A Case Study of Intermediate Phase Learners' success with Science Problem-Solving Tasks

by

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ABSTRACT

This is an evaluative case study to determine what science problem-solving skills learners have developed at the end of the Intermediate Phase. Grade six learners were used in this study as they represented the last grade within the Intermediate Phase. The main question that framed this study: How successful are learners with science problem-solving tasks at the end of the Intermediate Phase? An attempt has also been made to answer the key research questions relating to learners' success at solving problems, the types of problem tasks they can solve, any relationship between their ability at solving problems and their normal science achievement, any differences between groups such as male and female or across different classes, and the opportunities that enabled them to develop problem-solving skills?

Operating in a post-positivist/realist paradigm, qualitative as well as quantitative data were gathered through participant observation. The quantitative data was obtained by administering "paper and pencil" and group problem tasks to 116 learners in grade six. Learners' responses to the problem tasks provided the answers to questions relating to their success with science problems as well as the problem-solving skills used. The qualitative data was obtained from questionnaires based on the task and from semi-structured and focus group interviews with learners to attain a deeper understanding on how they responded to the problem tasks and thus determining their success.

Documents were analysed from grades four, five and six in an attempt to view the type of problem-solving skills learners had experienced in their science lessons within the Intermediate Phase. An interrogation of the documents provided answers to the research questions dealing with the opportunities learners were given to develop these problem-solving skills. The grade six learner's final Natural Science marks as well as the problem-solving tasks were analysed quantitatively as well as qualitatively to see if there was a relationship between the two.

From this study, it was found that in general learners' success was uneven. Learners had more success when problems were closed, inside type requiring one step simple reasoning and were presented as tables rather than as diagrams. They also seemed to have more success when answering the multiple-choice component of the question but had little success explaining their choice of answers. There was not a strong relationship between learners doing well at their normal school tests and being able to solve problems. Learners appeared to be unable to use reasoning to explain their answers. They were unable to work with more than one variable simultaneously.

Group differences within the case revealed that Black and Coloured learners had different levels of success with the problem tasks. There was no difference in the marks for boys and girls scores for the problem tasks but there was a difference in their scores for the Natural Science test. In general, learners within the 11 year age group had greater success with the problem tasks.

The findings of this study indicate that learners at the Intermediate Phase level are not taught to solve problems and therefore have very limited success with solving problem tasks. However, learners' uneven success also implies that although some learners were unable to solve problems there are others that do have the ability to use problem-solving skills even if they were not formally taught these skills within their science lessons. Learner's inherent ability to solve problems by constructing their own knowledge from their experiences forms the core of this study. Teachers need to build on these in the science classroom, which will result in learners becoming expert problem solvers.

This study suggests that providing learners with experiences relating to solving science problems can only assist in developing learners' problem-solving ability and thus benefiting society. The intention of this study is to open up the possibility of a more detailed research into science problem-solving in the primary school within the new reforms of our South African education system.

PREFACE

The work described in this thesis was carried out in the School of Science, Mathematics and Technology Education, University of KwaZulu-Natal, from August 2004 to June 2006 under the supervision of Professor P.A. Hobden (Supervisor).

This study represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others, it is duly acknowledged in the text.

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GLOSSARY

RNCS	Revised National Curriculum Statement
TIMSS	Trends in Mathematics and Science Study
C2005	Curriculum 2005
DOE	Department of Education

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DEDICATION

This thesis is dedicated to my loving sons, Nirav and Advik, whose enthusiasm and quest for knowledge motivated this study. Their inquisitiveness and love for science will undoubtedly make them expert problem solvers in the future.

CHAPTER 1

INTRODUCTION TO STUDY

With the implementation of the Revised National Curriculum Statement (RNCS) in South Africa, the focus of education has shifted to an outcomes-based approach. This has heralded with it changes in the science curriculum, which among others now emphasises problem-solving as a key element in transformation and development of the learners full potential resulting in producing "citizens of a democratic South Africa" (Department of Education, 2002, p. 1).

The changing context of South Africa's education system warrants an in depth look into the change in the science curriculum. The old curriculum was based largely on rote learning and did not invite the learners to display their creative responses. This emphasis should change and the move should be towards the acquiring of skills as envisaged in the new curriculum. Thus, the move to the new system means a shift to a more skills orientated approach.

This study originated from my personal interest in science at the Intermediate Phase. I have been a primary science teacher during the transition from the old education system to the new education system. Teachers have implemented the curriculum in the classroom resulting in learners having their own views of science. Being present in a school situation during the transformation, I was witness to the way learners' perceived science. The intended outcomes in the new curriculum were seldom focused on with little emphasis on the promotion of problem-solving skills. I could offer various excuses for this being so but as mentioned they would just be exactly that, excuses. We were guilty of not providing them with adequate experiences, as we were inexperienced in this field ourselves and felt this was beyond the learner's ability.

My views on this changed when I furthered my studies and developed an interest in problem-solving in science education. Through extensive reading around the subject, I have concluded that learners are able to solve problems from a very young age. What we as teachers failed to realise was that learners were using problem-solving skills whether we provided them with the experiences or not. In addition, they are able to apply these skills to different contexts. This study explores learners' success with science problem-solving and further investigates the type of skills learners possess at the end of the Intermediate Phase.

1.1 THE STUDY

The purpose of this study was to determine how successful learners were with science problem-solving tasks as a result of their experiences in the Intermediate Phase. To accomplish this, the research centred on the question: "How successful are learners with science problem tasks at the end of the Intermediate Phase?" In order to answer this research question I was guided by the following sub-questions, which all contributed, to answering the main question:

1. How successful are learners at solving problems?
2. What types of problem tasks can they solve?
3. Is there any relationship between their ability at solving problems and their normal science achievement?
4. Are they any differences between groups such as male and female or across different classes?
5. What opportunities enabled them to develop problem-solving skills?

An evaluative case study was considered to be the most suitable approach to answering these questions. Grade six learners were evaluated on how successful they were at solving problems given that it is part of the new curriculum. This approach involved participant observation during a one-year period with a class that I taught. The grade six learners of a primary school in the Sydenham area formed the case study. At the time of the study, the learner population at the school was made up of predominantly Coloured and Black learners (traditionally people were regarded in terms of four race groups, viz. Blacks, Coloured, Indian and White. The classes were not streamed and learners were therefore of mixed ability. Previously disadvantaged groups under apartheid were Blacks, Coloureds and Indians. The reason for using these race groups in this study is that Black learners are usually the second language English speakers.

The study was approached within a post positivist/ realist paradigm. A variety of instruments was used to enable me to collect both qualitative and quantitative data. The research tools used to gather data were a set of problem tasks, the final Natural Science test that learners wrote at the end of their grade six year, documents (textbooks, class notes, and tests), observations and interviews. The problem tasks took the form of individual "paper and pencil" tests as well as two group activities. For the purposes of this study, the "paper and pencil" problem tasks will be referred to as the Problem tasks and the group problem tasks as the Group tasks. The two Group tasks took the form of a construction task and an aquarium task.

Documents were analysed to obtain an in depth look at the skills learners experienced in their science classroom during the Intermediate Phase, that is grade four, five and six. The document analysis was carried out with the intention of providing the context to see what learners had experienced under the new curriculum and to help understand their success or lack of success when faced with problem tasks.

Learners' final Natural Science marks were compared to the scores they received for the Problem tasks. An attempt was made to see if there were any similarities or differences between the two. As with all studies of this nature, a few constructs need to be identified and explained before I proceed.

1.2 THE CONSTRUCTS

Within this study, a number of constructs are used to describe concepts, which have multiple meanings within the literature. In this section, I clarify my interpretations of certain constructs that are used frequently in my dissertation.

1.2.1 Primary School

Historically most schools are classified as primary and secondary schools. In South Africa, a primary school caters for learners for the first eight years of schooling from grade R (reception year) to grade seven. Grade R to three is referred to as the Foundation Phase and grade four to six is referred to as the Intermediate Phase. Although grade seven is part of the Senior Phase, it is still located in the primary school system. The primary school is also known as elementary school or middle school in other countries. Grade six forms part of the Intermediate Phase at primary school level. It is the exit grade of the Intermediate Phase.

With the implementation of the RNCS, teachers were required to be classroom based especially in the primary schools (Department of Education, 2002). Previously teachers were subject specialists, for example the "science teacher" taught all the science for a particular grade. This relatively new arrangement meant that teachers were expected to teach all learning areas in their particular grades. This resulted in teachers teaching learning areas they had not studied during their pre service teacher training. This influenced negatively on all learning areas especially science and mathematics, which requires specialisation. Teachers found it difficult to teach these learning areas because of the specialist knowledge required which is difficult to learn by themselves without pre service science courses.

1.2.2 Science Education in Primary School

Harlen (2000) points out: "Learning science is important for the future lives of all citizens and it is a required part of primary and secondary education in practically all countries" (p. 1). Science generates knowledge, which helps us to understand the world. In science, we are concerned with laying the foundation for this understanding. Harlen further explains that the way this is done depends on our view of how children learn best. It is from this view that teachers develop the way they teach.

According to the RNCS, the Natural Science Learning Area deals with the promotion of scientific literacy (Department of Education, 2002, p. 4). This is achieved by developing and using "science process skills, critical thinking skills and problem-solving skills in a variety of settings, developing and applying scientific knowledge and understanding and appreciating the relationships and responsibilities between science, society and the environment" (p. 4). The RNCS also maintains that the Natural Science Learning Area must be able to provide a foundation on which learners can build throughout life. Complimentary to this, it is at the primary school level that this foundation has to be laid for the future.

There are three learning outcomes in Natural Science, viz. 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 (Scientific Investigations), the learners will know and be able to interpret and apply scientific, technological and environmental knowledge (Constructing Science Knowledge) and the learner will be able to demonstrate an understanding of the interrelationships between science and technology, society and the environment (Science Society and the Environment). In the Foundation Phase, grades R-3 only the first learning outcome dealing with Scientific Investigations is taught and assessed. In the Intermediate Phase, Grades 4-6, as well as the Senior Phase, grades 7- 9, all three learning outcomes are taught and assessed.

The Natural Science Learning Area comprises a wide variety of fields of inquiry. The RNCS groups the four main content areas as Life and Living, Energy and Change, Planet Earth and Beyond and Matter and Materials, which are outlined as follows:

> Life and Living focuses on life processes and healthy living, on understanding balance and change in environments, and on the importance of biodiversity.
> Energy and Change focuses on how energy is transferred in physical and biological systems, and on the consequences, that human needs and wants have for energy resources.
> Planet Earth and Beyond focuses on the structure of the planet and how the earth changes over time, on understanding why and how the weather changes, and on the earth as a small planet in a vast universe.
> Matter and Materials focuses on the properties and uses of materials, and on understanding their structure, changes and recreations in order to promote desired changes. (Department of Education, 2002, p. 61)

These statements form the core minimum knowledge for learning programmes in the Natural Sciences Learning Area. Learning programmes are expected to draw content from all four strands over a phase.

Natural Science is taught with Technology in the primary school. The focus of Technology in primary schools is on solving scientific problems. Through its open-ended, problem-solving approach, the Technology Learning Area "links knowing with doing thus affording the learner opportunities to apply and integrate their knowledge and skills from other learning areas in real practical situations" (Department of Education, Technology, 2002, p. 5). Thus in primary schools the two learning areas are taught concurrently and are referred to as Natural Science and Technology (NSTech). Both Natural Science and Technology emphasise problem-solving.

1.2.3 Problem-Solving

In this study the term problem is used to describe any task in which a learner experiences a block, obstacle or barrier when solving the problem. The problem task requires critical thinking in order to overcome this block so it can be solved. These tasks can be often recognised as they have some or all of the following characteristics: the context of the task is not routine; it must be novel based on realistic situations; learners require more than one attempt in solving the task; the solution to the task is not routine; the task could have multiple solutions, be open-ended and provides a challenge. It is important to note that although some tasks can be a problem for one learner but may not be for another. These characteristics are used for tasks that are designed to be problems for almost all learners.

Research has shown that learners do benefit from instruction in problem-solving, they can and do learn to use integrated science process skills (Helgeson, 1992). They are also able to transfer these skills to new problems, which are similar to those the learners have experienced. Moreover, learners who "receive such instruction tend to learn more science and develop more positive attitudes towards science and more self-confidence in their own abilities" (Helgeson, 1992, p. 57).

1.2.4 Critical Thinking Skills

For the purposes of this study, critical thinking can be defined as non-routine, effortful thinking that requires reasoning. Critical thinking will involve the use of interpretation, analysis, application, inference and reasoning skills when solving the problem tasks in this study. It is apparent that problem-solving and critical thinking are closely related and it is rare to find one without the other. Critical thinking is required to overcome the "block" in problem tasks. Critical thinking forms part of higher order thinking skills.

Johnsey (1986) observed that we, teachers make all the decisions for our children with the "intention that they will learn to make choices for themselves in the future when they have sufficient experience" (p. 3). He questions if this is really the case and advises that children need to be given the opportunities to help build their confidence in their decisions, thereby developing a positive self-image they need in order to solve their own problems. De Boo (1999) supports an ethos where thinking is valued throughout school. Children who ask questions are self-motivated and can direct their own learning. Children who are taught to be critical and challenge ideas might appear discourteous. However, children need the opportunities to challenge them to make them efficient critical thinkers and problem solvers.

1.3 THE STRUCTURE OF THE STUDY

The introduction aimed to acquaint the reader with the motivation and background to the study. The literature review in chapter two links the theoretical background to local and international research already done in areas related to this study. I have reviewed the literature under different headings: problem-solving in the new curriculum, problem-solving in school science, knowledge and learning, gender and school science, language and school science, individual and group work, skills associated with problem-solving and characteristics of problems. Under the characteristics of problems, I examined at multiple-choice questions as well as the presentation of problems. A framework of problem-solving skills that form the basis of this study is included. The research methodology is presented in chapter three, which describes in detail the reasoning behind the way this research was conducted, the design of the study, selecting the sample, and the methods of data collection in all three of the activities as well as the analysis of the documents. The analysis and discussion for learners' responses to the Problem and Group tasks and the document analysis are the basis of chapter four. Chapter five provides further discussion of the main findings with further analysis. A summary, limitations and implications for future research appear in chapter six.

CHAPTER 2

LITERATURE REVIEW

With the focus of this study being problem-solving in primary school science, this chapter begins with an attempt to locate problem-solving in the new curriculum. The focus then shifts to problem-solving in school science. I proceed to examine the way I view knowledge and learning. Gender and language in school science will be examined. I will discuss the use of individual and group work when solving problems. I also review the skills associated with problem-solving (viz. critical thinking skills, process skills and reasoning skills) as perceived by other researchers. Using these skills, I attempt to draw a framework of problem-solving skills and sub-skills, which is further simplified for use by young learners in primary school. Since there is still a large amount of confusion around the characteristics of science problems to be utilised in the primary school with younger learners, I examine the literature on this. Included within the characteristics of problems, I briefly discuss the presentation of problems including the use of multiple-choice type items.

In this study an attempt will be made to determine the extent to which learners are successful learners are with science problem tasks taking into account their experiences with problem-solving throughout the Intermediate Phase. This study recognises the importance of the teachers' role in developing learners' problem-solving abilities but will unfortunately not be included in this study due to time limitations of a master's level study. I believe that the teachers role needs to be given appropriate attention and should form the basis of a whole new study.

2.1 PROBLEM-SOLVING IN THE NEW CURRICULUM

The new Revised National Curriculum Statement (RNCS) emphasises problem-solving as an important component in most learning areas, especially Natural Science, Technology and Mathematics (Department of Education, 2002). In the Physical Science Learning Area, which learners take in grades 10-12, problem-solving has had an emphasis on numerical problems and use of procedures and algorithms. In the Natural Science Learning Area in the senior phase, which learners are required to take in grades 7-9, problem-solving has slightly less emphasis on numerical manipulations and incorporates more technological problems. However, in Intermediate Science (primary school grades 4-6), problem-solving is more difficult to recognise and define, as it has not traditionally been seen as a focus of instruction.

The RNCS emphasises problem-solving in the Natural Science Learning Area giving it the potential to be an exciting learning area that ought to bring about stimulating changes in the way it is taught. The curriculum documents advise that this learning area should be approached from a practical basis with learners relating their knowledge to their contexts thus making it relevant to them. From my experiences teaching with other primary school Natural Science teachers, I do not believe that this is happening to the extent it should be. Teachers are not adequately trained to approach this learning area in this way. The training that was provided for teachers at the beginning of the implementation of the new curriculum was not sufficient in equipping teachers to introduce problem-solving and transform the teaching of the Natural Science Learning Area to be exciting and captivating for the learners. To teach primary school learners' problem-solving requires the teacher to create an environment in which "learners make connections between learning science skills in school and applying them in daily life" (Valentino, 2000, p. 3). I am not convinced that the majority of teachers are able to do this. The following discussion emphasises problem-solving in the RNCS across all discipline areas to show the importance attached to problem-solving and to show the integrated nature and links to the Natural Science Learning Area.

The RNCS highlights problem-solving and its associate "skills," viz. critical thinking and decision making in nearly all-learning areas. The reason for grouping these skills rather than dealing with them separately in this study is based on the definition of problem-solving as cited in Hobden (2002):

> Problem-Solving is a multifaceted cognitive activity in which we engage when we are confronted with a task in which routine action or normal thinking does not allow one to go from the given existing situation to the desired goal situation, but rather there is recourse to some form of critical thinking. Such critical thinking has the task of devising some action, which may overcome the perceived barrier between the existing and goal situations. (p. 5)

Hobden further emphasises that "problem-solving is closely associated with critical thinking and while all critical thinking is not problem-solving, all problem-solving involves critical thinking" (p. 4). It is evident that critical thinking is vital when attempting to solve problems. Keeping the above in mind that problem-solving encompasses a number of skills, an attempt is now made to locate where problem-solving fits in the outcomes of the various learning areas as laid out in the RNCS (Department of Education, 2002). These are described and then summarised in Table 2.1.

In the Natural Science Learning Area, learning outcome one, Scientific Investigations, states that 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" (Department of Education, 2002, p. 8). In the Technology Learning Area, the outcomes do not mention problem-solving explicitly. However, it is clearly emphasised in the definition of Technology which mentions, "The use of knowledge, skills and resources to meet people's needs and wants by developing practical solutions to problems while considering social and environmental factors" (p. 28).

In the Mathematics Learning Area, there is direct reference to problem-solving in learning outcomes one and two. In learning outcome one, mention is made of the learner being able to recognise, describe, represent numbers and their relationships, and to count, estimate, calculate and check with competence and confidence in solving problems. In learning outcome two, it is written that the learner will be able to recognise, describe and represent patterns and relationships, as well as to solve problems using algebraic language and skills. In learning outcome five, mention is made of the learner being able to collect, summarise, display and critically analyse data in order to draw conclusions and make predictions, and to interpret and determine chance variation (Department of Education, 2002).

