability to formulate their own investigable question. A comparison between this result and the findings from the teachers’ implementation of the strategy suggested that this could be due to the limited opportunity for engagement and participation provided by the teachers as the majority of teachers chose to provide their classes with a pre-determined investigable question. The learners were not provided adequate opportunities to learn how to formulate their own investigable questions, and thus did
not seem to develop this skill to the same degree as the other categories tested. It seems significant that the category of scientific investigation which experienced the least amount of improvement corresponds to one of the phases of the strategy where the teachers allowed the least amount of learner participation. However, the learners did improve in their abilities to formulate their own questions during the course of the intervention, suggesting that the class discussions of various questions, and opportunities provided for the learners to differentiate between investigable and researchable questions, helped them to develop their questioning skills to some degree.

The discussion above suggests that the strategy improved the learners’ understandings of scientific investigation through allowing the learners a greater degree of autonomy and participation in the learning process, and by equipping the teachers to teach certain concepts such as the use and purpose of variables. This finding is consistent with Webb (2009) and Millar’s (1996) observations that engaging in authentic science experiences such as the use of open ended questions leads to greater development of scientific knowledge and skills, and ultimately of scientific literacy, as opposed to more time efficient pseudo-inquiry methods which only require learners to follow a set of instructions provided in a worksheet.

As noted above, for each of these categories the total scores, the strong implementer group achieved greater improvements than the weak implementer group. This finding suggests that the successful use of the strategy, which requires the learners to engage authentic scientific experiences by developing, conducting and concluding their own investigations, can lead to improvements in their understandings and abilities relating to scientific investigations. These skills can contribute to ESD because they help learners to use processes such as “knowing, inquiring, acting, judging, imagining, connecting, valuing, and choosing” (McKeown, 2002, p., 20).

5. LEARNERS’ SCIENCE NOTEBOOKS

The initial findings illustrated that the learners struggled with developing their own questions and knowing what to write in their notebooks, which supports findings of poor levels of literacy in general (Christie et al., 2007). Many of the participating learners were not able to effectively communicate their questions and observations, and
struggled to write correctly in a scientific context. However, it appears as though repeated exposure to the strategy enabled the learners to improve their confidence and abilities to write their own questions and record their own observations and findings.

The purpose of the science notebooks in the strategy is to provide opportunity for learners to freely record their questions, predictions, observations and conclusions in their own manner (Nesbit, 2007). Teachers are urged to use reading and writing as tools to expand their learners’ science thinking and conceptual development within the context of inquiry-based learning experiences (Powell & Aram, 2007).

The data gleaned from the learners’ science notebooks provided insight regarding the learners’ procedural and conceptual understandings, their writing and inquiry abilities, as well as to support and clarify findings gained from the learners’ pre- and post-tests. While the use of the science notebooks did show slight improvements over the course of the implementation period, the findings revealed that many learners copied their teachers’ writings from the blackboard. This observation was most prevalent with regard to the learners’ construction of an investigable question, which corresponds with previous results indicating that the teachers provided their classes with a prescribed investigable question. In terms of their data collection and analysis, the learners generally used short sentences or lists to record their thoughts and observations. The final reflective interviews suggested that this was due to their weak conceptual and procedural scientific knowledge, as well as limited literacy and linguistic abilities.

The learners’ seemed to have the greatest success with describing the process followed for their investigation. While the written investigations were often incomplete, an overwhelming majority of the learners recorded their own investigation design, suggesting that they were working autonomously. This finding corresponds with previous findings indicating that the learners were given the greatest degree of independence during the doing phase of the investigation.

The science notebooks also indicated learner autonomy during the collecting and recording stages of the investigations, including the presence of scientific drawings. Despite some notebooks displaying no evidence of data, the remaining notebooks all indicated that the learners had generated their own information, even if incomplete. It is
important to note that the aim of the scientific notebooks is to encourage the learners to express their own thoughts and ideas without the fear of being marked. It is therefore less important that the information is not complete or accurate, and more significant that the learners are engaging in representing their thoughts and ideas (Nesbit, 2008).

Developing their own, appropriate conclusions from the investigations appeared to be a challenging step for the learners, as the majority of their explanations were incorrect, incomplete or merely copied from the teacher. The most common challenge was that many learners merely repeated the steps of the procedure followed, without critically analysing the relationship between their predictions and results. When compared with the findings from the teachers’ implementation of the strategy, the correlation between the learners’ difficulty with writing conclusions and the teachers’ difficulty with the notion of argumentation promoted by the ISLS seems to be of significant importance. The notebook data suggested that the learners lacked the abilities and confidence to write their own conclusions, and unfortunately, did not participate in the argumentation phase of the strategy due to their teachers’ similar struggle.

However, despite this challenge, the findings revealed that the notebooks provided an opportunity for the learners to practice and engage in writing and drawing their own thoughts and ideas, and that they improved over time. This observation is relevant in light of recent research highlighting the need for science education to include the development of literacy skills, particularly reading and writing (Norris & Philips, 2003; Yore & Treagust, 2006; Webb, 2010). The final reflective interviews with the teachers, also suggested that the use of the notebooks to encourage the learners to independently record their observations and findings, provides an opportunity for the learners to expand their conceptual development as they are not told what to write but have to think and decide for themselves (Powell & Aram, 2007; Ruiz-Primo, et al., 2002). The teachers also seemed to appreciate the science notebook approach, as the learners appeared to be more enthusiastic about using them once they discovered they would not be taken in and marked. This provided an opportunity for their learners to practice their writing and drawing skills, and also to attempt to develop their own conclusions and explanations.
6. CHAPTER SUMMARY