In the Language Learning Area, there is no direct reference to problem-solving, however in learning outcome one the learner is expected to listen for information and to respond appropriately and critically in a wide range of situations. In learning outcome three, mention is made of the learner being able to read and view information for enjoyment, and respond critically to aesthetic, cultural and emotional values in texts. In learning outcome five mention is made of the learner being able to use language to think and reason, and access, process and use information for learning.

In the Social Science, Economic Management Science, Art and Culture and Life Orientation Learning Areas there are no direct references to problem-solving but associated terms such as "enquiry skills"; and "making informed decisions" and "reflect critically" are mentioned. In learning outcome three for Life Orientation, Personal development, it is expected that the learner will be able to use acquired life skills to achieve and extend personal potential to respond effectively to challenges in his/her world. Here, I interpret the word "challenges" as being problems that might be faced in life. It is inferred that the learner is able to make informed decisions in learning outcomes one and five. The learning outcomes for the learning areas are summarised in Table 2.1 and it can be seen that problem-solving infuses most parts of the curriculum.

Table 2.1 The location of learning outcomes related to problem-solving skills and sub skills within the different learning areas

Learning Area	Learning Outcomes
Language – English	1, 3 and 5
Mathematics	1,2 and 5
Natural Science	1
Technology	Found in the definition
HSS:	
History	1
Geography	1 and 3
Economic Management Science	2
Art and Craft	2
Life Orientation	1, 3 and 5

South Africa is following in the footsteps of first world countries in terms of our new outcomes based education policy, which has a focus on preparing the learner for the life outside school. A life, which is surrounded by "problems" waiting to be solved. Consequently it is not unexpected to find that problem-solving is considered a core skill of the new curriculum.

2.2 PROBLEM-SOLVING IN SCHOOL SCIENCE

From the overview of the curriculum, it is unmistakable that although problem-solving, critical thinking skills and decision-making are mentioned in all learning areas, problem-solving itself features to a greater extent in Mathematics, Natural Science and Technology in the RNCS. Given that problem-solving is relatively new in our curriculum we can learn from what has happened in other countries where problem-solving has been the focus for many years.

Most of the definitions of problem-solving identify a hurdle using words such as "block, obstacle, barrier" that has to be surpassed before the problem is solved (Frank, 1986; Hobden, 2002; Watts, 1991; Woods, 1989). Learners need to experience this "block, obstacle, barrier" in real problem-solving activities before they can be said to have participated in problem-solving. It is important to clarify that a problem is not the same for everyone. This is argued by Wheatley (1995) when he says, "what is a problem for one person might be a routine exercise for another" (p. 2). Frank (1986) highlights the difference between exercises and problems in the way that they are solved. He indicates that a problem requires the use of heuristics and an exercise requires the use of algorithms to be solved. In my experience in Primary Science some of the tasks that are given to learners are problems, however many are not. Smith (cited in Helgeson, 1992) points out, "whether or not a task is defined as a problem is not determined by how difficult or how perplexing it is for the intended solver". He says, "problem-solving becomes a process by which a system generates an acceptable solution to such a problem" (p. 3).

As far as the overall curriculum is concerned, the first critical outcome in the RNCS (Department of Education, 2002) envisages learners who are able to "identify and solve problems and make decisions using critical and creative thinking." The seventh critical outcome envisages learners who are able to "demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation" (p. 1).

When it comes to problem-solving in the Natural Science Learning area, it appears in all three learning outcomes. Learning outcome 1, Scientific Investigations encompasses problems of four kinds when solving: problems in the scientific, technological and environmental contexts, problems of making; problems of observing, surveying and measuring; problems of comparing and; problems of determining the effect of certain factors. Learning outcome 2, Constructing Science Knowledge, encompasses the recall and application of knowledge to enable the learner to "produce an answer or product" (p. 10). The learner has to also categorise and interpret information. Learning outcome 3, Science, Society, and the Environment is a challenging outcome. The meaning provided in the documents for this outcome mentions "education as helping people to become problem solvers" (p. 11). The implication is that problem-solving should be embedded in the South African context, thus making it practical and useful. We know that the values of people are seen in the ways they choose to deal with problems, and even in the choice of issues, they define as problems. Therefore, this outcome requires that the learner "acquire increased understanding of the way values influence people's choices of technological and scientific solutions" (p. 11).

The argument is becoming convincing problem-solving needs to form part of school science. To do this Chin Ngoh-Khang, Chia, Lee and Soh (1994) suggest that "for problem-solving to become an integral part of the science curriculum, teachers must make it the focus of their instruction" (p. 41). In addition, Hobden (2000) highlights the importance of problem-solving as a teaching strategy, "It has the potential to help learners appreciate and understand scientific knowledge" (p. 5). In order to be convinced to focus on problem-solving, it is of utmost importance for teachers to understand the benefits that the teaching of problem-solving has on learners.

The TIMSS study (1994) summarises quite aptly by saying, "a major purpose of science education is to prepare learners to engage in scientific reasoning to solve problems, develop explanations, draw conclusions, make decisions, and extend their knowledge to new situations" (p. 66).Given that problem-solving is a relatively new emphasis in our curriculum, we can learn from what has happened in other countries where problem-solving has been the focus for many years. What follows is a summary of a few studies which show these benefits.

Baumert, Evans and Geiser (1998) used a sample of 10 year olds from Germany and the United States to investigate the structure of everyday experience and science learning (amidst other variables) in solving everyday technical problems. In this study young learners were used to try and link the contextualisation of knowledge and structural differences between knowledge acquired in the formal settings such as schools, and knowledge, which develops from every day life experiences (p. 990). This was done by developing construction tasks, which while directly connected to elementary school learners' experience with every day technical objects and construction games, did not allow spontaneous solution. It was found that children who could read thermometers and make judgments from those readings as well as understand everyday scientific phenomena, solved technical problems better, even when their cognitive ability was taken into account. This study showed that learners' everyday experiences have an influence on their success with problem tasks.

In a review study conducted in the United States, Curbelo (as cited in Helgeson, 1992) concluded after 68 experimental studies, "When groups of learners were given instruction in problem-solving, their achievement exceeded that of learners not provided with instruction in problem-solving" (p. 57). Helgeson later summarised that these learners were able to transfer these skills to new problems. This study is important as it implies that instruction in problem-solving contributes to learners achieving well. In keeping with this, Wallace (2002) remarks, "developing learners' problem-solving and thinking skills initially takes time, but once learners are familiar with the range of skills and are using them, they learn more efficiently and we save time" (p. 14).

McGhee (1997) looked at problem-solving within the Scottish 5-14 curriculum and developed problem tasks to determine the range and strategies that a learner might need and the stages to be gone through in order to solve a scientific or technological problem (p. 103). The three problems he used were the Heavier Bear, Froghop and Guess who I am. The Heavier Bear problem was regarded as open-ended where children were invited to suggest how two bears could prove which one was the heavier using only material found in a wooded area. The evidence collected suggested that more than fifty per cent of children in the 5-14 age groups required more than one reading of the problem. In the case of the Heavier Bear, re-reading the problem made little difference and it was not until an interpretation of key words such as "heavier" was sought by children that a clearer understanding developed. It was found, "irrespective of the difficulty of the problem as perceived by the children, quality ideas were provided by all ages" (McGhee, 1997, p. 107). Furthermore it was found that the "quality of ideas provided by the younger age was quite remarkable" (p. 107). This research has "highlighted that younger children not only have the enthusiasm to tackle problems, but the ability to master many of the skills and strategies of problem-solving" (p. 109).

From these illustrative studies we learn that despite their young age primary school learners are able to provide solutions to problems using their everyday experiences. Although attempts were made to add studies from a local educational context it was difficult to find local studies specific to problem-solving in primary science. This could be because the inclusion of a problem-solving focus in science education in the primary school is relatively new in the South African education system.

2.3 KNOWLEDGE AND LEARNING

Within the science education literature a constructivist view of learning is strongly supported (Wheatley, 1991). This view sees learning as occurring when children (as well as adults) are confronted with something new and they attempt to make sense of this new experience. The new knowledge or understanding cannot be transmitted directly from teacher to learner, but has to be actively built up by the learner. A constructivist view of learning perceives learners as active learners who come to the science lesson already holding ideas about natural phenomena, which they use to make sense of everyday experiences. Learning science therefore involves learners in not only adopting new ideas, but also in modifying or abandoning their pre-exist ones. Younger children need to be provided with experiences on which they can build their learning. Such a process is one in which learners actively make sense of the world by constructing meaning.

In this study, knowledge and understanding are seen not merely as things to be transmitted verbally but must be constructed and reconstructed by the learner. Wheatley (1991) suggested that it is very much a personal matter as it is based on learners' experiences. Knowledge is constructed by individuals as they interact with the world and with other human beings.

Accordingly we cannot assume that one can simply transmit information to young learners and expect that understanding will result (Confrey, 1990). Furthermore since learners construct their own meaning, teachers cannot assume that learners have the same set of understandings, or that their learners share their ways of coming to an understanding.

Problem-solving can be seen as synonymous with learning. As a learner solves a problem, learning is taking place (Stewart & Hafner, 1991). It can also be viewed as an outcome or a mechanism of learning. Such a view emphasises that the learning and teaching process is interactive in nature and involves the implicit and explicit negotiation of scientific meanings. This also implies that solving a problem as an individual should be different to solving a problem in a group. Consequently one would not expect learners to necessarily perform the same individually and in groups.

2.4 CO-EDUCATIONAL MULTICULTURAL CLASSROOMS

South African primary science classrooms are normally coeducational, i.e. mixture of boys and girls and multicultural (learners from different language and cultural backgrounds). These factors could influence problem-solving in the classroom so a discussion of them is provided in this review.

2.4.1 Gender

Although there is a fair amount of research on gender and science education, this seems to be concentrated at the secondary school level. In the primary school, girls and boys have to take science, as it is part of the curriculum. An area that needs investigating is whether there is a difference in boys and girls success with problem-solving.

In a study conducted by Beard, Fogliani, Owens and Wilson. (1993) with male and female secondary learners with chemistry quizzes, male learners consistently achieved a higher mean score in all year groups (7 to 12) even though the numbers of male and female entrants were approximately equal. These tests were multiple-choice questions with the percentage of males selecting the correct answer exceeding the percentage of females by more than ten percent in six questions. The study also "showed that boys often show confidence, assurance and are less inhibited by guessing when they are not certain of the correct answer" (p. 12). Therefore multiple-choice questions advantage male learners. Other reasons for males doing better than females could be their different out of school experiences. Learners will perform better in areas where they are more familiar with the context.

2.4.2 Language

Language plays an important role in teaching and learning science and technology. There are 11 official languages in South Africa which includes English, Afrikaans and nine indigenous languages. However, English and Afrikaans are used more widely as languages of instruction in schools at all levels of education. Although schools are now given the option to have an indigenous language as a medium of instruction, this offer is seldom taken up by the schools as there are insufficient qualified teachers to teach the content subjects in the indigenous language. Many learners have a language for school and a language for home.

Some studies in which language of learning played a role are now described. A test which was answered by a large number of learners from different language groups was the Third International Mathematics and Science Survey (TIMSS). Learners answered the TIMSS test in either Afrikaans or English. It was found that learners who took the test in Afrikaans achieved an average science score which was higher than those who took the test in English. Most learners taking the test in English attended township and rural schools and English would not likely be their first language. It seemed that the language of the test and learners' proficiency in that language contributed to the achievement scores attained. However, Reddy (2006) reports, "it is difficult to determine the extent of this contribution as there are other inequalities among the school types which also influence performance" (p. 3).

Howie (2003) addressed the effect of language on South African learners' performance in mathematics. Her research showed that in South Africa, learners' proficiency in English determined to a large extent their achievement in mathematics. Those learners that spoke English or Afrikaans at home tended to achieve higher scores in mathematics (p. 12).

The importance of language in the learning of science has often been underestimated as there is belief that the learners' meaning will "come through" despite language difficulties. Rollnick (1998) argues that the issue of language cannot be ignored as it impinges on the learning of science in important ways related both to attitude and cognition. She suggests that learners will lose interest in science if they do not understand what is taught. It has also been observed by Dlodo (1999) that if a learner's mother language has not been used in a science class then this learner will experience "very special additional difficulties of cognitive understanding if the language of instruction is English" (p. 328). Fortunately, in recent years the issue of language in science education has finally come to be recognised as being important because of the increasing number of second language learners studying science.

Hodson (1993) identifies language as a "cultural artifact" (p. 690). This supports the belief that racial minorities, whose language is not English, form a group that requires special attention. Unavoidably, reading and writing in English will represent a major obstacle to learning for these learners. Hodson suggests alternatives to writing tasks like "talking, making tape recordings, drawings, making models, setting up displays, taking photographs and making videos" could be used (p. 690). However, few of these are used in responding to traditional problem-solving tasks. From these and other studies, it seems that those not proficient in English find it difficult to engage with the problem and communicate their answer or reasons because they cannot understand the task. Therefore language can impact on learner's problem-solving ability by preventing access to the actual problem task.

2.5 INDIVIDUAL AND GROUP WORK

The RNCS critical outcome two, "envisages learners who are able to work with others as members of a team, group, organisation and community" (Department of Education, 2002, p. 1). Since group work is emphasised in the RNCS, the consequence is that much group work takes place in school. As a result, problem-solving often takes place within this context particularly in the primary school where group work has always been used.

Group work is said to have many advantages. It removes much of the personal pressure and celebrates learners' individual strengths as they work together in a team. Learners working in groups shared the responsibilities thus making the task more manageable. Learners working in groups also tend to increase their confidence (Watts, 1991).

De Boo (1999) noted that primary school teachers who use a range of teaching styles tend to stimulate the children's capacity to learn independently and work collaboratively. She further states that finding the right balance is a professional skill. Fisher (as cited in De'Boo) maintains that children working in pairs and groups produce more effective solutions to logical problems than children working alone do. It is argued that learner's discussions and arguments encourage thinking.

On the issue of assessment, De Boo lists a range of strategies for assessing children's knowledge of which group discussions forms part. She goes on to iterate that it is "difficult to assess children's knowledge on a strictly 1-10 in paper and pencil tests which often require high levels of skill in English and Mathematics" (p. 101). She suggests that it is important to assess children's skills in practical tasks.

The study conducted by Kempa and Ayob (1995) addressed itself to the question of how effective group work is in promoting learning from peers. The tasks attended to during the group work were all concerned with the planning of scientific information. Apart from indicating a generally satisfactory level of achievement from group work, they also demonstrated a significant amount of learning from other members of their group to have occurred, in the sense of individual learners including in their written answers, points of knowledge and insight that had initially been contributed by other learners to the group discussions (p. 750).

2.6 SKILLS ASSOCIATED WITH PROBLEM-SOLVING

Trying to understand what problem-solving involves proved difficult because the term is tied up with general activities of enquiry within the literature. When talking about problem-solving, skills such as critical thinking, reasoning and process skills appear in the literature. This section attempts to highlight the skills involved in the problem-solving process, viz. critical thinking, process skills and reasoning skills with the intention of devising a framework of skills that will outline this study. It was very difficult to categorise and label the many skills reported in the literature to be involved in the complex process of problem-solving. Consequently, it was found that there was considerable overlap making it impossible to produce hard and fast categories of skills.

2.6.1 Critical Thinking Skills

As indicated in chapter one, critical thinking is intimately linked to problem-solving and is one of the critical outcomes of the curriculum. Facione (1998) discusses the importance of critical thinking and critical thinkers in the different sectors of society. He says that the need for good critical thinkers in society is of paramount importance. He supports the idea embedded in our new curriculum that schools should serve as a foundation to develop critical thinking skills in learners so that they can be of value to society.

A review of the extensive literature in this field shows that most authors agree that critical thinking embraces a number of skills. I have opted to include the lists used by three researchers in an attempt to draw out the similarities associated with the skills involved in teaching critical thinking. The work of Valentino (2000), Wade (as cited in Adsit, 1999) and The Delphi Report (Facione, 1990) are considered. Firstly, Wade describes eight characteristics of critical thinking being : asking questions; defining a problem; examining evidence; analysing assumptions and biases; avoiding emotional reasoning; avoiding oversimplification; considering other interpretations; and tolerating ambiguity. Secondly, Facione (1990) provides a list of the core critical thinking skills and sub-skills agreed on in the Delphi Report, which is presented in Table 2.2.

Table 2.2 Critical thinking skills and sub-skills according to Facione, (1990, p. 1)

Skill	Sub – Skill
Interpretation	Categorisaton
	Decoding Significance
	Clarifying meaning
Analysis	Examining Ideas
	Identifying Arguments
	Analysing Arguments
Evaluation	Assessing claims
	Assessing Arguments
Inference	Querying Evidence
	Conjecturing Alternatives
	Drawing Conclusions
Self- Regulation	Self-examination
	Self-correction

Thirdly, Valentino (2000) organises and describes the skills associated with critical thinking differently and these are presented in Table 2.3.

Table 2.3 Description of critical thinking skills according to Valentino (2000, p. 2)

Skill	Description
Analysing	studying something to identify constituent elements or relationships among elements
Synthesising	using deductive reasoning to pull together key elements
Evaluating	reviewing and responding critically to materials, procedures or ideas, and judging them by purposes, standards, or other criteria
Applying	using ideas, processes or skills in new situations
Generating ideas	expressing thoughts that reveal originality, speculation, imagination, a personal perspective, flexibility in thinking, invention or creativity
Expressing ideas	presenting ideas clearly and in logical order while using language that is appropriate for the audience and occasion

It can be seen that all three authors refer to aspects such as analysis, evaluation and inference which are all higher order skills, i.e. critical thinking is not routine or low level thinking but rather thinking that is effortful. This is precisely the thinking required to get around the "block" in problem-solving.

It is evident from the different skills involved in critical thinking that these skills are important in the learners' development as responsible problem solvers in society. The skills need to be taught as the learners' progress through the different phases in the education system. The skills that need to be taught would depend on the types of problem tasks the learners encounter. These skills then become part of the "learners' repertoire" and so can be called on repeatedly (Watts, 1991). Watts emphasises, "problem-solving involves skills, knowledge and understanding that the learner already possesses and through the art of problem-solving can add new skills to the learner's store" (p. 5). He goes on to say, "These skills and knowledge can transfer from one problem to the next, both in and out of school" (p. 5).

Marlow & Inman (1997) emphasises the need for primary school learners to think and make decisions in problem-solving activities. The problems that are set for the learners need to allow learners to make choices. If this is done then the learner is making decisions and thinking critically. The decision that the learner makes would be an extension of his or her personality. If the choice leads to a solution, the learner will gain confidence in solving problems. Teachers therefore need to set problems that allow for creativity but are within the learners' ability (Johnsey, 1986).

From my experiences, I found that learners are generally reluctant to think for themselves. They await the assistance from the teacher or their fellow peers. This apparent apathy is usually a deterrent in the teaching of critical thinking skills. Attitudes and motivation play an important part in promoting good habits of thinking because thinking is not easy but involves effort (Hobden, 2002). Nisbet (undated) states, "Knowing about effective thinking is not enough: we also need to have the will to use that knowledge and to develop the habit of thought" (p. 3).