The discussion in this chapter focused on the analysis of qualitative and quantitative data presented in chapter four. A discussion of the exploratory interviews provided a greater understanding of the teachers’ understandings, experiences and challenges relating to sustainable development and ESD. A comprehensive analysis of the implementation of the ISLS provided insight into both the teachers’ implementation of the strategy in their classrooms and their theoretical perspectives concerning their views of the ISLS and their experiences with implementing the strategy. Subsequently, a discussion of the statistical analysis of the learners’ pre and post-tests described the learners’ perspectives of environmental issues, as well as engaging in discourse concerning the improvements in their understandings and abilities relating to scientific investigation as a result of the implementation of the strategy. Finally, the learners’ notebooks were evaluated regarding their approach towards scientific investigations and their participation in the strategy.
CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

1. INTRODUCTION

The shift in science curricula in the 1980’s away from content-based school curricula towards the application of scientific knowledge saw the expansion of science education to encompass socio-scientific decision making abilities (Fensham, 2008; Marks & Eilks, 2009). Notions of scientific literacy include the application of scientific knowledge to dynamic relationships between the nature of science, technology, society and the environment (Millar, 2008), and developing children’s scientific literacy in both the fundamental and derived senses were identified by Yore and Treagust (2006) as imperatives of science curricula internationally. The derived sense of science is of value to concepts such as ESD, which aims at promoting scientifically literate societies that are able to make informed decisions concerning the natural environment and the promotion of sustainable livelihoods (Læssøe, et al., 2009; McKeown, 2002; Rosenberg, 2007).

ESD has gained increasing recognition and influence as the reality of environmental degradation, climate change and increasing poverty become more evident and transparent (Breiting, 2009; Heimlich & Storksdieck, 2007). In response, the ‘United Nations Decade of Education for Sustainable Development’ advocated that the principles, values and practices of sustainable development should be integrated into all aspects of education and learning (Lotz-Sistika, 2006; Rosenberg, 2007). This integration requires an effective framework for teaching ESD to be developed to equip and enable teachers to help learners identify and think about the complexities relating to sustainable development and the need to acquire the necessary skills to analyse the issues and problems relating to ESD (McKeown, 2002).

However, despite these aspirations, there are still many teachers with insufficient teacher knowledge and there is still a lack of in-service training to upgrade their
knowledge, skills and attitudes (Lassoe et al., 2009; McKeown, 2010). Le Grange (2010) and Winter (2009) also identify the lack of capable and knowledgeable teachers, and the challenges of training teachers to effectively teach the concepts, skills and knowledge associated with ESD, as some of the greatest challenges facing sustainable development within South African education. In response to these problems and challenges, this study investigated the potential of the Integrated Scientific Literacy Strategy (ISLS) to contribute to ESD by developing more scientifically literate learners in primary education.

2. CONTRIBUTIONS OF THE ISLS TOWARDS SCIENTIFIC LITERACY

The literature review for this study identified the following approaches as beneficial to developing scientific literacy in learners: authentic science experiences, developing literacy skills, promoting curiosity, and learner-orientated teaching techniques. This study revealed that by using the ISLS to promote a greater degree of open-ended investigation, the teachers were able to promote more authentic scientific experiences for their learners, affording them an opportunity to experience how science produces new knowledge through their own process of discovery. The learners’ participation, combined with the use of the scientific notebooks, provided opportunities for the learners to engage in reading and writing, as well as generating genuine curiosity, which increased their motivation to read further. The findings also suggested that by nurturing a sense of curiosity, the teachers were able to better employ learner-participation in their lessons.

The observations discussed above are important in light of Norris and Philips’s (2003) view that scientific literacy encompasses both a fundamental and derived sense of science. Yore, et al. (2007) argues that these two aspects of science are not meant to be viewed as separate and distinct, but as Norris and Philips (2003) maintain, that by strengthening learners’ fundamental sense of science, such as their ability to read, write and communicate; the overarching goals of understanding the derived sense of science will be achieved. This study indicated the potential for ISLS to foster the fundamental sense of science by promoting skills such as critical thinking, plausible reasoning and the opportunity to develop learners’ abilities to read, write, talk and ‘do’ science.
Chapter 6: Conclusions and Recommendations

Through the use of the learner-orientated inquiry investigation, the potential contribution for the ISLS to cultivate learners’ derived senses of science was also suggested, with concomitant implications for successful teaching of ESD.

3. POTENTIAL CONTRIBUTIONS OF THE ISLS TOWARDS ESD

Scientific literacy aims to provide learners with the ability to make responsible decisions based on knowledge and the ability to interpret, understand and apply relevant scientific concepts and ideas (Holbrook & Rannikmae, 2009). Recent research suggests that this can be achieved through a school science curriculum that aims to provide learners’ with an ability to apply their knowledge and engage in critical and creative thinking (Pearson, et al., 2010; Shaheen, 2010), effective communication and literacy skills (Marks & Eilks, 2009; Norris & Philips, 2003) and the ability to work cooperatively and employ democratic decision making skills (Barrow, 2010; Daniels et al., 2001). This study has shown how the use of a learner-centred, inquiry-based teaching approach can lead to the development of these skills, which have been identified by Lotz-Sisitka (2006) and McKeown (2010) as essential for ESD.

Webb (2008b) suggests that the development of communication skills through practice in discussion and argumentation are essential for learners to develop their abilities to apply scientific knowledge and ways of thinking to social contexts. The findings of this study suggest that the ISLS can be used to foster learners’ communication skills due to its continued focus on the processes of reading, writing and talking (Webb, 2008c, Webb, 2009). Through the process of inquiry-based investigations, the ISLS provided opportunities for the learners to engage in discussion when choosing and planning their questions and investigations, when writing in their science notebooks and planning their presentations, and when reading further during the research phase of the strategy.