The above discussion highlights the strong link between problem-solving and critical thinking and the general agreement that it should form a core focus of the school science curricula.

2.6.2 Process skills

The Natural Science Learning Area deals with the promotion of scientific literacy. It does this by the development and use of science process skills in a variety of settings. According to the RNCS the teaching and learning of science involves the development of a range of process skills that may be used in "everyday life, in the community, and in the work place" (Department of Education, 2002, p. 4). It is suggested that learners can gain these skills in an environment that supports creativity, responsibility and growing confidence. The RNCS views "process skills as the building blocks from which suitable science tasks are constructed" (p. 13).

The RNCS lists a set of process skills which are essential in creating outcomes-based science tasks and which could also be used in solving appropriate problem tasks (p. 13). They are interpreting information, predicting, and hypothesising. Interpreting information involves making inferences from the given information, perceiving and stating a relationship between two variables, and constructing a statement to describe a relationship between two variables. Barr (1994) identifies this "ability to control variables in a science experiment" as a process skill also necessary for successful problem-solving (p. 239). Predicting (according to the RNCS) involves using knowledge to decide what will happen if something is changed in a situation. Hypothesising involves giving possible reasons why something has happened using prior knowledge as well as other information. The statement also indicates that reflection on the process is important for the acquisition of process skills.

Harlen (2000) suggests that process skills are "not single skills but a conglomerate of coherent skills" (p. 31). She emphasises that they are important as part of the core, key and thinking skills that are valued as outcomes in education. They are also essential in enabling children to develop understanding and the ability to identify and use relevant scientific evidence in solving problems and making decisions. However, children have to acquire these skills; they are not born with them. It is the teachers' responsibility to help the learner in the development of theses skills by providing them with opportunities to use process skills. If well developed then learners should be able to apply them when dealing with problem-solving tasks.

2.6.3 Reasoning Skills

Reasoning skills also form part of problem-solving skills and for some authors are considered critical thinking skills. Reasoning skills quite simply put are "giving reasons for opinions and actions, draw inferences and make deductions" (Davies, Rosso & Scott, 2002, p. 96). Reasoning is involved in the more multifaceted tasks associated with science. The Trends in International Mathematics and Science Study (TIMSS, 1994) states, "a major purpose of science education is to prepare learners to engage in scientific reasoning to solve problems, develop explanations, draw conclusions, make decisions, and extend their knowledge to new situations (p. 66). In science it is expected that learners may be required to draw conclusions from scientific data and facts, providing evidence of both inductive and deductive reasoning and an understanding of the investigation of cause and effect.

Within the TIMSS study the various questions are categorised. The following criteria are used to categorise a question as problem-solving: (a) Problems are analysed to determine the relevant relationships and concepts. (b) Interpretation uses diagrams and graphics to visualise and solve problems, give evidence of deductive and inductive reasoning processes used to solve problems. (c) Data are interpreted using appropriate mathematical computations/techniques to obtain derived values to draw conclusions and detect patterns in data. (d) Draw conclusion is defined as making valid inferences on the basis of evidence and/or understanding of science concepts that address questions/hypotheses, and demonstrate understanding of cause and effects. (e) Justification involves using evidence and scientific understanding to explain problem solutions; construct arguments to support the reasonableness of solutions to problems, conclusions from investigations, or scientific explanations (TIMSS, 1994, p. 67).

There are many types of reasoning skills. Piaget (1966) when discussing the concept of a formal operational stage categorises formal reasoning patterns as theoretical reasoning, combinatorial reasoning, proportional reasoning, control of variables and probabilistic and correlational reasoning. Lawson (2002) draws on Piaget and identifies his own set including generating predictions, identifying and controlling variables, drawing conclusions and probabilistic and correlational thinking as reasoning skills. The reasoning skills common to both Lawson and Piaget are controlling variables and probabilistic and correlational reasoning.

2.6.4 Framework of problem-solving skills and sub-skills

Although it is difficult to teach all learners' problem-solving, it would be particularly challenging to teach this skill to primary school learners. Burkhardt (1984) states, "teaching problem-solving is harder" (p. 17). It is no longer to be taught implicitly and left to chance as it now forms part of the RNCS. Teachers need to provide opportunities for developing problem-solving skills in their learners. These skills need to be taught explicitly to the learners.

Critical thinking skills require learners to apply information in new situations and in solving problems (Valentino, 2000). Process skills are used to gather information about the world. Reasoning skills help children make sense of the information they gather by fostering an open mind. It is these three types of skills that could be said to constitute problem-solving skills.

Using the skills and sub-skills that are common to all three types of skills, critical thinking, process skills and reasoning skills, a framework of problem-solving skills was devised to make sense of the complex process of problem-solving. I then went a step further and attempted to group these skills with their related sub-skills. I arrived at the following table (Table 2.4), which attempts to explain my understandings of the different skills as represented by the literature.

Table 2.4 Framework of problem-solving skills and related sub-skills

Skills	Sub – Skills
Reasoning	synthesis (use deductive reasoning to pull together key elements) evaluation (use reasoning to substantiate decision) explanation (stating results, justifying procedures, presenting arguments) questioning reflection (looking back to see if decisions taken were the right ones)
Inference (drawing conclusions from observing and comparing)	querying evidence conjecturing alternatives drawing conclusions observing researching surveying measuring comparing examining ideas
Analysing (breaking a complex situation in its constituent parts to find the underlying structure)	identifying arguments analysing arguments
Application (apply knowledge to a new situation or context)	using ideas and process skills in new situations transferring
Interpretation	categorising decoding significance clarifying meaning exploring

Unfortunately on further examination, this all inclusive framework of problem-solving skills and sub-skills, seems too complicated to be implemented in a primary science classroom and needed further simplification. In primary school, the tasks that learners are asked to do are not very complicated and rarely involve multiple skills. In that, sense the above framework would be too detailed to apply to primary problem-solving tasks. Table 2.5 attempts to provide a simple framework of problem-solving skills that could be used effectively in a primary science classroom. This simplified framework is used in the current study to classify the skills used to solve problems.

Table 2.5 Simplified framework of problem-solving skills for primary school science learners

Skills	Explanation
Interpretation	Understand (tables and illustrations) and find the meaning of what is expected in the problem.
Analysing	Simplify the problem into steps that make the problem easier to solve. Break up the problem in its constituent parts to find the underlying structure.
Application	Apply knowledge (prior knowledge or information given in the problem itself) to a new situation or context (the problem).
Inference	Drawing conclusions and making decisions from observations and comparisons.
Reasoning	Explanation to substantiate decisions taken, justification as well as reflect on decisions taken.

2.7 CHARACTERISTICS OF PROBLEMS

Many tasks were considered for the purposes of this study. However, they had to meet the following basic criteria. Problem tasks chosen for the study were (a) non-routine, (b) had an initial barrier so learner could not recall a solution and (c) required a combination of critical thinking and reasoning. From the literature it seems problem tasks have many characteristics, however the main characteristics that I have identified as being useful in discussion of problem tasks in primary school are:

1. *Specific or integrated* - the problem could be specific and involve only a single concept or the problem could be integrated and involve several concepts across the same or different learning areas.
2. *Closed or open* - if the problem is closed, the solution to the problem could be only one answer rendering it either right or wrong and if the problem is open there could be more than one solution to the problem.
3. "*Paper and pencil" or "make and do*" - the problem could either be answered on paper or could require the learners making something.
4. *Outside or inside* - for an outside type problem the learner is expected to draw on information from their past experience as all the information is not provided and for the inside type problem everything is given in the problem itself. In some problems learners might have to apply previously learnt skills to the information given in the problem to solve it. If this is the case then the problem is regarded as an inside type problem as its solution depends on specific information given in the problem itself.

Examination of the many problems used in TIMSS and other studies shows that problems do not necessarily have only one characteristic. This implies that a problem could have more than one characteristic.

2.8 CONCLUSION

Problem-solving is important for life and developing the skills is part of the first critical outcome of the new curriculum. Besides being an aim of the curriculum, the research literature also emphasises the importance of learners acquiring skills to solve problems. Nevertheless, not much guidance is given to educators on how to implement problem-solving into the science curriculum. Unfortunately, we are not that certain how much problem-solving is taking place in schools and what skills the learners are developing if any.

In addition, we are still not sure what effect gender and language has on learners' achievement in our schools or whether group work has encouraged the development of problem-solving skills. This study attempts to find out how successful learners are in solving science problems at the Intermediate Phase. To aid the analysis a framework was generated to classify the skills used to solve problems. In the following chapter the case study used as well as the research methods that were employed in this study are described.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter will provide a concise description of the methods used in this study. I will also provide an explanation on the suitability of design to answer the main research question: How successful are learners' with science problem tasks at the end of Intermediate Phase? Other key research questions that guided the study were:

1. How successful are they at solving problems?
2. What type of problem tasks can they solve?
3. Is there any relationship between their ability at solving problems and their normal science achievement?
4. Are there any differences between groups such as male and female or across different classes?
5. What opportunities have they had to develop problem-solving skills?

3.1 DESIGN OF STUDY

The study is approached within a post-positivist/realist paradigm (Krauss, 2005), which states that a single mind-independent reality exists, but there are multiple perceptions of this. Realism as a philosophical paradigm recognises the differences between perceptions and reality, and the need for researchers to interact with the participants to understand their perceptions, and so try to reach a partial understanding of the reality itself (Krauss, 2005).

Within a realism framework, both qualitative and quantitative methodologies are seen as appropriate. This is because the dichotomy between quantitative and qualitative is replaced by an approach that is considered appropriate given the research topic. In this study a pragmatic, mixed method approach to research (Johnson & Onwuegbuzie, 2004) is consistent with the purpose of the research and was adopted. This means that the combination of methods and procedures that works best for answering the research questions was used. Both qualitative and quantitative data was collected, using within-stage mixed-model designs (Johnson & Onwuegbuzie, 2004)

It was felt that the most suitable way of approaching the research questions was to do empirical research in the form of an evaluative case study. In general, a number of different categories of empirical research can be identified such as theoretical research, which is enquiry carried out in order to understand; action research, which is enquiry carried out in order to understand, evaluate and change a context; and evaluative research, which is enquiry carried out in order to understand and evaluate. Within educational research, these lead to different types of case study research being theory-seeking and theory-testing case studies, story-telling and picture-drawing case studies and evaluative case studies (Bassey, 1999).

This study being an evaluative case study set out to describe, interpret or explain what is happening with respect to problem-solving in a particular grade at a school. By its nature, this form of study sets out to make value judgements, or to portray events so that others may make value judgements, about the worthwhileness of the case. The expected endpoint is that someone will use these findings to decide whether or not to try to induce change in their situation. In this case, study, the focus was on problem-solving skills with a view to informing policy makers and others of how successfully the new curriculum has been implemented with a view to improving practice.

Bassey (1999) sets out a number of descriptors of educational case study. He writes that an educational case study is an empirical enquiry which is, "conducted within a localised boundary of space and time (i.e. a singularity); into interesting aspects of an educational activity; mainly in its natural context and within an ethic of respect for persons; in order to inform the judgements and decisions of practitioners or policy-makers; in such a way that sufficient data are collected for the researcher to be able (a) to explore significant features of the case; (b) to create plausible interpretations of what is found ; (c) to test for the trustworthiness of these interpretations; (d) to construct a worthwhile argument or story; (e) to relate the argument or story to any relevant research in the literature; (f) to convey convincingly to an audience this argument or story; (g) to provide an audit trail by which other researchers may validate or challenge the findings, or construct alternative arguments" (Bassey, 1999, p. 62).

Using the above characteristics the current study can be described as follows. This was an empirical study conducted at a local primary school during 2004. The particular "singularity" or case was the Intermediate Phase grade six Natural Science classes. The focus was on the Natural Science Learning Area in which the learners were required, in terms of the curriculum, to develop problem-solving skills. The study was carried out by the researcher who was one of the teachers of the three grade six classes enabling much of the data to be collected in its natural context by an insider.

In order for the researcher to evaluate the case, a large amount of data was required in order to explore learners' problem-solving skills, create interpretations and test for trustworthiness. Given the constraints of time and resources of a masters' research study it was not possible to be exhaustive in data collection but sufficient data was collected that could be handled in the time available. The data collected took the form of administering individual and group problem tasks, observation, questionnaires, individual and focus group interviews, document analysis and analysis and comparison with learners' final Natural Science test marks. This ensured that a worthwhile description of learners' problem-solving skills could be convincingly conveyed and the interpretations leading to "fuzzy" assertions would appear plausible (Stenhouse, cited in Bassey, 1999, p. 65). Fuzzy generalisations, according to Stenhouse predict possible occurrences in situations similar to the case. This was then related to the relevant literature in order to contribute to our understanding of primary science problem-solving.

Given that this was an illuminative evaluative case study, it required considerable detail in order to demonstrate that the description of the skills was trustworthy. A very clear audit trail in the form of full data descriptions is provided by which other researchers may validate or construct alternative assertions.

The case study approach of the research process offered a unique opportunity for me, to use my knowledge and involvement in my own research to investigate the process of teaching and learning. When discussing the teacher as researcher, Hitchcock and Hughes (1989) maintain that the "teacher researcher is always normally always an active participant as an observer" (p. 202).

Since case study research takes place among human beings, in this case children, there were a number of ethical concerns I needed to be aware of before commencing with research.
I had to follow ethical procedures when carrying out my research. An ethical clearance form was submitted to receive ethical clearance from the university. Schostak (2003) outlines certain ethical principles, which I had considered when carrying out my research. These were:

- Do you ask permission?
- Do you do it covertly or say precisely what it is you are doing and for what purposes?
- Will anyone be hurt by disclosure of your findings?
- Are there vested interests, which you might be unwittingly supporting?

(Schostak, 2003, p. 6)

Reflecting on these questions helped me to actively develop my own ideas on the methodology that I used for my research. As my research involved grade six learners, parental permission was a pre-requisite before commencing with the research. A description of as well as the reasons for doing the research accompanied the consent letter.

When interviewing, I had to keep in mind the power relationship that existed between the learners and me. Schostak (2003) explains that within the "community of the classroom, teachers are powerful figures in the lives of children" (p. 4). This is even more relevant when research involves primary school learners as these learners are highly impressionable and hold their teachers in high esteem. Gabel (1995) justifies by saying, "the involvement is of a knowing nature with no hidden controls or prescription of direction by the researcher" (p. 4).

My research locates itself in the scheduled programme of the learners, allowing me to proceed with the required curriculum. Primary school teachers are usually classroom-based teachers teaching all learning areas. This simplifies the inclusion of the research within the class program. The outcomes-based education system also provided me with the freedom to implement my research within the set curriculum.

According to Cohen, Manion and Morrison, (2000) "both qualitative and quantitative methods can address internal and external validity" (p. 107). Internal validity refers to the extent to which findings are congruent with reality. Lincoln and Guba (cited in Merriam, 1988) refer to dependability and consistency of data as the qualitative equivalent of reliability. Walker (cited in Merriam) says this involves "presentation of material in forms where it is open to multiple interpretations" (p. 44). Consequently, detailed descriptions will be provided to allow readers the opportunity to both check the researcher's interpretations and warrant for the assertions. Triangulation will be obtained by comparing multiple sources of data. Triangulation and making the audit trail explicit (Merriam, 1988) will also be used to ensure reliability. External validity refers to the generalisability of the study to other situations. Case study research is primarily done in order to understand the particular in depth however; there may be a possibility of generalisations being made about the population to which the individual unit belongs

3.2 THE CASE

The research site for this study was an urban school in the greater Durban area. The participants were grade six learners of a primary school in Sydenham, Durban. This was historically a school for Coloured learners. At the time of this study, the school had a learner population of 900 learners from Reception year to grade seven. Class sizes ranged from 38 to 45 learners per grade unit. The learner population was made up of predominantly Coloured and Black learners. The school is on a central public transport route and therefore attracts many learners from the surrounding townships. Most of the learners are from low socio- economic backgrounds.

All grade six learners at the school participated in the study. The learners were grouped into three classes taught by three different teachers. The class teacher taught Natural Science. The classes were not streamed and therefore comprised of mixed ability learners. Thirty-six percent of the learners were in the A class, thirty-four percent were in the B class and thirty percent were in the C class. Their ages ranged from 11 –15 years.

The learners in this study comprised of Black, Coloured and Indian learners. Since there were only three Indians, they were omitted from the discussion of the results. The majority of grade six learners that participate in this study were Black learners. From my experiences with teaching these grade six learners most of the Black learners do not speak English at home. As a result, school is the only place that many of these learners converse in English. The home language of the Coloured learners is English. The three Indian students were omitted because it was difficult to produce meaningful statistical analysis with such a small group.

The Problem tasks (Appendix A) required learners to choose an answer from a few alternatives given and explain their choice. Thereafter, ten learners were interviewed using a framework of questions on their experiences of the problem-solving tasks. The ten learners were selected for the interview ensuring a balanced sample representing learners who performed well and not so well.

A single class taught by the researcher was chosen for the Group tasks. The smaller group allowed the researcher to observe the group activity. This option was not accessible in the other classes as all were timetabled together. Forty grade six learners participated in groups for the Aquarium problem (Appendix B) as it was a "hands on" activity that required manipulation and smaller learner numbers were needed. These learners were required to complete a questionnaire (Appendix C) based on the task. A random group was selected for the focus group interview because all the groups had managed to complete the task. Thirty-six learners participated in the Construction task (Appendix D). These learners also completed a questionnaire (Appendix E) on completion of the task. Documents from grade four, five and six class work, tests, and textbooks were analysed according to the framework of skills that was used to design the tasks.

The grade chosen as the case study was convenient as I worked in the school. Where it was possible only to work with one class due to the need to observe and interview my own class was chosen purely for convenience. As mentioned, all classes were following the same program and were of mixed ability.

3.3 METHODS OF DATA COLLECTION

3.3.1 Problem Tasks Test

In compiling the test, a search of local textbooks and other sources was carried out with little success. In the end, the majority of the tasks were taken from the TIMSS data bank of released items. This was done because these problems were specifically constructed for primary learners and their validity and reliability had been established. Two questions were sourced from McGhee (1997) and Austin, Holding, Bell and Daniels. (1998).

A test comprising of seven problem tasks (henceforth denoted as the Problem tasks) was administered to all 116 learners (Appendix A). All the Problem tasks were "paper and pencil" items, i.e. learners did not have to construct anything or carry out investigations to obtain information in order to solve the problem. The format of responses was a combination of multiple-choice and free response giving the reasons for their choice. One question was free response only.

Each problem was also scrutinised in the way it was presented. The presentation of the problems in this study took the form of diagrams, tables and text. McGhee (1997) maintains that careful consideration should be given to the presentation of problems, in view of the fact that each learner generally demonstrates a preference for at least one problem format and an associated stimulus. He also advises that problems should be presented in an unambiguous manner to help minimise the difficulties experienced (p. 109).

The Group tasks were selected to deal with a "make and do" task, i.e. Construction task (Cope, 1990) and a decision making task which had manipulatives enabling the learners to work together as a group, i.e. Aquarium task (New Standards Project, undated).

The tasks were analysed carefully to ensure they fitted the curriculum, involved a range of problem-solving skills, had different characteristics and relied on information presented in a variety of forms. The analysis is presented in Tables 3.1 to 3.4. It can be seen that the tasks covered these aspects and were not biased to one particular type of problem. A detailed analysis of each problem is provided in chapter four with the findings.

Table 3.1 Framework of Problem tasks according to skills

Problem Tasks	Skills				
	Interpretation	Analysis	Application	Inference	Reasoning
1. Weights			x		x
2. Snow	x	x	x		x
3. Party	x				x
4. Food Web	x				x
5. Planets	x			x	x
6. Machines	x	x		x	x
7. Heavy Bear	x		x		x
8. Aquarium	x	x			x
9. Construction		x			x

The Natural Science Learning Area consists of four main content areas, Life and Living, Energy and Change, Planet Earth and Beyond and Matter and Materials (Department of Education, 2002). The knowledge and concepts for the Problem tasks were drawn from these four main content areas. The Party problem was the only problem that was content free. These content areas form the science curriculum and would have been dealt with by these learners during the Intermediate Phase. The problems were classified according to their science content as in Table 3.2.

Table 3.2 Framework for Problem tasks according to content

Problem Tasks	Content Specific				Content Free
	Planet Earth & Beyond	Matter & Materials	Energy & Change	Life & Living	
1. Weights		x			
2. Snow	x				
3. Party					x
4. Food Web				x	
5. Planets	x				
6. Machines			x		
7. Heavy Bear		x			
8. Aquarium				x	
9. Construction		x			

Table 3.3 Characteristics of Problem tasks

Problems	Characteristics							
	Specific	Integrated	Closed	Open	Paper & Pencil	Make & do	Outside	Inside
1. Weights	x		x		x			x
2. Snow		x	x		x		x	
3. Party	x		x		x			x
4. Food Web	x			x	x		x	
5. Planets		x	x		x		x	
6. Machines		x	x		x			x
7. Heavy Bear	x			x	x			x
8. Aquarium		x		x		x		x
9. Construction		x		x		x		x

Table 3.4 Presentation of Problem tasks

Problem Tasks	Text	Diagram	Table
1. Weight	x	x	
2. Snow	x		x
3. Party	x		x
4. Food Web	x	x	
5. Planet	x		x
6. Machine	x		x
7. Heavy Bear	x	x	
8. Aquarium	x	x	x
9. Construction	x		

3.3.2 Multiple - choice questions

According to McDaniel (1994) multiple-choice questions have become the most common type of test item because of their "flexibility, clarity and reduced opportunity for guessing (p. 147). When deciding the type of test item to use in this research, the multiple-choice option seemed to be the best option especially when working with young primary school learners. Essay tests or paragraph type responses would have been beyond some learners as English was not their first language. It was also found that essentially the same educational achievement can be tested by either essay or multiple-choice tests (McDaniel, 1994). McDaniel suggested five essential rules to keep in mind while constructing multiple-choice items. These were to "avoid trivia and test important concepts, pack the important material into the stem of the question while keeping the alternatives sharp and crisp, make all of your distracters work for you, use novel situations to test applications and avoid trick items" (p. 148). It was assumed that the TIMSS process took all these into account when designing the items. However, the items were carefully checked to see if they were appropriate for the learners in this case.

Multiple-choice questions were used in the "paper and pencil" section of the Problem tasks where the "range of choices were designed to capture the likely range of responses to the given statements" (Cohen, et al., 2000, p. 21). The categories were discreet and exhausted the possible range of responses. The learners were guided on the completion of the multiple-choice questions. Instructions were both written and verbally given to learners to place a cross in the answer block they saw as correct. Learners were also asked to cross only one block.

The reason for opting for the use of multiple-choice questions as an instrument was because they can be "quickly coded and quickly aggregated to give frequencies of response" (Cohen et al., p. 21). This is also supported by Chase (as cited in McDaniel, 1994) when he recommends multiple-choice tests given the greater objectivity and stability of scores from objective tests. To eliminate the probability of respondents interpreting the words differently, I read and explained words that were unclear to the learners before they commenced with the questions. I could have chosen to provide "anchor statements" (e.g. "strongly agree, agree", etc.) to allow a degree of discrimination in response but there was no guarantee that respondents would always interpret them in the way intended (Cohen et al., p. 21). This could have presented a further confusion to the young learners. Instead I ensured as far as possible the questions were unambiguous. The number of distracters was also maintained at a minimum with the range being between two and four distracters.

3.3.3 Interviews and Questionnaires

On completion of the individual Problem tasks, a sample of learners was purposively selected for a semi-structured interview. The ten learners interviewed were selected based on their scores obtained and provided a balanced sample based on achievement. I opted to use a semi-structured interview as opposed to a structured interview as it provided me the opportunity to offer the learners a chance to speak as they wished without any inhibitions. The open-ended nature of the questions also allowed me flexibility when asking the questions to the young learners. A framework of questions was used in the interview:

1. How did you find the problems? What was your overall view of the problem tasks?
2. Which ones did you find difficult? Why?
3. Which ones were easy? Why?
4. Did you have the background knowledge to complete these tasks?
5. What skills do you think was required of you to complete these tasks?
6. Would you like to work out more problems like these?

The reason for providing a framework of questions gave me some direction in terms of covering all the aspects I wanted to. However, learners were still free to expand on any idea they wished to. I found the learners responses to be brief and to the point with few extra comments made. Nevertheless, I managed to obtain interesting information. Six headings based on the framework of questions for the interview were used to tabulate learners' responses and facilitate analysis. These were learners' overall view, difficult problems, easy problems, background knowledge, skills required, and opportunities to solve problems. The interviews served to obtain qualitative data about the solving of the Problem tasks.

A different approach was followed for the Group tasks. A focus group interview was conducted on completion of the Aquarium task. This type of interview worked well as the learners selected had worked in a group to complete this task. It was interesting to observe that learners converse with each other during the interview, assisting to clarify each other's thoughts.

Cohen, et al. (2000) sees this as positive and to be encouraged as, "participants interact with each other rather than with the interviewer, such that the views of the participants can emerge – the participants rather than the researchers' agenda can predominate" (p. 288). With younger children, this method is quite effective, as they need to be urged on by their peers (rather than the teacher). A framework of questions was devised to assist in covering all aspects during the interview:

1. What was your overall opinion of the task? What were your initial feelings when confronted with a task of this nature?
2. What were the difficult areas? Did you experience any challenges during this task?
3. Which parts did you enjoy doing?
4. Did you do this kind of activity before? If yes, then could you supply some examples?
5. What did you think was expected of you for this activity? Do you think you met these expectations?
6. Did you have all the information you needed to complete this task?
7. What skills are involved in this task? Do you think you displayed any of these skills?

Learners also completed a written questionnaire on their solving of the Aquarium task (Appendix D). Learners were allowed to consult with each when completing the questionnaire. Although the task was done in groups, each learner completed a questionnaire.

Learners' response to the Construction task was obtained through analysis of questionnaires, informal interview, observation and photographs. The data was tabulated, analysed and then reported under four different headings, namely teamwork, physical ability, reasoning and success. Information was extracted from this table as needed. Learners also completed a questionnaire on completion of the Construction task (Appendix E). Learners were allowed to consult with each other to complete the questionnaire.

3.3.4 Document Analysis

In an attempt to determine what experiences Intermediate Phase learners have when solving science problems, I collected the work done by the learners in grade four, five and six. This took the form of science notes, tests worksheets and textbooks. I scrutinised these for evidence of the skills relating to problem-solving. It was important to ensure the activities in the textbooks relating to problem-solving actually appeared in the learners' notes, work books or tests. Only this would imply that the learners actually experienced these skills.

The resulting tasks found were analysed according to the skills they required according to the framework for problem-solving skills as shown in Table 2.5. These were compared to the skills that were assessed in the Problem tasks and Group tasks. They were analysed according to their characteristics. From this information, an attempt was made to determine what type of problems learners had experienced during the intermediate phase.

3.3.5 Natural Science Test

Further evidence was collected in the form of the grade six learner's year-end Natural Science marks. The formal curriculum name for this learning area is Natural Science and Technology. However, in this study it is referred to as Natural Science. The Natural Science test was written by all the grade six learners towards the end of the year. It was written under examination conditions where no learners were allowed to copy or consult with his or her peers.

Learners were tested on work covered throughout the year. Although learners were not aware of how the questions in the test would be phrased, the content was known to them. This mark is added together with the learners' continuous assessment mark for Natural Science to get the learners' final Natural Science mark. Learners' continuous assessment mark is calculated by adding the test marks and Technology marks at the end of each section of work. The Technology mark is usually a project or an investigation. The marks used in this study were the final Natural Science marks obtained by each learner for the year.

The test comprised of six questions. Question one was a multiple-choice question where learners were expected to choose the correct answer from the four alternatives given. For question two, learners were required to fill in the blanks. The options were given to them. Question three involved matching two columns. For question four, learners had to decide which statements were true or false and provide a reason for their answer. Learners had to answer questions based on the diagram of the electric circuit for Question five. Question six was based on technology. Learners had to list the steps they would follow when solving a problem. Questions one, two, four and five were for ten marks and Questions three and six were for five marks. Thus, the total score that could be obtained was 50. Overall, the focus was on rote recall of learnt content and understanding of concepts. There were no problem-solving tasks as part of the test.

3.4 SUMMARY

A number of different tools were used to collect data to answer my research questions. These included Problem tasks to determine if learners could use problem-solving skills and Group tasks to determine if they could work together to solve problems. In addition, learners were interviewed to gain an insight to their responses. Their experienced curriculum was analysed searching for problem tasks learners had done over three years. Overall, this provided quantitative and qualitative data, which was analysed and presented in chapter four.

CHAPTER 4

PRESENTATION AND ANALYSIS OF FINDINGS

In this chapter, the findings of the study are described and presented in detail. Each problem attempted by the learners is described giving its characteristics, as summary of learner achievement and examples of their explanations. In addition, document analysis of all the materials used in teaching this grade during the Intermediate Phase is presented. The analysis of the findings is discussed in the following chapter.

4.1 RESPONSE TO INDIVIDUAL PROBLEM TASKS

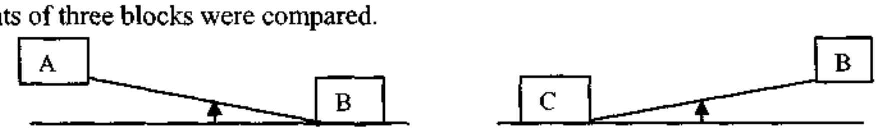
All 116 grade six learners wrote the Problem tasks test (Appendix A). The discussion of each Problem task has been done by first looking at the problem description and then learners' responses to the problem. For the first part of the task, the learners were given the option of choosing an answer from those that were given. Learners had to give a reason for their choice in the second part of the question. They had one hour to complete the seven tasks. I read all the questions to them before they started, as many learners were second language English speakers. I also explained how they should respond to the first and second part of each problem. They were given time to read the questions themselves and ask any questions if they wanted to. No questions were asked.

For comparison purposes, the TIMSS rubrics presented with each question were used which resulted in certain difficulties during marking and analysis. For example, under the category "other incorrect" the number of learners' responses in this category was larger than the given categories. Specific examples of these will be given later in the discussion. In hindsight, I should have adapted and expanded the rubric. Each question was marked using the rubrics and scored as follows: for the correct answer and reason, learners were given a score of four; for the correct answer and wrong reason or the wrong answer and correct reason learners were given a score of two; for the wrong answer and the wrong reason learners were given a score of zero. The maximum score that could be obtained was 28.

In addition to solving the problems, a number of learners were interviewed after the answers had been scored. The learners' responses were audio recorded, transcribed and tabulated. The sample that was chosen for the interview consisted of the learner with the highest score of 26 as well the learner with a low score of six and eight others in between. It was felt that this provided a well-balanced sample of learners.

4.1.1 The Weight problem

The weights of three blocks were compared.



Which one of the three blocks weighs the most? (A, B or C)

A. Block A ☐

B. Block B ☐

C. Block C ☐

Given a reason for your answer ____________________

Figure 4.1 The Weight problem

Problem Description: The content of the problem dealt with weight, which is specific to the Matter and Material content area of the Natural Science curriculum (Department of Education, 2002, p. 76). Learners had to rely on their knowledge of how a scale, balance or see-saw worked to solve this problem. This knowledge should have been obtained in normal lessons or from their playground or home experiences with see-saws and balances. This makes it an outside type problem.

The Weight problem had multiple steps. In the first step, learners had to observe the first illustration and work out which block was the heaviest. They would need prior knowledge of see-saws and balances to see that block B is heavier than block A as it is at the bottom of the scale with block A on the top. The second step was to observe the second illustration and work out which block, C or B was heavier. Once again, from their knowledge of balances, learners would deduce that block C is heavier than block B as block C is at the bottom of the scale with block B on the top. In the third step, which is the more difficult step, learners had to link the two steps through reasoning. This was where the "obstacle" of the problem came in, as it was found that many learners were able to state the given and the goal but were unable to talk about the manner in which they got their answer.

Overall this was a closed Problem task as there was only one correct solution to the question, learners were required to apply their prior experiences of balances to the diagram and reason that block C is the heaviest since it is heavier than block B which is heavier than block A.

Learners' Responses: Of the 116 learners, only thirty-one percent were able to provide the correct answer and reason. Other acceptable reasoning was considered when marking the problems. An example of this was, "C is weighing the most because B is beating A and B cannot weigh better than C". In this example, there was evidence of comparison but the learner could not articulate himself properly and instead used playground terminology. The use of "playground" terminology was accepted and marked correct.

From learners' responses (Table 4.1), it is evident that fifteen percent of learners gave the correct response but their explanations were inadequate in that they only referred to one or two steps of the solution. It appeared from these responses that these learners expressed their responses from just describing the given diagrams. These responses ranged from learners stating, "Block C it got most weight because C is going down," and "Block C is heavy because it touches the bottom line; this means it is heavier than Block B." From these responses, it was apparent that these learners understood the see-saw concept but they did not go beyond the description and attempt to link through reasoning. Only one learner gave the correct reason but chose the incorrect Block A as being the heaviest. This could have been a mistake in ticking the wrong box.

Table 4.1 Rubric and frequency of correct responses for the Weight problem

Code	Response	No. of Learners %	No.	
Correct Response (4 marks)		46	53	
01	C. Because B is heavier than A and C is heavier than B, or any			26
	Equivalent expression.			10
02	Other acceptable			
Partial response (2 marks)				
03	C. Explanation is inadequate.			15
05	The wrong block is chosen but the explanation is correct.			1
06	Other partially correct.			1
Incorrect Response (0 marks)		54	63	
07	B. With or without explanation.			41
08	A. With or without explanation			12
09	B and C (based on each of the two figures considered separately).			2
11	Other incorrect.			5
Nonresponse (0 marks)				
12	Crossed out/ erased, illegible, or impossible to interpret			2
13	BLANK			1
Total		100	116	

Fifty-four percent responded incorrectly. From their responses, it was noticeable that many learners merely stated what they saw in the diagram rather than including all steps. In particular they only chose Block A or B and not Block C indicating that they perhaps tended to focus only on the first diagram: "Block A – It is more slanted than Block B" and "Block B is nearly touching the ground, so I think B weighs the most".

During the interviews when asked which problems they found difficult two of the eight learners interviewed indicated finding the Weight problem difficult, saying "It took too long to find out which one weighed more or less," and "I re-read the whole problem and was confused with the choices A, B and C." One learner felt the Weight problem was easy but did not volunteer any reasons for this. Interestingly this particular learner was one of those who obtained the lowest score, which was zero, for the individual Problem tasks. In the interviews, learners had difficulty explaining how they solved or could not solve the problem.

In summary, the Weight problem was only correctly answered by thirty-one percent of learners. Those who got it in correct but could not provide an adequate reason appeared to have difficulty either dealing with two diagrams, i.e. they only focussed on the first diagram or were unable to link the information provided in the diagrams through reasoning.

4.1.2 The Snow problem

This table shows the temperature and precipitation (either rain or snow) in four different towns on the same day.

	Town A	Town B	Town C	Town D
Lowest Temperature	13 ° C	-9 ° C	22° C	-12° C
Highest temperature	25 ° C	-1 ° C	30° C	-4 ° C
Precipitation (either rain or snow)	0 cm	5 cm	2, 5 cm	0 cm

At which town did it snow?

A. Town A
B. Town B
C. Town C
D. Town D

Give a reason for your answer ______________________________

Figure 4.2 The Snow problem

Problem Description: The content of the problem is specific to the Planet Earth and Beyond content area in the Natural Science curriculum (Department of Education, 2002, p. 69). Learners had to analyse the table to find the town to meet the temperature criteria and then the precipitation criteria or vice versa. This was an outside type problem as learners needed to know the meaning of precipitation and the required temperature for snow to form.

More than one-step was required to solve this problem. Learners had to firstly interpret the data given in the table and then apply criteria for both temperature and precipitation. They had to compare the temperatures in the different towns and eliminate that which did not go below zero. This would immediately omit town A and C, as temperatures are much higher than zero degrees Celsius. In the subsequent step, the next limiting condition needed to be applied. The learner had to now look at town B and town D to see if precipitation was reported. From the table it was evident that there was no precipitation in town D implying that it did not snow there. Learners were then left with town B with temperatures below zero degrees Celsius and precipitation of five centimetres without which the problem could not be solved.

Overall, the problem required specific content knowledge. The problem required the elimination or inclusion of items based on two limiting conditions provided, i.e., multiple steps to the solution. The solution was closed but there was more than one possible path to the solution.

Learners' Response: Overall forty-three percent were able to give the correct answer but only three percent could give the correct answer with a correct explanation. These learners mentioned both temperature and precipitation as factors responsible for it snowing. The other forty percent of learners' answers were regarded as partial responses. Learners correctly predicted that it snowed in Town B but were not able to give an adequate reason and most focussed their explanations on the temperature. For example, a common response was, "Because town B has the lowest temperature" which was not actually correct. Learners appeared to be able to link snow with a low temperature. This is possibly an indication of a language or knowledge limitation preventing learners fully solving the problem.

Fifty-seven percent of the learners responded by selecting the wrong town and by giving the incorrect reason. Example of incorrect responses: "Town C – it is the highest temperature" and "Town D – precipitation was 0 cm". In the above responses, learners gave either the temperature or precipitation as reasons. The reason for this could be that learners are unable to deal with two linked variables at the same time. Some learners attempted to link the two concepts, but although learners mentioned both temperature and precipitation, their reasoning was not explained clearly and the choice of town was incorrect. Examples of this type of response: "Town C – the temperature in C is higher and the cm in town C is higher" and "Town D – temperature 0 cm will snow because the precipitation is lower than 0 °C it is 0 cm". The responses of learners are provided in Table 4.2.