This study also discovered how inquiry based investigation, such as those promoted by the ISLS, can enable learners to identify problems (an unanswered question) and to plan and conduct an investigation to solve the problem (find an answer). This is consistent with Meece’s (2003) observation that inquiry-based methods
can foster creative and innovative problem solving abilities. Additionally, Gott and Duggan (1995), and later, Roberts and Gott (2006), suggest that practical problem solving in science promotes both conceptual understanding and procedural understanding. The tasks of planning and conducting their own investigations provided opportunity for the learners to develop critical and creative thinking because they were required to make their own decisions and choices. For Higgs’s (2002) and Lotz-Sisitka (2006), these skills are of great importance for effective ESD.

The process of allowing groups of learners to work independently on their own investigations also seemed to compel the learners to engage in democratic discussion and decision making processes. For Wals (2007), dealing with issues of sustainability in the ‘real world’ requires an ability to actively participate and engage with groups of people. The ability to work in a group and engage in democratic decision making skills is, therefore, highly important (Lotz-Sisitka, 2006; Wals, 2007), and requires that ESD teaching approaches be participatory and incorporate democratic decision making processes (Bourn, 2005; Landorf et al., 2008; Bonnet, 2006).

In contrast to recent emphasis on co-operative work in school classrooms (Coetzee, et al., 2008; Nieman & Monyai, 2006), the exploratory interviews indicated that the teachers still struggle to effectively implement participatory group work, and are in need of strategies and tools to enable them to accomplish this (Pearson, et al., 2010). This study suggests that the ISLS can be used to equip and enable teachers to engage in more participatory teaching and learning approaches, providing opportunity for their learners to develop problem solving, critical thinking and communication skills.

In addition to the practical skills discussed above, the findings of this study suggest that the ISLS can be used to help teachers to integrate applications of science knowledge to sustainable development into their lessons. Unlike previous approaches to environmental education, which created a sub-section within curricula for environmental issues (Reid, 2002; Winter, 2009). Rosenberg (2007) and McKeown (2002, 2010) emphasise the need for education to be re-orientated towards ESD, which requires “teaching and learning knowledge, skills, perspectives and values that will guide and
motivate people to pursue sustainable livelihoods, to participate in a democratic society, and to live in a sustainable manner” (McKeown, 2002, p. 14).

This data generated in this study suggests that the ISLS can be used as a tool to help teachers integrate topics and issues relating to sustainable development into their lessons, specifically through the ISLS’s use of a stimulus and the line of learning phases. The opportunity for the teachers to link topics relating to sustainable development to the learners real life experiences (Wals, 2007) generated a genuine interest from the learners and helped them develop better understandings of the lesson’s topic. This integration of issues relating to sustainable development is especially relevant to the Natural Sciences Learning Area in South African education, as one of the desired outcomes is the ability to apply knowledge and understanding to issues concerning the relationships between science, society and the natural environment (Department of Education, 2002; Winter, 2009).

4. CHALLENGES FACED

The exploratory interviews revealed that the teachers had an incomplete understanding of the concept of ESD, specifically regarding the role of the human component and the interrelationships between the economy, society and the natural environment (Chatzifotiou, 2006, Corney, 2006). Therefore, while the ISLS can contribute as a teaching tool for ESD, it does not address the challenge of overcoming teachers’ insufficient theoretical knowledge regarding ESD.

A second challenge highlighted in this study was the time constraints experienced by the teachers. This experience is consistent with Fensham’s (2008) observations that “with such minimal time and so much content to cover it is not surprising that transmissive coverage of the content takes precedence over the active investigations that curricula also say is intended” (2008, p. 13). In addition, the teachers’ and learners’ limited access to resources restricted their abilities to use inquiry-based teaching methods. Despite the National Curriculum Statement’s focus on participatory teaching methods and learning methods (Department of Education, 2002), it seems as though the pressure to prepare for examinations and limited access to resources continue to hinder
learner-orientated approaches, and begs the question of how these challenges can be overcome (Department of Education, 2009, 2010).

5. **SUGGESTIONS FOR FURTHER RESEARCH**

The study contributes to understanding how teachers can use an inquiry-based teaching approach to improve scientific literacy, and therefore contribute towards ESD. However, while contributions are suggested, further explorations into the practical and theoretical uses of inquiry instruction are required to determine a greater extent of its potential contribution to ESD. In particular, the teachers’ understandings of and approaches towards scientific argumentation implored further examination. Firstly, why is it that the teachers struggled to understand the strategy’s approach to argumentation, and secondly, how could the training be improved to help the teachers understand and teach argumentation as required by the strategy?

In addition, while improvements in learners’ scientific literacy skills were measured, the more abstract concepts of critical and creative thinking, innovative problem solving and democratic decision making were suggested but not gauged. While this research has indicated the potential of the ISLS to be used as a tool to promote these skills, further empirical research is suggested to determine the measurable degrees of influence and impact on learners’ skills and abilities.

Finally, the teachers expressed the desire to teach in a way that would reach the level of values and changed behaviour. Considering the call for ESD to foster a new way of thinking that challenges an unsustainable world (Læssøe, et al., 2009), the importance of ESD to lead to changed values, attitudes and behaviour cannot be underestimated. While this study indicated the potential for the ISLS to promote participatory learning and to develop many of the skills required by ESD, the potential for the ISLS to impact learners’ values and attitudes was not determined. Therefore, further research into the use of inquiry-based investigation as a learning tool that can impact the level of values and attitudes is suggested.
6. CONCLUSION: REVISITING THE RESEARCH QUESTIONS

The process of integrating ESD into existing education systems includes the challenge of developing scientifically literate learners’ who are able to apply scientific principles and knowledge to their own lives. However, many teachers have insufficient knowledge and skills base to achieve this challenge. In response, this study investigated if the Integrated Scientific Literacy Strategy (ISLS) could make a contribution towards teaching ESD in South African primary education by developing more scientifically literate learners. In light of this study’s findings, the original research questions are now re-visited and discussed.

Can teachers be trained to properly implement the ISLS in grade 6 and 7 Natural Science classrooms?

This study indicated that just over half of the teachers were able to successfully implement the ISLS within their Natural Science lessons. The strategy’s focus on learner-orientated learning seemed to be very different to the teachers’ usual approach to teaching, and thus some teachers struggled to relinquish control of the learning process. As opposed to the holistic, pre-implementation training workshops which this study used, a continuous, step-by-step training program is suggested where each step of the strategy is taught and modelled, before allowing the teachers to implement each phase. Teachers would then be able to report back and clarify questions and concerns, before moving onto the next step in the strategy. This form of training may lead to a higher success rate.

If implemented properly, can the ISLS be used to develop grade 6 and 7 learners with skills and understandings needed for scientific investigations (graphs, variables, process of investigation, formulating questions)?

The data suggested that, when properly implemented, the Integrated Scientific Literacy Strategy can be used to help teachers develop their learners’ scientific literacy by exposing them to open-ended inquiry investigations. Statistically significant differences were noted when comparing improvements in learners’ abilities and understandings of scientific investigations (graphs, variables, inquiry and investigable
questions) between those learners whose teachers who were judged to have successfully implemented the strategy in their classrooms, and those learners whose teachers were considered to be weak implementers of the strategy.

*Can the teachers use the ISLS to integrate topics relating to sustainable development into their Natural Science lessons?*

The participating teachers expressed appreciation for the use of the strategy as a tool for integrating their science lessons with topics and issues relating to sustainable development. Most of the teachers had not thought of doing this before, and discovered that by using the stimulus and the line of learning, they were able to effectively link scientific concepts learnt in class with environmental issues experienced in the ‘real world’.

*Can the successful implementation of the strategy provide opportunity for learners to engage in communication, critical thinking, democratic decision making and problem solving opportunities (skills required for ESD)?*

Finally, the findings suggested that the learner-orientated approach of the ISLS enabled the learners to engage in autonomous learning environments, providing them with opportunities to develop their communication, critical thinking, democratic decision making and problem solving skills. Recent literature regarding ESD has highlighted the necessity for these skills to be developed in learners, and thus this study proposes the ISLS as an effective teaching tool (amongst others) which can be used to instruct, inspire and motivate teachers to change out-dated teaching practices. South Africa is by no means immune to the need of radical restructuring in order to reach a higher level of sustainability, and true change needs to begin in the minds of our young learners - tomorrow’s leaders and decision makers.
REFERENCES


References


References


References


References


References


References


References


References


APPENDIX A

Exploratory Interview Questions

A) General awareness concerning Sustainable Development and ESD

1. What does the term ‘sustainable development’ mean to you?

2. Which concepts or topics can you think of, for which sustainable development is important?

3. How did you find information about the topic of sustainable development? Do you update your existing knowledge? If yes, how so?

4. Are you familiar with the phrase, Education for Sustainable Development? If yes, what do you understand by this concept?

5. Why do you think ESD has recently been considered to be so important?

6. Do you think it is important for students to deal with the contents of ESD? Why or why not?

7. Are you trying to include / incorporate ESD in your class? If yes, how are you trying to achieve this?

8. Which methods do you use when teaching ESD contents? Why?

B) Perspectives concerning their learners’ responses to ESD related topics

1. What knowledge and skills do the learners need to be able to participate in an ESD letter?
2. How would you describe their background knowledge to topics relating to ESD?

3. How would you describe their previous experience with ESD?

4. How would you describe their approach to ESD?

**C) Challenges and Obstacles faced when teaching ESD**

1. Do you have material about ESD? If so, have you developed them on your own or did someone provide them to you?

2. Would you like to get more information and material about ESD or do you feel well prepared?

3. In what area would you like to have more support and help?

4. In which areas do you think that you are already doing enough regarding ESD? Which areas can be improved?

5. How significant is ESD for you next to other fields of education in school?

6. What are the main aims of ESD, in your opinion?

7. Do you think that you reached these aims in the past satisfactorily?
# APPENDIX B

## Science Questions: The Environment

Date: ______________________  Grade: ________________

School: _______________________________________________________

Time started: _______________  Time finished: _______________

### 1. Your views on the environment

For the following statements, say whether you strongly agree, agree, disagree or strongly disagree. If it asks you for an example and you can think of one, please write it down in the space provided.

<table>
<thead>
<tr>
<th>A: My views on the Natural Environment</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Human actions are causing serious damage to the environment. For example:</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

| b. If things stay the way they are now, we will soon have serious problems in the environment. |   |       |          |                  |
|                                                                                       |   |       |          |                  |

| c. The earth has many natural resources but we must learn how to use them correctly, otherwise we will run out. |   |       |          |                  |
|                                                                                       |   |       |          |                  |

| d. There are too many people on the earth. The natural environment can’t provide for all the people. |   |       |          |                  |
|                                                                                       |   |       |          |                  |

| e. Everyone is responsible to do their best to look after the environment |   |       |          |                  |
|                                                                          |   |       |          |                  |

<table>
<thead>
<tr>
<th>B: Me and the Natural Environment</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
a. When the environment is harmed, it can affect me and my family. For example:
________________________
________________________
________________________

b. I am aware that my actions can affect the natural environment negatively (in a bad way). For example:
________________________
________________________
________________________

c. I should protect the environment by making small changes in my own life. For example:
________________________
________________________
________________________

d. I can join an environmental group at school that does projects aimed at protecting the environment. For example:
________________________
________________________
________________________

2. The Greenhouse Effect: fact or fiction?

Living things need energy to survive. The energy that sustains life on earth comes from the sun.