Table 4.2 Rubric and frequency of correct responses for the Snow problem

Code	Response	Learners %	Learners No.	
Correct Response (4 marks)		43	50	
14	Town B because the temperature is below 0 °C and there is 5 cm of precipitation.			4
Partial response (2 marks)				
15	Town B but mentions only the very low temperature			41
16	Town B but mentions only the 5 cm of precipitation			4
06	Other partially correct			1
Incorrect Response (0 marks)		57	66	
18	Town A with or without a reason			15
19	Town A and D because the amount of precipitation is the same.			1
20	Town C because of the precipitation			8
21	Town D because of the low temperature.			1
11	Other incorrect.			36
Nonresponse (0 marks)				
12	Crossed out/ erased, illegible, or impossible to interpret			2
13	BLANK			3
Total		100	116	

When interviewed none of the learners selected the Snow problem as being one of the easier tasks but two selected it as being one of the difficult ones. When asked why, these learners said, "The temperature was confusing" and "I misunderstood low and high temperatures". When asked what background knowledge they needed to solve the problems in general, two learners mentioned that they needed to "know at what temperature it snows" and what was meant by precipitation. Perhaps for these two learners their lack of content knowledge prevented them from solving the problem and not necessarily their reasoning ability to apply the limiting conditions.

As mentioned earlier using the TIMSS rubric presented some difficulties. In this problem, most learners (from the 44 learners) who gave other incorrect response said that it snowed in town C because of the high temperature. This response was not given in the rubric but could indicate some type of pervasive misconception. This type of problem dealing with two limiting conditions, temperature and precipitation, seems to be more difficult for learners. The significant finding is that there is a big difference between getting it correct and providing a reasonable explanation. It appears many can intuitively work it out but are unable to describe their thinking.

4.1.3 The Party problem

Four learners went to a party. After the party, three of the learners were feeling unwell. They were Thembi, John, and Musa. Sally was perfectly well and did not feel sick. This is what they each ate during the day.

Thembi	John	Sally	Musa
Ice cream	Ice cream	Ice cream	Ice cream
Hotdog	Meat pies	Hamburger	Orange
Chips	Chips	Chips	Chips
Meat pies	Hamburger	Fish	Meat pies
Tomato sauce	Popcorn	Popcorn	Tomato sauce

What food do you think could have caused the three learners to feel sick? ____________

How did you work out your answer? ____________

Figure 4.3 The Party problem

Problem Description: The content of this problem is not related to the syllabus but forms part of life experiences and is therefore not a new context for the learners. This was an inside type problem as all the information needed to solve the problem was given in the problem itself. Learners' responses could have been influenced by their real life experiences. Learners had to interpret the table and use reasoning to find a pattern or the common things that were eaten and then eliminate these to find out what food Sally did not eat.

In order to solve the problem learners need to eliminate ice-cream and chips as all the children have eaten this. It could not have been the popcorn or the hamburgers as Sally also ate this and she did not get sick. It could not have been the tomato sauce as only Thembi and Musa had this. It could not have been the orange as only Musa ate this. Using this process of conditional elimination learners would be left with the meat pies as all other children ate this making them sick except Sally.

In summary, this problem required no prior knowledge but was specific to the context of food. It was an inside type problem with only one solution that could be obtained through table analysis by elimination based on one limiting condition of Sally not eating it.

Learners' Response: Fifty-five percent were able to correctly deduce that the meat pies were responsible in making the other learners sick. Only one learner's response looked at what the other children ate and did not compare it to what Sally ate and was thus rated as a partially correct answer: "I looked at what they were eating during the party; I found it was meat pies that make them sick." Forty-four percent responded incorrectly to the problem. Most of the incorrect responses chose ice cream as making the learners sick. Various reasons for this could be that ice-cream appears first on the list or learners have had personal experiences of eating too much ice-cream and getting ill!

> Ice cream – I can see that they all ate the same thing, which was ice cream, and they all became sick.
> Ice cream – because ice cream has much fat than the others and has too much fat in it and sugar.

One learner did not seem to understand what was expected of the problem and suggested different things that each one ate that made them sick. This learner may have based his or her answer on personal experience of food and ignored the data supplied.

> Because Thembi and all had not nice things, I worked out the answer by eating tomato sauce that is not good. John ate meat pies, which is junk food that's why he's sick and Musa ate ice cream, which was ice cold, and that's why he's sick.

The responses of learners' are provided in Table 4.3.

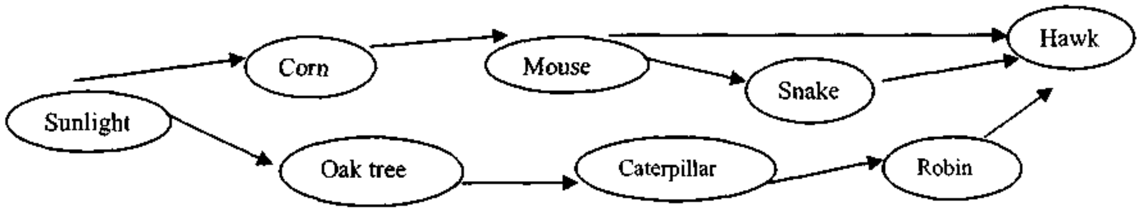
Table 4.3 Rubric and frequency of correct responses for the Party problem

Code	Response	Learners		
		%		No.
Correct Response (4 marks)		55	64	
21	Because all the others ate meat pie except Sally.			49
22	Sally did not eat the meat pie			8
02	Other acceptable.			6
Partial response (2 marks)				
06	Other partially correct			1
Incorrect Response (0 marks)		44	52	
24	Incorrect reason given			2
25	Any other			38
11	Other incorrect			10
Nonresponse (0 marks)				
12	Crossed out/ erased, illegible, or impossible to interpret			1
13	BLANK			1
Total		100	116	

During the interview three learners made it known that the Party problem was easy. The reasons cited for this include, "It was easy to find out what they ate," and "I looked at what they all ate and only Sally did not eat meat pies, I used reasoning to think about the answer." Only one learner that was interviewed admitted to finding the Party problem difficult because "of the number of food given". The significant finding is that learners answered this problem reasonably well and could provide reasons. This is possibly because this problem had a context all could understand and only required the application of one limiting condition. Where learners got it wrong they appear to have ignored the given data and focussed on personal experience or bias. They were possibly distracted from the task by the context.

4.1.4 The Food Web problem

Look at the Food Web below.



If the corn crop failed one year what would most likely happen to the robin population?
Robin population may decrease ☐
Robin population may increase ☐
Robin population would stay the same ☐

Explain your answer. ______________________________

Figure 4.4 The Food Web problem

Problem Description: The problem was content specific to the theme Life and Living (Department of Education, 2002, p. 62). Learners had to use their past experience of a food web and the mutual dependency between plants and animals to solve this problem making this an outside type problem. The answer could be any one of three making this an open problem. If the corn crop failed the robin, population may decrease, increase or remain the same. Any one of these responses would have been correct if a correct explanation was given. Expected answers included: The robin population may decrease because the mouse population would decrease and the hawks would eat more of the robins; the robin population may increase because the hawk will die if the mouse starves as there is no corn; the robin population may remain the same because the mouse would find other grain to eat so the hawk will be unchanged. In summary, this was an outside type, open-ended problem requiring previously learnt knowledge of the food web and the mutual dependency of plants and animals. Learners had to express their reasoning in the form A is linked to B, which is linked to C.

Learners' Response: In this problem, no marks were awarded for a partial response as all three options could be chosen. Only eleven percent provided a choice and the corresponding correct reasoning. Eighty-one percent responded with incorrect reasons. Some examples of incorrect responses showed evidence of faulty reasoning:

> Robin population may decrease – It will decrease because it will not have food to eat.
> Robin population may increase – If the crop failed one year the robin will not have some crop to eat.
> Robin population would stay the same – Robins do not eat corn they eat caterpillars.

However many learners (50%) gave responses which were incorrect because there was no evidence of reasoning either incorrect or correct. From these responses, it appears that the concept of the food chain and the mutual dependency of plants and animals were not understood, as learners were unable to explain the reasons for their choice. The responses of the learners are provided in Table 4.4.

Table 4.4 Rubric and frequency of correct responses for the Food Web problem

Code	Response	Learners %	Learners No.
Correct Response (4 marks)		11	13
26	Robin population may decrease. Explanation based on predators (snake/hawks) eating more robins if mice die.		6
27	Robin population may increase. Explanation based on predators (snakes/ hawks) dying due to lack of food (mice).		2
28	Robin population would stay the same with a feasible explanation.		3
02	Other acceptable.		2
Incorrect Response (0 marks)		88	103
29	Robin population would decrease. Incorrect explanation based on robins starving if snake die. (confuses prey/ predator relationship)		5
30	Robin population would decrease. Incorrect explanation based on the robin needing corn to survive.		14
31	Robin population would stay the same. Incorrect explanation based on the robins' not needing corn to survive or not being connected to corn in the Food Web. (Does not consider the effect of the predators)		18
11	Other incorrect responses		57
Nonresponse (0 marks)			
12	Crossed out/ erased, illegible, or impossible to interpret		7
13	BLANK		2
Total		100	116

During the interviews, five learners selected the Food Web problem as being difficult. Learners did not seem to be able to read the food chain and interpret the direction of the arrows correctly. This was evident when a learner said, "I was confused about how sunlight can eat mouse." Other reasons given were, "I did not understand," "it took long to work out but I managed them," and the "Food Web was hard, I too had to figure out what to write." One learner admitted that if the problems were hard then she wrote down anything. None of the learners interviewed said that they found this problem easy. Two learners felt that they required background knowledge to answer this question, as they needed to know if population will increase or decrease as they "struggled with this." In summary learners found this problem difficult with only eleven percent able to respond with coherent reasons. It is surmised that the context of the food web was not well understood and learners had difficulty expressing their reasoning.

4.1.5 The Planet problem

Simone and Renata were discussing what it might be like to live on other planets. Their science teacher gave them data about two imaginary planets. The table shows these data.

	Astrid	Athena
Atmospheric conditions	21% oxygen 0,03% carbon dioxide 78% nitrogen Ozone layer	10% oxygen 80% carbon dioxide 5% nitrogen No ozone layer
Distance from a Star like the sun	148,640,000 km	103,600,000 km
Rotation on Axis	1 day	200 days
Revolution around Sun	365 ¼ days	200 days

On which of the two planets would it be difficult for humans to live?

A. Astrid ☐
B. Athena ☐

Give reasons why it would be difficult to live on this planet. ________________

Figure 4.5 The Planet problem

Problem Description: This question was content specific to the theme Planet Earth and Beyond in the Natural Science curriculum (Department of Education, 2002, p. 69). Learners had to study the information given in the table and decide which planet would be difficult to live on and provide reasons for their choice. They needed to know the atmospheric conditions required for comfortable living, making this an outside type problem. Learners would have deduced that it would be difficult to live on planet Athena since there is a larger amount of carbon dioxide than oxygen, which is required to breathe. The close distance from the sun and no ozone layer would make the suns rays harmful. The rotation of the earth on its axis takes too long and the earth's revolution around the sun is short. This is a closed problem since there is only one correct answer and fixed reasons based on the data given. The solution requires learners to compare the data against a standard and use simple deductive reasoning.

Learners' Response: Over seventy percent responded with the correct answer and reason to this problem. Thirty-five percent responded by giving a combination of reasons for their choice of planet. The most common reason given was that there was too little oxygen and too much carbon dioxide. Fifteen percent gave a partial response mentioning that it would be difficult to live on Athena but provided incorrect explanations. Some learners' responses were impossible to interpret: "Athena – because Athena was difficult to live on that planet for human to live" and "Athena – because it is an Athena in the planets so we will be in a planet." (sic)

Only about one learner cited rotation and the position of the sun as a valid reason for his choice. Twenty-nine percent responded incorrectly to the problem. For example, responses given included:

> Astrid – is not far away from earth so they can go to the planet and revolution around the sun.
> Astrid – because it has less oxygen, no ozone layer, less nitrogen and has too much carbon dioxide and too many days so that is why you can not live there.

Five of the learners interviewed said that the Planet problem was difficult. Learners said that they chose Astrid because it had the highest level of oxygen because they knew oxygen was needed to breathe. Another learner said, "People need to breathe but we don't need to breathe every time but we need to have some air". None of the learners found this problem easy and yet learners performed well. On reflection, this might not be a problem, as most learners know oxygen is required for survival. They could see after the first data line that the answer was the choice with the least oxygen. The responses of learners are provided in Table 4.5.

Table 4.5 Rubric and frequency of correct responses for the Planet problem

Code	Response	Learners %	Learners No.
Correct Response (4 marks)		71	82
33	States that there would be too much carbon dioxide.		3
34	States that there would be too little oxygen to breathe.		16
35	Refers to bound rotation that is the periods of revolution around the planets own axis and rotation around its sun are the same. Hence, one side of the planet is always facing the sun and therefore is hot while the other side is always dark and cold.		1
36	States there is no ozone.		5
37	Any combination of above codes.		40
Partial Response (2 marks)			
38	States correct choice, B with incorrect reasoning		17
Incorrect Response (0 marks)		29	34
11	Other incorrect or seriously incomplete.		27
Nonresponse (0 marks)			
12	Crossed out/ erased, illegible, or impossible to interpret		4
13	BLANK		3
Total		100	116

The significant finding is that learners performed relatively well as most of them could identify oxygen as a requirement for living. The task only required prior content knowledge and application by simple comparison.

4.1.6 The Machine problem

Machine A and machine B is each used to clear a field. The table shows how large an area each cleared in 1 hour and how much gasoline each used.

	Area of field cleared in 1 hour	Gasoline used in 1 hour
Machine A	2 hectares	¾ litre
Machine B	1 hectare	½ litre

Which machine is more efficient in converting the energy in gasoline to work?

A. Machine A ☐
B. Machine B ☐

Explain your answer. ______________________________

Figure 4.6 The Machine problem

Problem Description: This question was specific to the Energy and Change content area in the Natural Science curriculum (Department of Education, 2002, p. 66). At the start of the test, learners were told that "gasoline" is the same as petrol. The data given in the table had to be interpreted to find the relationship between the area of field cleared and the gasoline used in one hour. To be able to compare the two machines, the area of field cleared has to be the same. It is easier to double the area and gasoline used for machine B than to halve that of machine A. Therefore, machine A clears two hectares using ¾ litre of gasoline and machine B clears two hectares using one litre. From the information it is now evident that machine A is more efficient as it uses less gasoline than machine B to clear the same area.

The problem had to be analysed by breaking it up into the three concepts of time, gasoline used and area cleared. Learners had to realise that time was a constant given at one hour. In summary this is an inside type problem which is closed with more than one possible path to the solution. The emphasis is on arithmetic reasoning and producing a situation where a fair comparison could be made between the two.

Learners' Responses: Although fifty-four percent of learners responded with the correct choice, only eighteen percent were able to supply both the correct choice and correct reason. Forty-six percent responded incorrectly. A significant fact is that a large number offered explanations, which were wrong. The majority either focussed on the smaller number, ½ or simply wrote a description rather than gave a reason. Some incorrect responses were: "Machine B – takes less gasoline it makes it better to cut the field cause it take one hectare," and "Machine B – can clear the area field in one hour. And ½ a litre of gasoline used."

A pattern that emerged from the incorrect responses indicated that learners did not realise there was anything to work out and chose machine B as it used less gasoline. They looked at the table and saw that machine B only used ½ litre compared to machine, A which used ¾ litres. There was no sense of the need to have a fair comparison. Thirty-six percent correctly predicted that machine A is more efficient but the reasons given merely restate the evidence in the table without explaining. An example of this is: "Machine A – is 2 hectares but B is 1 hectare so it means it is working more than machine 1". The responses of learners are provided in Table 4.6.

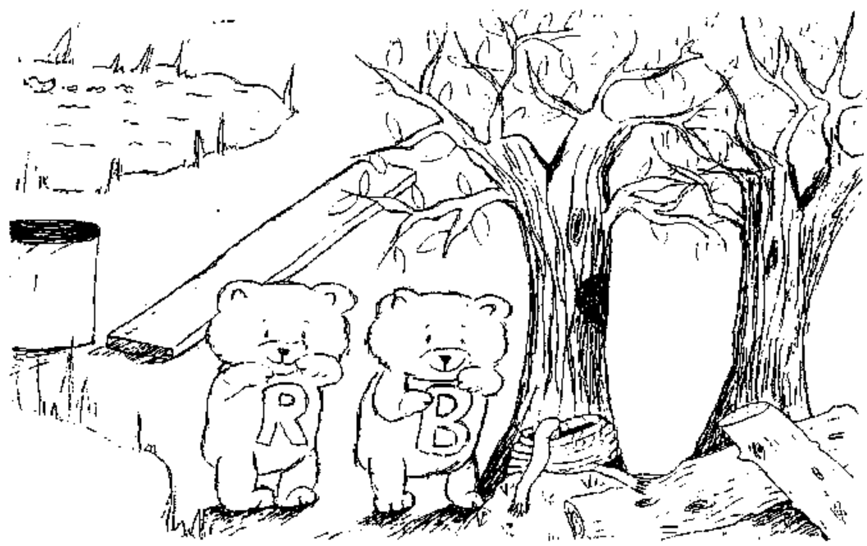
Table 4.6 Rubric and frequency of correct responses for the Machine problem

Code	Response	Learners		
		%	No.	
Correct Response (4 marks)		54	63	
39	A. Because it uses less gas per hectare.			11
40	A. Because $^{3}/_{8} < \frac{1}{2}$, OR a similar expression			1
02	A. Other correct.			9
Partial Response (2 marks)				
43	A. Mentions that it is clear the most area is cleared per hour.			11
44	A. Other wrong explanation or no explanation given			31
Incorrect Response (0 marks)		46	53	
41	B. With an explanation.			40
42	B. With no explanation.			2
11	Other incorrect			8
Nonresponse (0 marks)				
12	Crossed out/ erased, illegible, or impossible to interpret			0
13	BLANK			3
Total		100	116	

During the interviews, only one learner acknowledged finding the Machine problem difficult. Besides saying that it "took long to work out," no other reason was given. A significant finding was the big difference between choosing the correct machine and providing a reasoned explanation for the choice. Learners appeared to look at the table and just focussed on the smaller number (½) and did not realise that a fair comparison and arithmetic calculations were required to arrive at the answer. They did not engage with the problem but dealt with it superficially resulting in a large portion of incorrect explanations.

4.1.7 The Heavy Bear problem

The diagram below shows two bears in a wood, surrounded by various materials.