The earth’s atmosphere acts like a blanket over the surface of the earth, preventing too much of the sun’s energy (heat) from escaping back into space. Because of this effect, the earth stays warm.
The Greenhouse Effect is very important because it keeps the earth warm. However, over the last 100 years or so, the Greenhouse Effect is increasing and the earth is getting hotter. Carbon dioxide is often blamed as one of the main reasons why the Greenhouse Effect is increasing and the earth is getting hotter.

Andre is very interested in the Greenhouse Effect and finds the 2 graphs below while looking for more information:

Andre concludes from these 2 graphs that it is certain that the increase in the earth’s temperature is due to increased levels of carbon dioxide.

2.1 What is it about the graphs that supports Andre’s conclusion?

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2.2 Another student, Jamie, disagrees with Andre’s conclusion. Andre is convinced that his conclusion is right but Jamie thinks that he doesn’t have enough information yet to make a definite conclusion. She says, “Before you make this conclusion you must be sure that other factors that could influence the Greenhouse Effect are constant”. Why does she say this?

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2.3 How much do you agree with the following statements? Tick the relevant box.

<table>
<thead>
<tr>
<th>Statement:</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. It is very bad that the earth is getting warmer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. It is due to man’s actions that the earth is getting warmer</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>c. It is important that we learn about the Greenhouse Effect so that we can prevent the earth from getting warmer</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. We should change our actions which are causing the earth to get warmer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Wind Farms

Many people believe that wind should replace oil and coal as a source of energy for producing electricity because it is ‘clean’ and does not produce pollution. The wind causes the windmills rotators to spin round which cases electricity to be produced.

The graphs below show the average wind speeds in 4 different places throughout a year.
3.1 Which one of the graphs shows the best place to build a wind farm? Why?

3.2 How much do you agree with the following statements? Tick the relevant box.

<table>
<thead>
<tr>
<th>Statement:</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Pollution is bad for the environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. It is important for us to learn about how to reduce the amount of pollution we produce</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. It is important that we learn about new forms of energy which are ‘clean’ and don’t produce pollution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. It is okay if we pollute the air because people need things like cars and factories</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. New strain of corn

Scientists have developed a special strain of corn that is unaffected by a new and powerful poison which kills the weeds which often grow in cornfields. The poison is sprayed over the fields with this new corn to kill all the weeds which grow amongst the corn.

Some wildlife groups are saying that this corn should be banned because the weeds are actually important for the small insects who live in the areas. These insects feed on these weeds and will die if all their food is poisoned. They say that this new type of corn is bad for the environment
Because of this argument between scientists and wildlife groups, a scientific study was done:

- Corn was planted in 200 fields across the country
- Each field was divided into 2. The new type of corn was grown on the one half and the new and powerful poison was used on this corn. On the other half of the field, a normal type of corn was grown without the use of a normal poison.
- After a period of time, the scientists went and counted all the insects on each side of all the fields

4.1 Which of the variables below was deliberately varied in the study above. Circle ‘yes’ or ‘no’ for each one:

<table>
<thead>
<tr>
<th>Variable:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. The number of insects in each half of the 200 fields</td>
<td>Yes / No</td>
</tr>
<tr>
<td>b. The types of poison used on the crops</td>
<td>Yes / No</td>
</tr>
</tbody>
</table>

4.2 The corn was planted in 200 fields across the country. Why did the scientists choose so many places?

A. So that many farmers could try the new corn
B. To see how much of the new corn they could grow
C. To cover as much land as possible with the new corn
D. To include many different types of growth conditions for the corn
4.3 How much do you agree with the following statements? Tick the relevant box.

<table>
<thead>
<tr>
<th>Statement:</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. A solution should be found where the insects are not harmed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. It is okay if the insects die because people need the corn for food</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Intelligent Clothing

Read the extract below and answer the questions which follow:

**New intelligent clothes!**

A team of British scientists are developing “intelligent clothes” that will provide new solutions to keeping warm in winter. Just like an electric blanket, the material will be able to heat up to keep you warm.... Without being damaged, the material can be washed, wrapped around objects or scrunched up. The scientist also claims it can be mass-produced cheaply.
5.1 Which of the claims made in the extract above can be tested by scientific investigation in a laboratory? Circle either ‘Yes’ or ‘No’ for each question:

<table>
<thead>
<tr>
<th>The material can be...</th>
<th>Can the claim be tested through scientific investigation in the laboratory?</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Washed without being damaged</td>
<td>Yes / No</td>
</tr>
<tr>
<td>b. Scrunched up without being damaged</td>
<td>Yes / No</td>
</tr>
<tr>
<td>c. Wrapped around objects without being damaged</td>
<td>Yes / No</td>
</tr>
<tr>
<td>d. Mass-produced cheaply</td>
<td>Yes / No</td>
</tr>
</tbody>
</table>

6. Male Stickleback Behaviour

The Stickleback is a fish that is easy to keep in a fish tank. Bradley has read the following information about Stickleback Fish:

During the breeding season, the male’s belly changes colour from silver to red.

During the breeding season, the males will attack any other male that comes into its territory and try to chase it away. This is called aggressive behaviour.

If a silver-coloured female approaches, he will try to guide her to his nest so that she will lay her eggs there.