You are invited to suggest how two bears could prove which one was the heavier using only material found in a wooded area. ____________________

____

____

Figure 4.7 The Heavy Bear problem

Problem Description: The content in this problem was specific to the Matter and Material content area of the Natural Science syllabus (Department of Education, 2002, p. 76). This was an open-ended problem and all suggestions were considered provided that a valid explanation was given. Learners had to find ways in which to compare the weight of the bears. From their background knowledge of weights and see-saws, learners should realise they needed a scale or a balance to compare the weights of the bears.

Learners needed to know that using a scale or balance, the heavier bear would be at the bottom of the balance or scale with the lighter bear at the top. By observing and interacting with the illustration, they had to decide what they could use to make the scale or balance. A few alternatives are available. Learners could use the plank and a drum to make a see saw which would be used to compare the weights of the bears. They could also use the plank on the log or the log on the drum to make a see saw.

In summary, this was an open, inside type problem that required learners to interpret the illustration, apply their knowledge of weights and use reasoning and creativity to arrive at the solution.

Learners' Responses: In this problem, no marks were given for partial responses as all the responses could have been accepted if they were accompanied by plausible explanations. Thirty-seven percent were able to solve his problem and provide ways to find out which bear weighed the most. Fifty- three percent of the responses made were considered incorrect. Some incorrect responses focussed on the bears' strength and not their weight:

> They will prove which one is the heavier they will need to pick up the tree that was already chopped down. So the one that picks it up lighter is the heaviest and the one that can't pick it up is not the heaviest (sic).

Ten percent of responses were either blank or impossible to interpret. This number was significant because all the information required to solve this problem was provided in the illustration itself and yet learners were unable to put together a plausible explanation. Children usually have playground experiences of see-saws and it is surprising that as many as ten percent of learners were unable to even begin to apply this prior experience to this problem.

During the interviews, only one learner reported finding the Heavy Bear problem difficult. The learner did not elaborate on this but simply said, "If the problem was hard then I wrote my own things down". This is a point of concern, as it seems learners might not have given the problems the attention they deserved. Six learners out of the ten interviewed felt this problem was easy because they could look at the picture and think of the answer, i.e. the answer was available in the picture. For example one response was, "It was easy because had to look at the pictures to see which is the heaviest." The responses of the learners to the Heavy Bear problem are provided in Table 4.7.

Table 4.7 Rubric and frequency of correct responses for the Heavy Bear problem

Code	Response	Learners %	No.	
Correct Response		37	43	
47	Using the plank or log as a see- saw			42
02	Other acceptable.			1
Incorrect Response		63	73	
49	Tasks involving feats of pure strength, e.g. Lifting logs			2
50	Pulling themselves up the tree			2
51	Climbing the tree			9
52	Tug-o-war			4
54	The amount of splash as they landed in the water			1
11	Other incorrect responses			44
Nonresponse				
12	Crossed out/ erased, illegible, or impossible to interpret			5
13	BLANK			6
Total		100	116	

A large number of learners' responses were coded as other incorrect responses. From this group of the 44 learners whose responses were coded as "other" two main reasons surfaced. Learners either mentioned all the things in the table without saying how they could be used or they looked at the pictured and saw that bear B looked slightly larger than bear R and assumed that if the bear was larger it should weigh more. A significant finding was that learners appeared confused about the concept of weight and strength and incorrectly assumed that if the bear was stronger it weighed more.

4.2 RESPONSES TO GROUP TASKS

The Aquarium task and Construction task were carried out as group activities. The purpose of this was to see if learners respond differently to Group problem tasks. The analysis for the Aquarium task was done using data from learner's responses to the questionnaire, the evidence of reasoning scores and the focus group interview. The analysis of the Construction task was derived from the questionnaire as well as information obtained from interviewing learners and observing them while they completed the task.

4.2.1 The Aquarium task

Imagine that your science teacher asks you to do a special job and gives you these written directions: Your class will be getting a 135-litre aquarium. The class will have R25,00 to spend on fish. You will plan which fish to buy, which will help you design an attractive aquarium with no problems. Use the accompanying information (Choosing Fish for your Aquarium) to help you choose the fish. The information tells you things you must know about the size of the fish, how much they cost and their special needs.

Choose as many different kinds of fish as you can. Then complete the task sheet explaining which fish you choose.

1. Tell me how many of each kind of fish to buy
2. Give reasons why you choose to buy those fish for the aquarium
3. Show that you are not overspending and that the fish will not be too crowded in the aquarium.

Figure 4.8 The Aquarium task

The Aquarium problem (Appendix B) was adapted from the New Standards Project (undated). The concept of community of animals, in this case fish in an aquarium, is dealt with in the Life and Living content area of the Natural Science syllabus (Department of Education, 2002, p. 62). This was an extended, open-ended problem with more than one solution. Forty grade six learners participated in this activity. Groups of six or seven learners were formed according to where learners sat in class. There were four groups of seven learners and two groups of six learners. Learners had an hour to work together in groups to plan and design an aquarium.

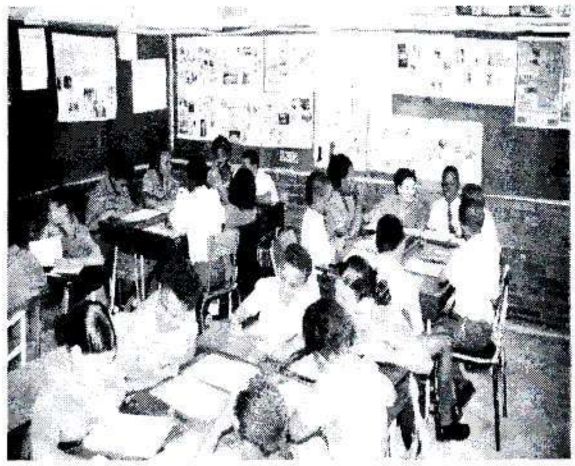
 

Figure 4.9 Learners working in groups on the Aquarium task

Although there were two main limiting criteria of money and crowding there were also other criteria to consider to complete this task. Learners had to also consider the total length of the fish that could not exceed 75 cm, the cost not exceeding R25, the total number of fish in the tank, the special needs of the fish as well as the attractiveness of the aquarium. Templates of the needs, cost and length of individual fish were supplied so assist learners. Since the information required to solve this problem was given in the task itself, this is regarded as an inside type problem.

Even though the Aquarium task was performed in groups, learners were required to complete an individual questionnaire (Appendix D) in class immediately after the completion of this activity. The reasoning behind this was to establish individual learners understanding of the task they had just completed. Learners were not penalised for language related errors in their explanations. A rubric, which focussed on evidence of reasoning in designing the overall aquarium, was used to score the questionnaires. This was adapted from the New Standards Project (undated). Scores ranged from one to five.

Applying the evidence of reasoning rubric to the questionnaire yielded Table 4.8, which shows the number of learners scoring from one to five. From the scoring, it is evident that the majority of learners were able to apply reasoning skills to solve this problem. Only ten percent of learners were unable to do this. Learners were able to work out that they needed to triple the length of fish needed for a 35-litre aquarium. The example given was that of a 45-litre aquarium. This showed that learners were able to use reasoning to work this out.

Table 4.8 Range of scores for Aquarium task

Score 1-5	No. of learners N=40
5	6
4	10
3	9
2	11
1	4

Since all groups completed the task that was assigned to them, a random group was selected for the focus group interview. Given that the focus of the interview was to establish how members of the group worked together, therefore all the learners interviewed belonged to the same group. Many different aspects of the Group task could be discussed based on the data collected. However, given time and space limitations only the two main limiting criteria, crowding and money will be discussed in detail.

It was interesting to note that each of the six groups that participated in this activity chose a different combination of fish. For example one group of learners chose five different fish and another group of six learners chose just two fish. Surprisingly there were inconsistent responses from members of the same group regarding the number and type of fish chosen. For example from one group, three learners reported choosing fish that were not what the rest of their group members chose. A number of reasons for this can be given. These learners might not have understood the questions. They might have not had sufficient time to complete their answers. Or they might not have worked with their group in choosing the fish and could not remember the choices made by the group. Unfortunately by the time the questionnaires were analysed it was too late to follow this up through individual interviews.

Learners were unable to apply all the criteria simultaneously to the task on hand. They were also unable to explain their choice of fish, relating it to the criteria, which were given for the task. Although one group of six learners chose Ramirez Dwarf Cichlid and Velvet Cichlid, only one learner from that group indicated the reason as being that these fish must be kept together with other Cichlid which should have been the main reason.

Learners did not apply all the criteria while the majority chose a variety and correct cost many forgot to take into account length. Only three learners indicated the length of fish did not exceed 75 cm and was thus not overcrowded. Seven learners worked out the length of fish to be 74 cm. Twelve learners choice of fish totaled 72 cm. Four learners had just 50 cm of fish.

Learners had a budget of R25 to spend on fish for the aquarium. From learners responses the money spent ranged from R15 to R30. Since learners performed the task in groups it was not expected that learners in the same group would differ e.g. one learner spent R15 and one learner spent R30. Table 4.9 shows the money spent on fish.

Table 4.9 Money spent on fish chosen for the aquarium

Cost	Number
R15	1
R18	5
R20	4
R22	8
R24	5
R25	13
R30	1
No response	3
Total	40

Arithmetic skills were required to calculate the cost, length and number of fish. It was surprising that only seven learners gave cost as their reason. Learners' inconsistent responses could be a sign of learners having difficulty with the arithmetic calculations needed to work out cost.

It seems learners were absorbed with their real life experiences which resulted in their being unfocused from the criteria given to them. This was evident from the interview when learners mentioned "learning new names of fish", "colours of fish", "cutting and sticking" and "being with friends and working together" as things they enjoyed in this task.

Overall, there was a positive attitude towards the task as learners described the activity as "kinda fun." During the focus group interview learners said, they were "hesitant" to begin the task, as it seemed difficult. Nevertheless, once they got started "it was very interesting" and "they began to enjoy the activity." When asked what they found difficult, learners mentioned the limiting criteria that were set for the task. The many criteria set out for the activity contributed to the learner's initial feelings, as learners felt "overwhelmed" by the task before them.

In many instances the reasons given were unrelated to the criteria but tended to be more towards personal preference. Learners "picked out fish they liked" for their aquarium. Learners who worked well in groups seemed to enjoy the activity and were much more successful in the tasks than other groups. They "learnt to work together as a group as the group listened." They felt that this was better than working individually as you "can depend on members of your group." In hindsight I might have allowed learners to complete the questionnaire in a group as the task was performed in a group.

4.2.2 The Construction task

Instructions:

1. You are required to construct the highest free – standing structure from the newspaper provided and 50 cm of cello tape.
2. You have one hour to complete the task.
3. You can only use the newspaper and cello tape provided nothing else.
4. I will walk around every 15 minutes to monitor your progress.
5. You are going to work in-groups of six.
6. At the end of the task, the group with the highest freestanding structure wins!
7. Please, answer these questions after the activity. You may consult with members of your group.

Figure 4.10 The Construction task

Problem Description: Thirty-six grade six learners carried out the Construction task (Appendix C). The Construction task could be associated with the Matter and Materials content area of the Natural Science syllabus. Learners were expected to work in groups to complete this task in one hour using the paper and cello tape provided. Due to the nature of the task, which required the groups to construct a physical tower it, was difficult to allocate a problem-solving mark to each learner. The focus here was to determine how they worked in groups to solve a problem. To obtain information, I observed the groups, questioned individuals as they worked and gave all learners a written questionnaire about the task. Their responses to these questions gave an indication of how they felt at that precise moment. On completion of the task, learners were given a questionnaire to complete (Appendix E). The questionnaire provided the learners who were shy to respond to the verbal questioning, a medium to voice their opinions. Learners were observed and photographed at regular intervals. The photographs provided a visual sense of how learners worked together as a group. A detailed description will be provided of two groups, one group, which worked well in a group, and one which did not.

Figure 4.11 Learners working in groups on the Construction task

The group that finished the task first worked well together. They listened to each others suggestions and the tasks were shared equally. The tasks of rolling, sticking as well as placing rolls of paper one on top of the other was done efficiently. All members in this group enjoyed working together and appeared to realise the importance of team work in completing the task. This group began with rolling the paper and proceeded to form the tallest free-standing structure in the class. Initially their structure fell but they persevered and strengthened the base of the structure by using more rolls of paper. Trying an alternative method indicated the group used trial and error as a problem-solving strategy.

The group that finished last did not get on well together. They fought continuously with each other with each learner trying to have his or her own way. There was no initial distribution of tasks, which could have led to the group being disorganised. The first structure had a flat bottom which was later replaced with rolls of paper. Learners reused their cello tape numerous times and as a consequence it was not sticky enough towards the end of the task. This resulted in the final structure being tied with paper at the joints. The structure itself was not very high and unable to stand on its own. This group also used the trial and error strategy. However, their inability to work together as a group contributed to their being unsuccessful in this task.

Analysis of the questionnaire revealed that twenty-eight learners enjoyed working together and the remaining eight learners did not enjoy working together. The groups that were successful in this task enjoyed working together. In answer to the question" what was your favourite part" two responses stood out. Twelve learners' commented on the success of getting the tower to stand while the next highest was finding the falling of the tower as most enjoyable. Many learners expressed their enjoyment during the activity and thought it funny when the towers fell. Other responses included "cutting, sticking and rolling the paper, "working in a group". This could be attributed to the learners' difficulty in trying to express them in the English language. Unexpectedly only two of the six learners in the winning group said that finishing first was the most enjoyable aspect. I expected all learners in the group that finished first to have included this as their favourite part of the activity. Two learners who indicated that they did not have a favourite part explained that they enjoyed the entire activity and could not just pick out one part.

Fourteen learners felt the part when the tower fell was the unfavourable part of the activity. Six learners complained that members from there own groups sabotaged the activity. This was done deliberately as learners dropped the towers by kicking and blowing them down. Eight learners said they did not enjoy the activity when members of the group fought with each other. Although some learners clearly found working as a group as an advantage, some learners' thought otherwise.

Twenty- three learners said they learnt something from this activity. Although no learners responded in the negative, thirteen learners did not respond to the question. Some of the learners might have wanted to express a negative response but did not, as they did not want to offend the teacher. Twenty-five learners indicated they learnt to work well in a group, to listen and not to fight. Eight learners said they learnt that planning and designing has advantages. Six learners felt their confidence and perseverance increase during this task.

Overall it appears learners answered the questionnaires haphazardly and simply wrote the first thing that came to their mind which resulted in inconsistencies. There were some contradictory responses within the groups. For example, all the learners in group two enjoyed working together as a group except one learner. Although this learner said "no" he did not enjoy working as a group, he later cited working as a group as the part of the activity he enjoyed the most. In response to the last question (Do you think you learnt anything from this task?); he answered in the affirmative and explained that he learnt to work with others. The reason for this could be that he did not understand the initial question (Did you enjoy working with your group?). In the same group, one learner responded as having enjoyed the activity because there was no fighting as they all had turns to do the various tasks. Another discrepancy arose about the amount of cello tape required for the task. One learner said in his response to the questionnaire that they had "too much cello tape." Others in this group did not raise the issue of cello tape as being problematic.

It was surprising that all except one group began the task by rolling the newspaper. Since learners worked in an open area it could be that they copied each other. Although group six initially made a flat base, they too had eventually rolled the paper. Continuous review of the structures occurred sometimes ending with a better product while at other times not. Only one learner mentioned time as a constraint although all learners seemed to be working against the clock to complete the task.

The problem-solving strategy that was used in this task was that of trial and error as learners tried various methods of working the paper to obtain the sturdiest structure. They tried something and got the feedback and when it did not work they tried something else. During my periodic questioning, I asked learners in group two how they got the structure to stand freely. The learners replied that the structure needed to be heavier at the bottom. They therefore rolled four sheets of paper to form the base. They then rolled three sheets and then two sheets and so the weight was distributed evenly.

In summary the evidence collected from this task revealed that learners' success or lack of it was dependent on the group. When learners worked well together their success was greater than when they did not.

4.3 DOCUMENT ANALYSIS

An in depth analysis was done on the documents (science notes, worksheets, tests and textbooks) learners had been exposed to from grade four to six. The purpose of this was to determine learners' breadth of experience with problem tasks. There were twenty-one activities found in science textbooks and learners' class workbooks. Of the twenty-one activities, seven were found in the learners' class workbooks providing evidence that learners had done these tasks. Since an activity on graphs was found both in the grade four and five learners' class work, they are discussed here together. Each of these activities is described in detail according to the framework of skills identified in Table 2.5 as well as the characteristics they displayed.

4.3.1 Description of activities that required problem-solving skills

1. Water Wheel

This "make and do" activity involved making a water wheel. It was found in the grade six-text book, Spectrum by Clacherty, Esterhuysen, Paxton, Ntho and Scott. (2002) as well as the class work, which indicated that the learners completed it as part of their class work. It was content specific to the Life and Living content area of the Natural Science syllabus (Department of Education, 2002, p. 62). This "make and do" activity required learners to design and make a water wheel using recycled material that was able to lift a 500g stone without breaking or falling apart. This task was set after learners completed the section on water. Learners were required to research when, where and why water wheels are used and how water wheels work and apply this to the task making this an outside type problem. The solution to the problem involved more than one step. It was an integrated problem involving the water wheels as well as weight. It was an open problem as all learners' versions of the water wheel would be accepted provided it used recycled material and could lift a 500g stone.

2. Rolling Tank

This "make and do" activity required learners to use elastic force to make a rolling tank. This activity was found in the grade six-text book, Discovering science and technology by Harper (2002) as well as the class work, which indicated that the learners completed it as part of their class work. The content was specific to the Energy and Change content area of the Natural

Science curriculum (Department of Education, 2002, p. 66). Learners had to decide which tank could travel the farthest, which could climb the steepest slope and which is the fastest. The task required more than one step to solve the problem. It was a specific problem dealing with previously learnt knowledge of elastic force making it an outside type problem. It was open-ended as there was no one correct answer and all the learners' efforts were considered.

3. Parachute

The first part of this activity was found in the grade six-text book, Discovering science and technology by Harper (2002) as well as the class work, which indicated that the learners completed it as part of their class work. It involved more than one step in solving it. The content was specific to the Life and Living content area of the Natural Science syllabus (Department of Education, 2002, p. 62). This "make and do" activity required that learners had to firstly make a parachute that will carry a wheat seed to the ground as slowly as possible. They then had to choose one thing that they would change on their first parachute that will make it fall more slowly.

At the start of the activity learners had to research the task to find out what would make the parachute move slowly. In this open-ended problem, various models had to be observed and compared before conclusions could be drawn on which moved the slowest. Reasoning skills were used when changing one aspect in their parachutes. This activity was done at the end of the section on plants as it involved using seeds. However the actual model of the parachute had to be researched by learners in terms of what could be used to make a light parachute thus making it an outside type problem. This task was specific to the factors affecting dispersal of seeds.

4. Electrical toy

This activity was found in the textbook, Discovering science and technology by Harper (2002) as well as the learners' class work, which indicated that the learners have done this task.

The content was specific to the Energy and Change content area of the Natural Science curriculum (Department of Education, 2002, p. 66). In this "make and do" activity, learners could make their own toys or choose from the examples given. This task required learners to know how a circuit works, making use of switches and to incorporate this into their design thus integrating several concepts. It was an open-ended problem as all learners' efforts were considered. This outside type activity was based on previously learnt knowledge of electric circuits.

5. Moral Issues

The activities on moral issues were located in the grade five learners' class work. Although the activities were content free, it formed part of Learning Outcome three, Science, Society and the Environment of the Natural Science curriculum (Department of Education, 2002, p. 10 - 11). This was classified as a problem because it involved critical thinking and reasoning skills in a relevant context. Learners were required to make decisions on various moral issues like crime, abortion, smoking, alcohol and drugs, prostitution, AIDS, experimentation with animals, chemical warfare. The decision taken had to be explained by presenting arguments.

The activities required more than one step to be solved. It was specific as learners had to understand the context of the problem and make decisions on these moral issues. The problem was open-ended as there was no right or wrong answer. It was "paper and pencil" task as learners had to justify their choices by writing it down. It was an inside type problem as learners had to read the extract provided and make informed decisions.

6. Graphs

This activity appeared in the grade four and five learners' class work and not in the grade four and five textbooks. Although the content was free, process skills of interpreting information were required to answer the questions. A graph depicting the uses of petroleum was given to grade five learners. This task was a specific to the issues being discussed. This task was dependent on previously learnt knowledge of interpreting graphs and was thus regarded as an outside type problem. The problem was closed, as the answers to the questions were either right or wrong. The answers had to be written down on paper thus making this a "paper and pencil" task.

4.3.2 Discussion

The analysis of the documents shows that only seven out of the 21 activities available were actually found in the learners' class workbooks in the Intermediate Phase. This suggests that only these seven activities were actually done by the learners for the three year duration of the Intermediate Phase. Of the seven activities, four were "make and do" tasks that were completed in grade six. Three were "paper and pencil" tasks, which were completed by grades four and five.

A summary of the seven tasks described above which learners showed evidence of having done themselves is presented in Table 4.10 below. They were analysed in terms of the analytical tool referred on page 39.

Table 4.10 Summary of the documents analysed

Grade	Task	Skill	Content	Characteristics			
6	Water wheel	Application	Life & Living	Open	Outside	Make & do	Integrated
6	Rolling tank	Application	Energy & Change	Open	Outside	Make & do	Specific
6	Parachute	Inference	Life & Living	Open	Outside	Make & do	Specific
6	Electrical toy	Analysis	Energy & Change	Open	Outside	Make & do	Integrated
5	Moral issues	Reasoning	Free	Open	Inside	Paper & pencil	Specific
5	Graph	Interpretation	Free	Closed	Outside	Paper & pencil	Specific
4	Graph	Interpretation	Free	Closed	Outside	Paper & pencil	Specific

There were many tasks done over the Intermediate Phase but according to the criteria given for them to be problem-solving tasks; many did not fit these criteria. Examination of all the texts found many worksheets most of which had many notes, leaving no place for the learners to interact with the notes. A few worksheets given consisted of filling in the blanks as well as questions that learners had to answer. The grade six work involved technology where learners had to make various things and test them out to make sure they worked according to the criteria given to them. Some tasks, especially in the grade six textbooks were structured questions. Although the structure could serve to guide the learners, it could also restrict them in solving the problem. Learners were not given the freedom to proceed in their unique ways. From the overall document analysis, it is apparent that learners had very few tasks to do that involved problem-solving. Only seven tasks were identified as involving problem-solving of some description or another.

In the following chapter, the overall findings will be discussed and compared to learners' normal end of year tests. In addition, a more detailed analysis to report differences between groups will be presented.

CHAPTER 5

DISCUSSION OF FINDINGS

In the previous chapter, the individual Problem tasks used in the study were described and learners' responses to individual tasks were analysed. In this chapter, analysis and discussion is presented on the problems as groups, e.g. individual problems and group problems, and comparisons are made with other tests e.g. TIMSS. The learners' success at different problem types is also discussed. In addition, findings in relation to differences between the different groups of learners in grade six such as gender groups and classes are presented. Attempts are made to link the findings in this study to other studies.

5.1 LEARNERS SUCCESS WITH PROBLEM TASKS

Examining the overall success at the Problem tasks in Table 5.1, it can be seen that learners' success was uneven.

Table 5.1 Summary of learners' success with the Problem tasks

Problem Tasks	% Fully correct with reasons	% Partially correct	% Incorrect	Mean (max =4)	Mean as percent
1. Weights	31	15	54	1,57	39
2. Snow	3	40	57	1,07	27
3. Party	54	1	45	2,28	57
4. Food Web	11	0	89	0,45	11
5. Planets	56	15	29	2,50	63
6. Machine	18	36	46	1,45	36
7. Heavy Bear	37	0	63	1,48	37

In some, they did well e.g. Planet problem, but in others, they did poorly e.g. Food Web. The same applies for the reasons they gave for the answers. For example in the Snow problem, forty percent could choose the correct answer but only three percent could provide good reasons. However, with the Weight problem it was the opposite with only fifteen percent unable to supply reasons but thirty-one percent getting it correct with a reason.

When looking at the characteristics of the problems there was no strong pattern but rather some preferences. For example, learners seemed to perform better in inside type problems compared to outside type problems. Learners had more success with the Party, Planet and Machine problem (inside) than the Weight and Snow problem (outside). This could be because the outside type problems required the learner to rely on previously learnt knowledge, which appeared to be a challenge for some learners. The exception was the Heavy Bear problem which was categorised as an inside type problem and yet learners did not perform well in this task. The reason for this could be that the Heavy Bear problem was an open problem with multiple answers, just like the Food Web problem. Learners performed poorly in both these open Problem tasks.

Careful consideration was given to the presentation of each task as suggested by McGhee (1997) and there was no indication that the presentation of problems affected learners' success. In general learners achieved higher marks for the four problems with tables (average 46 %) than the three with diagrams (average 29 %) but this is not significant given the large differences within each group. For example, sixty-three percent had the correct answer for the Planet problem but only twenty-seven percent had the correct answer for Snow problem yet both are presented as tables. Obviously, it is not the presentation alone that is causing this large difference but it is more likely to be a combination of factors.

In an attempt to investigate these variables all, the responses were submitted to a factor analysis. Factor analysis is a data reduction technique, which attempts to show if there is an underlying factor to a group of variables. It can be seen that the factors loaded strongly into three components (Table 5.2) with the first component group being the Party and Planet problem, the second component was the Weights, Food Web and the Heavy Bear problems and third component was the Snow and the Machine problem.

Table 5.2 Rotated Component Matrix for the Factor Analysis of Problem tasks

	Component		
	1	2	3
Task Weight		0,606	
Task Snow			0,792
Task Party	0,793		
Task Food Web		0,632	
Task Planet	0,781		
Task Machine			0,697
Task Heavy Bear		0,687	

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 5 iterations.

The problems were then analysed in an attempt to find the most likely underlying factors. These appear to be:

1. Component One – simple reasoning: These two problems were easier as they only required the application of one condition at a time in order to produce the answer. In addition, both problems were inside type problems as all information needed to solve the problem was given, the information was presented in a table format and the problem had only one answer i.e. closed.
2. Component Two – conditional reasoning: These three problems all required the learner to apply linked or conditional reasoning i.e. there were at least two reasoning steps to the answer. In addition all three problems were presented via diagrams and required some prior knowledge i.e. they were outside problems
3. Component Three – number manipulation: Both these problems required the learner to manipulate numbers in some way to obtain a solution. In addition, they required reasoning with two linked variables. The Snow problem involved temperature as well as precipitation. The Machine problem was concerned with the relationship between the area of field

cleared, amount of gasoline used as well as the time. In addition, these problems were closed with only one feasible answer but there was more than one possible path to the solution.

Taken together with the preliminary analysis it appears that there might be factors, which are related to learners' success. Firstly, learners are more successful with problems, which only require one step simple reasoning compared to multiple step linked reasoning. Secondly, learners find information in tables easier than information presented in sketches or diagrams. Thirdly, learners have difficulty reasoning while manipulating numbers.

5.2 LEARNERS VIEW OF SUCCESS

There is very little relation between what problems learners thought they had success in solving and the problems that they actually had success in solving. During the interview, learners were asked which problems they thought were easy and which were difficult. Table 5.3 illustrates the frequency of the problems that were cited as being difficult and easy by the ten learners interviewed.

Table 5.3 Interviewed learners' view of difficulty of Problem tasks

Problems	No. of learners	(n = 10)
	Difficult problems	Easy problems
1.Weight	2	1
2. Snow	2	0
3. Party	1	3
4. Food Web	5	0
5. Planets	5	0
6. Machines	2	0
7. Heavy Bear	1	6

When looking at the comparison of the responses of how difficult or easy the problems were (Table 5.3) and their actual percentage correct (Table 5.1), it is apparent that there is very little relationship between the learners' views of difficulty and the actual difficulty of the problems. Learners performed poorly in the Snow problem with only three percent of learners answering this question correctly. Yet only two out of the ten learners interviewed regarded this problem as difficult.

For the Food Web and the Machine problems only eleven percent and eighteen percent of learners obtained correct answers respectively. One would expect similar difficulty rates to be reported yet five learners thought the Food Web problem was difficult but only two learners thought the Machine problem to be difficult. The correct responses obtained for the Weight and Heavy Bear problem were very similar with thirty-one percent and thirty-six percent respectively. Although six learners thought the Heavy Bear problem was easy, only one thought it was difficult. Learners did not perform well for this problem.

Although learners were most successful with the Planet and Party problem, they focussed on the Party and Heavy Bear problem as being the easiest. Learners were unable to recognise the inherent difficulty in all the problems. Six learners found the Heavy Bear problem to be easy and three learners found the Party problem to be easy. Only one learner (who scored zero out of the possible 28) mentioned the Weight problem as being the easiest.

Some of the learners who scored poorly reported that they found the problems easy while on the other hand those learners who scored well regarded the problems as being difficult. The learner who scored the highest (26 out of the possible 28) remarked, "All the problems were difficult". The learner that scored the lowest said, "They were hard but I coped". One learner who scored 12 (out of the possible 28) found none of the problems difficult and said, "I knew all the answers". On closer inspection, it seems that there is little relationship between what problems learners thought they had success in solving and the problems that they actually performed well in.

5.3 GROUP TASKS

Learners had more success in solving problems when working together in groups. The sets cannot be compared as the task type is different. The Group tasks were "make and do" and the Problem tasks were "pencil and paper". Learners worked well in groups to solve the problems as they all contributed so the success was greater. Groups enjoyed greater success if there were no underlying tensions between the learners in the groups. Reasons for learners performing better in the Group tasks could be attributed to learners working in a group which seemed to increase their confidence as they were able to depend on members of the group.

Learners seemed to have little success with the multiple criteria set for the Aquarium task. It appeared that learners were unable to use all the criteria simultaneously when providing a solution to the problem. Learners were more successful using trial and error to solve the Construction task. The only criteria set for the Construction task was to make the highest free standing structure using the paper and cello tape provided. Learners seemed to have managed with this task.

Both the Group tasks were "make and do", inside type, and open activities. Groups that worked well had more success with the task than the groups that did not work well together. Their confidence increased and they managed to produce solutions to the problems more effectively working together as a group. This observation concurred with the findings of Watts (1991) and Fisher as cited in De Boo (1999) as indicated in chapter 2. Learners seemed to be more involved in the tasks and enjoyed working together. When interviewed after the Aquarium task learners said, "They learnt to work together as a group as the group listened" and they could "depend on members of your group". This could result in the pressure on the individual learner decreasing as there was shared responsibility making the task more manageable (Watts, 1991).

Learners reported they enjoyed working together. For example for the Construction task about seventy-eight percent of learners enjoyed working in a group. I expected them to consult each other when reporting. When they were asked to write up the Problem tasks, which they have done in groups there is evidence they want to give their own answer. From the questionnaires and interviews learners indicated that they learnt from members in their group. However, they did not include the knowledge they learnt in their written responses. Learners were asked to complete the questionnaire for the Aquarium task individually and they were allowed to consult with each other to complete the questionnaire for the Construction problem. However, responses from the questionnaires for the Aquarium and Construction tasks indicate that learners did not work together to complete the questionnaires as there were inconsistent responses within the groups. Unlike the findings of the study by Kempa and Ayob (1995) learners did not seem to include in their written responses views and knowledge obtained from other learners in their groups. This resulted in the inconsistent responses. In this study, it seems that each learner has confidence about writing his or her own explanations. Maybe the nature of the task in this research differs from that in the study conducted by Kempa and Ayob.

5.4 COMPARISON WITH TIMSS AND OTHER STUDIES

The Problem tasks will be compared to other studies they appeared in. This is to highlight the similarities or differences in learners' responses to these problems for the different studies. From this comparison, it would also be interesting to see in which study learners performed better.

For the TIMSS (1994) study, the percent of learners responding correctly to the item reflects the internal average across the countries participating in the study at each grade tested. It is explained in the study that first the percentage of learners responding correctly to the item was calculated for each country. Thereafter an average was calculated across the countries. Since this study used learners from grade six, I used the grade seven scores from the TIMSS study when comparing the scores obtained by the learners as there were no grade six comparative scores. Table 5.4 shows the mean and correct responses to the Problem tasks for this and other studies in which they appeared.

Table 5.4 Mean and correct responses to the Problem tasks

Problems	Source	Mean (max. =4)	This Study Percentage of fully correct responses	Other Studies
1. Weight	TIMSS	1,6	31,0	24,0
2. Snow	TIMSS	1,1	3,4	32,0
3. Party	Hobden	2,3	54,0	12,0
4. Food Web	TIMSS	0,5	11,2	27,0
5. Planets	TIMSS	2,5	56,0	75,0
6. Machines	TIMSS	1,5	18,1	29,0
7. Heavy Bear	McGhee	1,5	37,0	100,0

Out of the five problems that appeared in the TIMSS study, learners had less success with four of them. However, in only one, learners were more successful. Learners had more success with the Weight problem in this study than in the TIMSS study. While this result indicates that more learners can use prior knowledge and reasoning than in the TIMSS study, unfortunately about seventy percent of learners cannot solve the problem.

There was a large difference between the scores for the Snow problem. Given the higher percentage that gave the correct answer but were unable to explain their answer might indicate an underlying language problem. Learners could have also experienced difficulty manipulating more than one variable. It would appear that for the Machine problem learners' inability to manipulate variables and deal with arithmetic calculations resulted in them being less successful than the TIMSS study. Factors contributing to this could be learners experiencing difficulty in manipulating more than one variable as well as language skills required to explain their reasoning. The factor of language was also raised as a contributing factor in the TIMSS study (Reddy, 2006).

The Party problem was also used in a study conducted by Hobden (2003) who found that fifty percent of rural learners correctly identified the meat pies as making the pupils sick but only twelve percent supplied the correct explanation as well. The remaining thirty-eight percent was unable to answer the question correctly. In this study, fifty-four percent of learners were able to answer this problem correctly with the correct reasoning as well. This could be attributed to the context of the problem, which was something learners could relate to. This problem also appeared in the Assessment Matters booklet Number 7, Pattern and Relationships in School Science (Austin, et al., 1998) where it was acknowledged that the "meat pie" could initially be obtained from everyday knowledge of food. However, if a reliable inference is to be made, then initial identification needs to be backed up by the logics of the data. It was deduced that children's belief and personal experience could either override or support their interpretation. They thus concluded, "Scientific interpretation requires the application of personal knowledge and common sense knowledge" (p. 12).

McGhee (1994) conducted a research in an attempt to identify the stages, skills and strategies associated with problem- solving with a sample of sixty learners between the 5-14 age groups. There were a maximum of six learners per age group. He used three problems in his research of which the Heavy Bear problem was one of them. For the Heavy Bear problem, all 18 learners (100 %) between the 10-12 age groups successfully demonstrated the skill reasoning logically to solve the problem. In this study, only thirty-seven percent of the learners answered the problem correctly.

Although the context of the problem is something learners could have related to, a possible reason for this difference in success rates between his study and the current one could be learners' inability to formulate written explanations due to language difficulties.

5.5 COMPARISON WITH THE NATURAL SCIENCE MARKS

The Problem tasks had as their focus the testing of various problem-solving skills. The Natural Science test assessed routine class work, which was strictly out of learners' class notes. The Natural Science test was done under examination conditions after learners had time to learn the prescribed content. The Problem tasks were scored out of 28 marks for each learner for the seven problem-solving tasks. The marks were converted to percentages, which were then compared to the same learner's final Natural Science mark obtained for the year. Only six percent of the 116 grade six learners achieved better results in the Problem tasks than for the Natural Science test. Although this six percent seems like a small percentage, it is significant because these learners were able to use problem-solving skills to complete the tasks assigned to them.

The average score for the Problem tasks was thirty-nine percent and that for the Natural Science test was sixty-four percent. Only three learners obtained below forty percent for their Natural Science marks. It is interesting to note that the same learners that had below forty percent for the Natural Science marks also had below forty percent for the Problem tasks.

Histograms (Figure 5.1) were drawn to give a visual description of the distribution of the marks to see if there is a relationship between the Natural Science and Problem tasks. These graphs represent all 116 learners from all three classes who participated. Examination of the distributions shows that for the Natural Science test the marks are skewed toward the right with a relatively normal distribution i.e. the mean is above fifty percent, while for the Problem tasks the marks are skewed to the left and significantly spread out i.e. the mean is below fifty percent and a high standard deviation. This indicates that there was a much higher variation in success for the Problem tasks- some could do them and achieve high marks while there were others who scored zero.