Bradley wants to test this information in an experiment. This is what he does:

He places a male fish on its own in a fish tank. Then he makes three fish models which he attaches to pieces of wire. He hangs each one of the separately into the fish tank for the same amount of time. He watches the male behaviour and counts the number of times the male shows aggressive behaviour by trying to attack the models.
The results of his experiment are shown below:

6.1 What is the question that this experiment is attempting to answer?
## APPENDIX C

### Learner’s Test Rubric

**Teacher’s name: ....................................................................  Grade Level: .............................................**

<table>
<thead>
<tr>
<th>Question 1A: Views on the natural environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marks:</td>
</tr>
<tr>
<td>Indicates:</td>
</tr>
<tr>
<td>Learner is fully aware and concerned about environmental problems and can provide examples</td>
</tr>
<tr>
<td>a</td>
</tr>
<tr>
<td>b</td>
</tr>
<tr>
<td>c</td>
</tr>
<tr>
<td>d</td>
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<tr>
<td>e</td>
</tr>
<tr>
<td>Comments</td>
</tr>
<tr>
<td>Marks:</td>
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<tr>
<td>--------</td>
</tr>
<tr>
<td>Indicates:</td>
</tr>
<tr>
<td>a</td>
</tr>
<tr>
<td>b</td>
</tr>
<tr>
<td>c</td>
</tr>
<tr>
<td>d</td>
</tr>
<tr>
<td>Comments</td>
</tr>
</tbody>
</table>
**Question 2: Understanding Scientific representations (graphs)**

<table>
<thead>
<tr>
<th>Marks:</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicates:</td>
<td>Poor – unable to read and understand graphs</td>
<td>Average ability to read and understand graphs</td>
<td>Excellent ability showing further insight</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q 2.1</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Q2.2</th>
</tr>
</thead>
</table>

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**Question 2.3 Greenhouse effect – views on environmental crisis**

<table>
<thead>
<tr>
<th>Marks:</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
</table>
| Indicates: | **Strongly agree**  
Learner is fully aware and concerned about environmental problems | **Agree**  
Learner is aware and concerned about environmental problems | **Disagree**  
Learner has limited understanding | **Strongly disagree**  
Learner has no understanding or concern |

<table>
<thead>
<tr>
<th>a</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>b</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>c</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>d</th>
</tr>
</thead>
</table>
### Question 3: Wind Farms - Understanding Scientific representations (graphs)

<table>
<thead>
<tr>
<th>Marks:</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicates:</td>
<td>Poor – unable to read and understand graphs</td>
<td>Average ability to read and understand graphs</td>
<td>Excellent ability showing further insight</td>
</tr>
</tbody>
</table>

#### Q 3.1

### Question 3.2: Wind Farms – views on environmental crisis

<table>
<thead>
<tr>
<th>Marks:</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicates:</td>
<td><strong>Strongly agree</strong> Learner is fully aware and concerned about environmental problems</td>
<td><strong>Agree</strong> Learner is aware and concerned about environmental problems</td>
<td><strong>Disagree</strong> Learner has limited understanding</td>
<td><strong>Strongly disagree</strong> Learner has no understanding or concern</td>
</tr>
</tbody>
</table>

a  
b  
c  
d
### Question 4: Strain of corn - Understanding scientific investigation (use of variables)

<table>
<thead>
<tr>
<th>Marks:</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicates:</td>
<td>No understanding</td>
<td>Good understanding</td>
</tr>
<tr>
<td>Q 4.1a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q 4.1b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q 4.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Question 4.3: Strain of corn – views on environmental crisis

<table>
<thead>
<tr>
<th>Marks:</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicates:</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly disagree</td>
</tr>
<tr>
<td>Learner is fully aware and concerned about environmental problems</td>
<td>Learner is aware and concerned about environmental problems</td>
<td>Learner has limited understanding</td>
<td>Learner has no understanding or concern</td>
<td></td>
</tr>
<tr>
<td>a</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Question 5: Intelligent clothes - Understanding scientific investigation (investigable questions)

<table>
<thead>
<tr>
<th>Marks:</th>
<th>1. No understanding</th>
<th>2. Good understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c</td>
<td></td>
<td></td>
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<tr>
<td>d</td>
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<td></td>
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</tbody>
</table>

### Question 6: Male Stickleback - Understanding scientific investigation (Ability to formulate an investigable question)

<table>
<thead>
<tr>
<th>Marks:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicates:</td>
<td>Unable</td>
<td>Average ability</td>
<td>Adequate ability</td>
<td>Good ability</td>
</tr>
<tr>
<td>Q 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## APPENDIX D

### Strategy Implementation Rubric

(Classroom Observations and Learners’ Science Notebooks)

Date: .................. School: .................................................................

Teacher’s name: ............................................. Grade Level: ............

No of learners:........................ Small Groups / large class? ....................

<table>
<thead>
<tr>
<th>Component 1: Use of Stimulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>Teacher has no introduction or stimulus.</td>
</tr>
</tbody>
</table>

Comments / Description:
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### Component 2: Exploratory talk and class discussion

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No discussions in class. Teacher lectures while the learners listen.</td>
<td>Learners provide rote, one word or shortened answers and do not engage in discussion.</td>
<td>A few learners participate in class discussion but do not critically challenge each other’s ideas.</td>
<td>Teacher facilitates and encourages exploratory talk amongst the learners.</td>
</tr>
</tbody>
</table>

**Comments / Description:**

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### Component 3: Investigable Question

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<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
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<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>There is no question for learners to investigate.</td>
<td>Teacher provides a question for learners to investigate without any discussion or input from the learners.</td>
<td>Teacher provides a question for the class, but does allow some discussion about investigable questions.</td>
<td>Teacher guides learners to choose an investigable question. Learners experience the process of identifying and choosing an investigable question.</td>
</tr>
</tbody>
</table>

**Comments / Description:**

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## Component 4: Planning an investigation

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<tr>
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<th>2</th>
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<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>There is no opportunity for investigation.</td>
<td>Teacher provides step-by-step instructions to answer the investigable question, allowing some participation from small groups.</td>
<td>Teacher guides class / groups of learners through planning their investigations.</td>
<td>Groups of learners freely discuss problems and questions and provide ways to investigate the question themselves.</td>
</tr>
</tbody>
</table>

**Comments / Description:**

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## Component 5: Doing an investigation

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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>There is no investigation.</td>
<td>Teacher demonstrates investigation to the class.</td>
<td>Teacher demonstrates the investigation to the class using selected participants.</td>
<td>Groups of learners independently complete their investigation.</td>
</tr>
</tbody>
</table>

**Comments / Description:**

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### Component 6: Learner Writing with Science Notebooks

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<th>2</th>
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<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Learners do not write at all.</td>
<td>Teacher dictates to the learners or learners copy the teacher’s notes off the blackboard.</td>
<td>Teacher guides learners through what they should write.</td>
<td>Learners are given the freedom to write their own conclusions and thoughts in their books – active engagement with the writing process.</td>
</tr>
</tbody>
</table>

Comments / Description:

> ..........................................................................................................................
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### Component 7: LOL and further research

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<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No discussion of the LOL or evidence of further research.</td>
<td>Teacher provides learners with research hand-outs.</td>
<td>Teacher guides discussion on researchable questions and dictates research process.</td>
<td>Learners are given the freedom to pose researchable questions and to research their answers independently.</td>
</tr>
</tbody>
</table>

Comments / Description:

> ..........................................................................................................................
> ..........................................................................................................................
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> ..........................................................................................................................
### Component 8: Argumentation and Presentation

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>There is no process of argumentation or opportunity for learners to present their findings.</td>
<td>The teacher provides an argument for the class and does not allow the class to participate or engage.</td>
<td>Learners provide incomplete / insufficient arguments and presentations.</td>
<td>Learners provide accurate and complete arguments and presentations.</td>
</tr>
</tbody>
</table>

Comments / Description:

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### Component 9: Incorporation of Sustainable Development topics

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<tr>
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<th>4</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>No link to Sustainable Development topics.</td>
<td>Brief mention of the link to sustainable development, separate to the strategy.</td>
<td>Teacher provides the link to sustainable development using the strategy.</td>
<td>Teacher effectively uses the strategy to link the lesson to a sustainable development topic – initiates discussion and encourages learners to investigate further.</td>
</tr>
</tbody>
</table>

Comments / Description:

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## Component 10: Degree of Teacher control and pupil participation (learner-orientated learning)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Entire learning process dominated by the teacher. No participation from the learners.</td>
<td>Teacher-dominated learning process with limited opportunity for learner participation in decision making processes – teacher makes decision and the learners participate.</td>
<td>Teacher guides groups through the learning process, allowing each group some opportunity to participate in the decision making processes.</td>
<td>Teacher guides small groups of learners to independently engage with the learning process, as they make decisions among themselves.</td>
</tr>
</tbody>
</table>

**Comments / Description:**

<p>| | | | | |</p>
<table>
<thead>
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<tbody>
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</tbody>
</table>

**Additional Comments:**

<p>| | | | | |</p>
<table>
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</tbody>
</table>

APPENDIX E

Theoretical Understanding of the Strategy

(Teacher Portfolios and final Reflective Interviews)

Date: .................... School: ..........................................................................................

Teacher’s name: .................................. Grade Level: ............... 

No of learners:......................... Small Groups / large class? .........................

<table>
<thead>
<tr>
<th>Assessment Component</th>
<th>ISLS Description</th>
<th>Notes / Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Use of Stimulus</strong></td>
<td>Does the teacher use a relevant stimulus to engage with the learners and create interest and enthusiasm?</td>
<td></td>
</tr>
<tr>
<td><strong>Exploratory talk and class discussion</strong></td>
<td>Does the educator facilitate exploratory talk amongst the learners themselves, or do they try to control class discussion, or even take over completely?</td>
<td></td>
</tr>
<tr>
<td><strong>Investigable Question</strong></td>
<td>Does the teacher guide the learners in developing their own question or do they provide the class with a question they have developed?</td>
<td></td>
</tr>
<tr>
<td>Appendix</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>Planning an investigation</td>
<td>Does the teacher facilitate groups of learners in planning their own investigation, or do they lead the class in an experiment they have found or designed?</td>
<td></td>
</tr>
<tr>
<td>Doing an investigation</td>
<td>Does the teacher facilitate groups of learners in doing their own investigation, or do they show the class an experiment?</td>
<td></td>
</tr>
<tr>
<td>Learner Writing with Science Notebooks</td>
<td>Are the learners encouraged to write their own thoughts and ideas in their books, or do they merely copy what the teacher has written on the board?</td>
<td></td>
</tr>
<tr>
<td>LOL and further research</td>
<td>Are the learners encouraged to engage in further research by themselves, or does the teacher provide information they have found?</td>
<td></td>
</tr>
<tr>
<td>Argumentation and Presentation</td>
<td>How well do the learners demonstrate their understanding of the concepts and procedures taught in class? Are they able to effectively use argumentation to defend their claims and warrants?</td>
<td></td>
</tr>
<tr>
<td>Incorporation of Sustainable Development topics</td>
<td>Is the teacher able to effectively link the topic to relevant examples relating to sustainable development using the ISLS?</td>
<td></td>
</tr>
</tbody>
</table>
Appendices

| Degree of teacher control and pupil participation | Does the teacher control the process, or do they allow the learners to participate as fully as possible in making their own decisions? |

Additional Comments:

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APPENDIX F

Science Notebook Checklist

Date: ........................................ School: ...............................................................

Teacher’s name: ........................................ Grade Level: ................................

Component 1: How well does the learner construct an investigable question? (Constructing an investigable question)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>There is no evidence of a question</td>
<td>Learner copies teacher’s question</td>
<td>Learner writes a question using his/her own words but question is not investigable</td>
<td>Learner writes an investigable question using his/her own words but the question is missing important details</td>
<td>Learner writes an investigable question using his/her own words and the question has all the relevant details</td>
</tr>
</tbody>
</table>

Comments / Description:
### Component 2: How well does the learner design and implement a plan to answer the question? (Designing the investigation)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is no evidence of what was done</td>
<td></td>
<td>Learner copies teacher’s sequential procedure</td>
<td>Learner writes a plan using his/her own words but plan is incorrect for answering the question</td>
<td>Learner writes a plan correctly using his/her own words, but plan is missing details and the investigation cannot be replicated.</td>
<td>Learner writes a plan correctly using his/her own words. It contains all the relevant details and the investigation can be replicated.</td>
</tr>
</tbody>
</table>

Comments / Description:

### Component 3: How well did the learner complete record their data? (Collecting data)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
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<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is no evidence of data collection</td>
<td>Learner copies teacher’s data</td>
<td>Learner records his/her data but data are not accurate</td>
<td>Learner records his/her own data. Data are accurate but incomplete.</td>
<td>Learner records his / her won data. Data are complete and accurate.</td>
<td></td>
</tr>
</tbody>
</table>

Comments / Description:. 
Component 4: How well does the learner draw their observations? (Scientific Drawings)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>There are no drawings</td>
<td>Learner copies teacher’s drawings</td>
<td>Learner produces original drawings but they are not labelled correctly and have no relevant detail.</td>
<td>Learner produces his/her own drawings which are labelled and have limited relevant details.</td>
<td>Learner produces his/her own drawings which are correctly labelled and have relevant detail.</td>
<td></td>
</tr>
</tbody>
</table>

Comments / Description:

Component 5: How well does the learner construct scientific meaning from investigation? (Drawing Conclusions)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is no evidence of understanding the science concept being investigated</td>
<td>Learner copies the teacher’s words for explanation</td>
<td>Learner explains the concepts in his/ her own words. The explanation is not correct.</td>
<td>Learner writes a correct and complete explanation using his / her own words but the explanation is missing details.</td>
<td>Learner writes a correct and complete explanation using his / her own words and the explanation includes relevant detail.</td>
<td></td>
</tr>
</tbody>
</table>

Comments / Description:
APPENDIX G

Reflective Interview Questions

1. How often were you able to complete the strategy with your science class?

2. Describe how you used the strategy to help you teach various topics / lessons.

3. Was the strategy different to how you normally teach? If so, how or in what way?

4. Did you feel confident about your ability to teach and apply the strategy in your science lessons?

5. Do you think the strategy made an impact in terms of:
   a. Your learners’ interest in the learning process / science lessons? Why or why not?
   b. Your learners’ ability to design and carry out an investigation? Why or why not?
   c. Your learners’ understanding of what an investigation entails such as variables and control factors, developing an investable question and planning an investigation? Why or why not?
   d. Your learners’ ability to present an argument of what they did, why they did it and what they found out?

6. Did you feel that the strategy enabled you to teach in a more learner-centered / discovery based way? Why or why not?

7. Did you feel confident that the strategy achieved its aim in promoting increased learner participation? Why or why not?
Appendices

8. From your experience, what would you say are the strategy’s main strengths and weaknesses / challenges?

9. Were you able to use the strategy to incorporate issues relating to Sustainable Development into your science lessons through the use of investigations? Why or why not?

10. Did the strategy provide you with opportunities to introduce / incorporate elements of ESD into the teaching process? Why or why not?

11. Do you think the strategy influenced the learners of interest in issues relating to Sustainable Development? Why or why not?
## Appendices

### APPENDIX H

**Participating teachers’ biographical profiles**

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Experience</th>
<th>Age</th>
<th>Qualification</th>
<th>School location</th>
<th>Average Class size</th>
<th>School’s access to resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3 years</td>
<td>&gt;40</td>
<td>BSc and PGCE</td>
<td>Poorer area – township</td>
<td>33</td>
<td>Limited</td>
</tr>
<tr>
<td>B</td>
<td>20 years</td>
<td>&gt;40</td>
<td>Diploma in Education</td>
<td>Poorer area - township</td>
<td>35</td>
<td>Limited</td>
</tr>
<tr>
<td>C</td>
<td>13 years</td>
<td>&lt;40</td>
<td>BA and PGCE</td>
<td>Affluent suburb</td>
<td>25</td>
<td>Good</td>
</tr>
<tr>
<td>D</td>
<td>3 years</td>
<td>&lt;40</td>
<td>BSc and PGCE</td>
<td>Affluent suburb</td>
<td>25</td>
<td>Good</td>
</tr>
<tr>
<td>E</td>
<td>20 years</td>
<td>&lt;40</td>
<td>BA and PGCE</td>
<td>Affluent suburb</td>
<td>20</td>
<td>Excellent</td>
</tr>
<tr>
<td>F</td>
<td>28 years</td>
<td>&gt;40</td>
<td>Teaching Diploma</td>
<td>Middle class suburb</td>
<td>35</td>
<td>Adequate</td>
</tr>
<tr>
<td>G</td>
<td>7 years</td>
<td>&lt;40</td>
<td>BCom and PGCE</td>
<td>Middle class suburb</td>
<td>35</td>
<td>Adequate</td>
</tr>
<tr>
<td>H</td>
<td>16 years</td>
<td>&lt;40</td>
<td>B Prim Ed and Hons</td>
<td>Poorer area – inner city</td>
<td>35</td>
<td>Limited</td>
</tr>
<tr>
<td>I</td>
<td>29 years</td>
<td>&gt;40</td>
<td>BA and teaching diploma</td>
<td>Poorer area – inner city</td>
<td>35</td>
<td>Limited</td>
</tr>
</tbody>
</table>