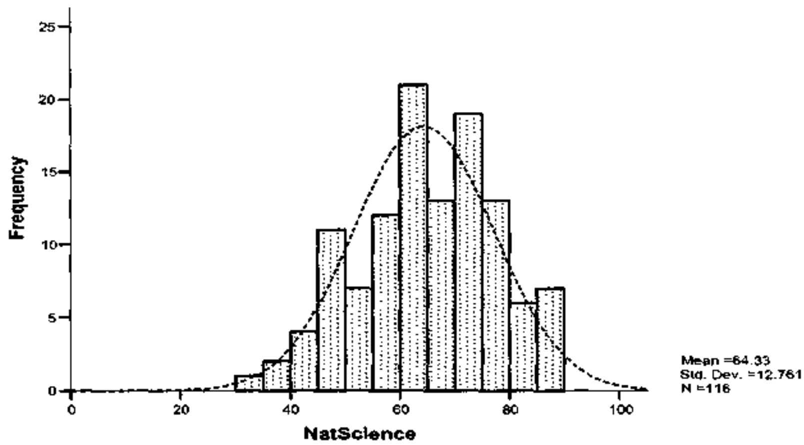


Figure 5.1 Histogram illustrating the distribution of marks for the Natural Science test

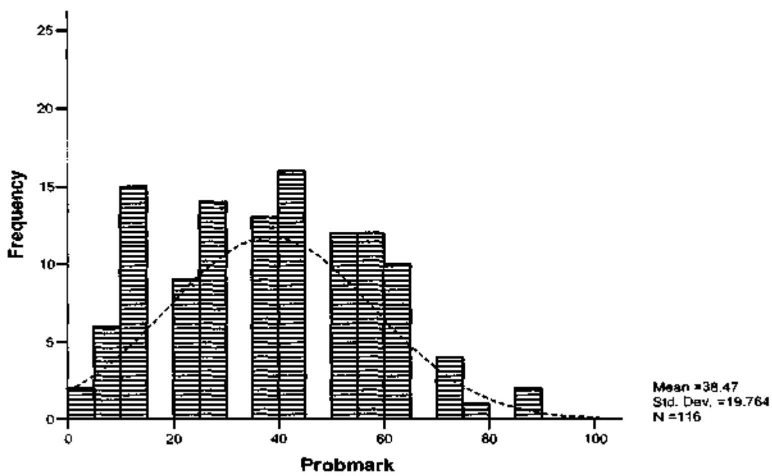


Figure 5.2 Histogram illustrating the distribution of marks for the Problem tasks

A t-test (Paired sample test) was carried out to further see if there is a statistically significant difference between the two sets of scores as both sets of scores are generated by the same group of learners. A statistically significant difference (t = -15,69 df = 115, p< 0.000 two-tailed) was found between the learners scores on their Natural Science test (M = 38,47 SD = 19,764) and their Problem tasks (M = 64,33 SD = 12,761).

This difference was further investigated by producing a scatter plot (Fig. 5.3) to visually see how the marks were related. It can be seen that there are many outliers not close to the line, which would detrimentally influence any attempts at doing a regression analysis. However, you can visually see that the relationship is not strong. Correlation statistics were done to see if a learner has a high score on one task; will this learner have a higher score on the other? The relationship was investigated using the Pearson product-moment correlation coefficient. There was a statistically significant medium positive correlation between two variables (r = ,472 n = 116, p < 0,01) with higher results for Natural Science marks associated with higher results for problem-solving tasks. Although related, the problem-solving mark is not a strong predictor of the Natural Science mark (or vice versa) given the many outliers and medium strength of the relationship. In figure 5.3, the dotted line indicates a perfect correlation while the solid line indicates the calculated regression line for the relationship.

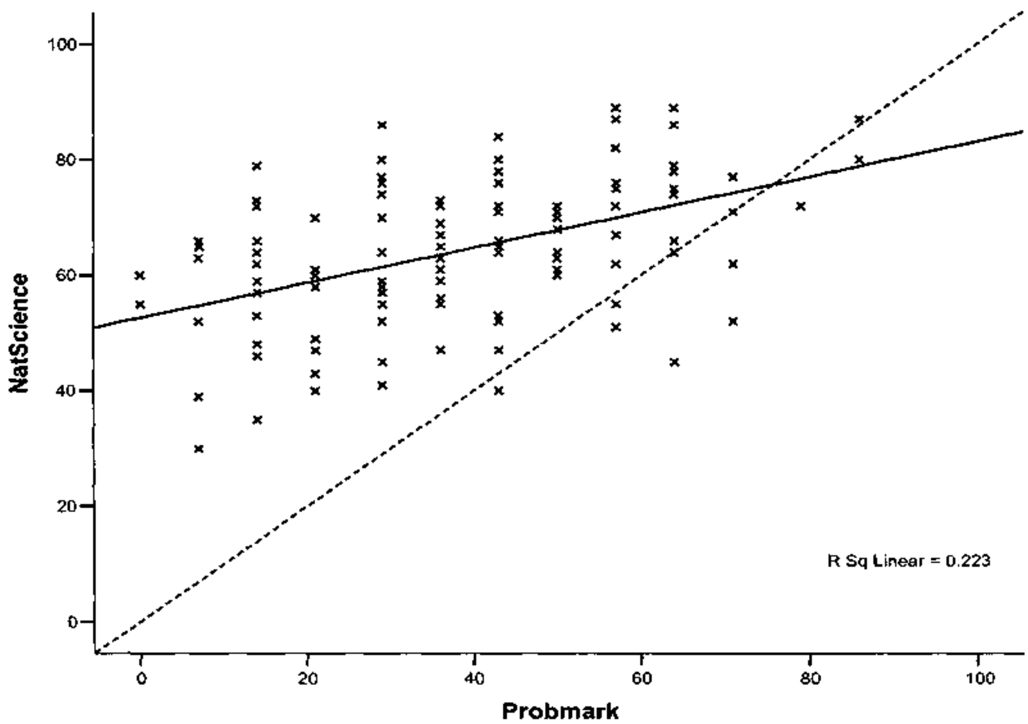


Figure 5.3 Scatter plot showing the relationship between the Problem tasks and the Natural Science marks for all 116 learners

A number of reasons could be cited for the deviation in marks for these two assessments. However, the most important one could be that the Natural Science paper that had no tasks that could be considered as problem-solving questions. The only reference to problem-solving was in the technology section of the paper where learners were asked the various steps that need to be followed when solving a technology problem. All the other questions were recall type with no scope for reasoning and applying the knowledge learnt. The Problem tasks on the other hand were unseen and were chosen to test learners' problem-solving skills. Overall, it would appear that although some learners did well on both tests, in general it appears that there is not a strong relationship between learners doing well at their normal tests and being able to solve problems. There are definite variations and getting a high mark in one is not a strong predictor of a high mark in the other.

5.6 COMPARING ALL THREE TYPES OF TASKS

This relationship was further investigated by looking closely at the results within one of the classes taught by the researcher (referred to as Class B) who had also completed the group tasks. The other learners did not do the Group tasks for reasons indicated earlier. Thirty-four learners performed all three types of tasks allowing for comparisons to be carried out between a learner's performance in the Natural Science test, Problem tasks and Group tasks results.

Before comparing the various tasks, the group Aquarium and Construction tasks were compared to see if there was any relationship between the two. However a t-test (paired samples test) was carried out for the Aquarium and Construction task which shows there is no significant difference (t= 0, df= 33, p= 0,599). The means were similar at 77,06 for the Aquarium task and 75,59 for the Construction task. Since there was no difference in the learners response to the two tasks the scores for the Aquarium and Construction group tasks were combined to form the group score which was used to compare them to the Problem tasks and Natural Science test (Table 5.5).

Table 5.5 Class B's mean percent score for all three tasks

	Problem tasks	Group tasks	Natural Science test
Mean	43,26	76,32	61,15
Std. Deviation	21,509	15,024	14,125
Range	86	73	62

The Group tasks scored the highest. Reasons for this could be attributed to learners working in a group, which increased their confidence, as they were able to depend on members of the group. The box plot (Figure 5.4) shows the scores for the Group tasks and Natural Science test as being closer together (lower standard deviations). This is expected as learners worked together for the Group tasks and knew what to expect for the Natural Science test. On the other hand, the results for the Problem tasks show a wide distribution of marks as was found for the whole grade.

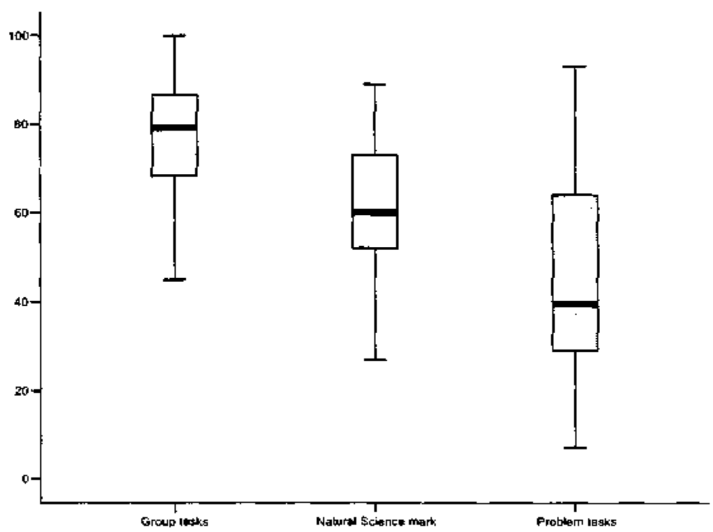


Figure 5.4 Box plots for the three different types of tasks

What was of interest was to see if the marks the learners obtained for the different tests were in any way related. To do this a Pearson correlation statistic was calculated and medium to strong correlations found between each other (Problem tasks with Group tasks, r=,507; Problem tasks with Natural Science test, r =,643; Group tasks with Natural Science test, r = ,712). All tests were statistically significant at 0,01 level (2-tailed).

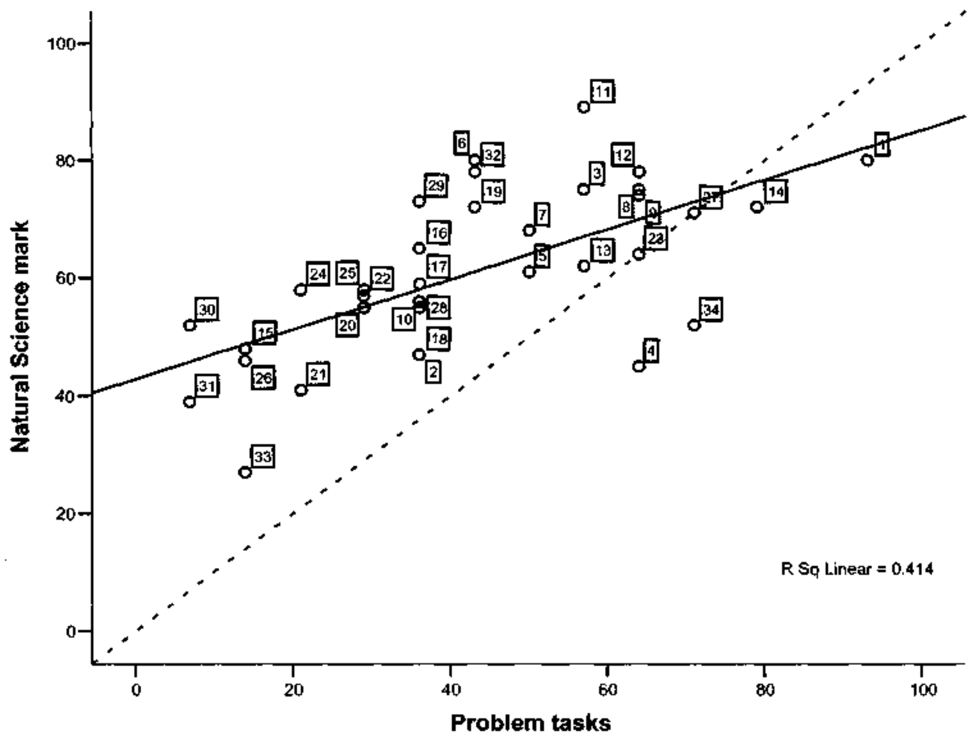


Figure 5.5 Scatter plot to show the relationship between Natural Science and Problem tasks for class B

For this class there was a much stronger correlation between the Natural Science mark and the mark for the Problem tasks than that produced for the whole group. However, there were many outliers, which weaken the confidence in the correlation. For example:

- Learner One obtained the best mark for the Problem tasks. This learner was usually very creative and enthusiastic in class yet she was normally placed somewhere between the 5th to 10th position in class. She speaks and writes English very well.
- Learner Eleven obtained the highest mark for the Natural Science test yet did not do that well with the Problem tasks. This learner usually comes out first in class. She speaks and writes English very well.
- Learner Thirty-Four obtained a good problem-solving mark but did not do well on the Natural Science test. Although this learner responded well when questioned verbally, she was very slow to complete class work thus lost marks for assessments.

- Learner Thirty-Three obtained low marks in both tests. This learner did not perform well in class. She did not understand English very well and her written and verbal skills were not well developed.

It appears that if a learner is very successful at the normal tests it does not guarantee they will be very successful in the Problem tasks. However, if the learner scores very low marks on the Natural Science test then the chances are good that they will score low on the Problem tasks perhaps because they do not have the language skills to understand the problems and express their reasoning. For those in the middle there does not appear to be a pattern, some doing better on the test and others doing better on the Problem tasks. It is not known if this finding is unique to this study as no studies in which similar comparisons were made in primary school were found.

When a scatter plot is produced of the Group tasks and the Problem tasks (Fig. 5.6) it is as expected. The marks are all above the "perfect" correlation line indicating they all did better in the Group tasks. However, the correlation appears much weaker due to the many outliers. In addition, many learners who did poorly on the Problem tasks did well on the Group tasks. This is expected as they would most likely be part of a group who perhaps had learners who could do the task and so they benefited. They could also have been more motivated in a group and made more of an effort. This reinforces the idea that learners should be given different types of assessment, as you cannot rely only on group or individual performance. This is in keeping with the suggestions made by De Boo (1999) about using different forms of assessment. If we want learners to experience success when solving problems, they have a better opportunity when doing them in groups.

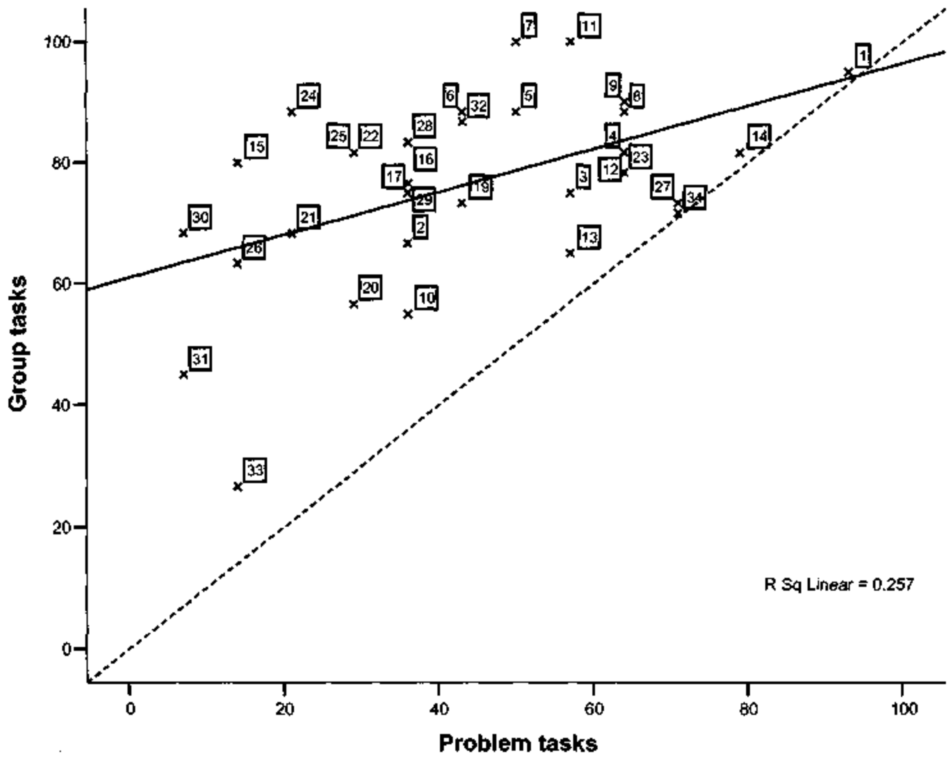


Figure 5.6 Scatter plot to show the relationship between Group tasks and Problem tasks

5.7 GROUP DIFFERENCES WITHIN THE CASE

5.7.1 Class

There is no significant difference in the marks for the different classes for the Problem tasks. However, if you look at the means (Table 5.6) or the graphs (Figure 5.7) it looks as if the one class does better at the Problem tasks but this is not statistically significant. Class B had a slightly lower mean for the Natural Science test but higher a mean for the Problem tasks. This was not unexpected due to the possible unconscious bias that the research had due to her interest in problem-solving. As explained earlier the classes followed the same curriculum and nothing different was done. However, the researchers' interest in problem-solving could have influenced presentation of the lessons.

Table 5.6 Comparison of the Problem task and Natural Science marks for the three classes

		N	Mean	Std. Deviation	Std. Error
Probmark					
	Class A	42	36,00	18,497	2,854
	Class B	39	43,77	21,924	3,511
	Class C	35	35,51	17,963	3,036
	Total	116	38,47	19,764	1,835
NatScience	Class A	42	64,98	13,488	2,081
	Class B	39	61,77	14,239	2,280
	Class C	35	66,40	9,611	1,624
	Total	116	64,33	12,761	1,185

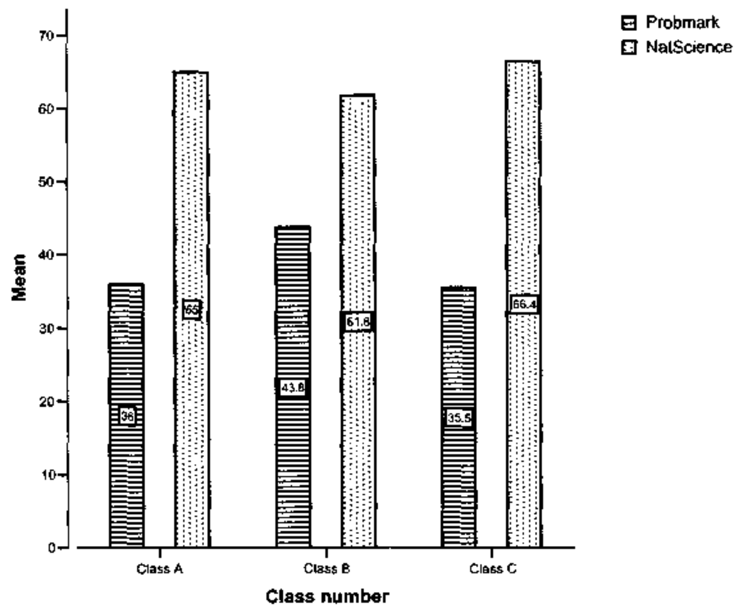


Figure 5.7 Bar graph showing the Problem task and Natural Science marks for the different classes.

In both cases there was no significant difference between the marks of the three classes for the Problem tasks ($F= 2,164$ $df = 2$, $p = 0,120$) or the Natural Science test ($F= 1,306$ $df = 2$, $p =$ 0, 275). This is to be expected as all three classes follow the same curriculum and assessment tasks. The different teachers are not able to deviate significantly from the common agreed curriculum. In addition, these classes are not streamed.

5.7.2 Language groups

Black and Coloured learners had different levels of success with the Problem tasks. As mentioned already race is a proxy for the language spoken since all Coloured speak English while nearly all Black do not speak English at home. An attempt is made to find out if learners' language ability plays a role in determining their success. It is realised that this is a crude indicator and in future studies the language marks will be included as a better indicator of language ability. Since there were majority Black and Coloured learners and only three Indian learners in this study the Indian learners were not included in the discussion on language. However, for the completion, I have represented the Indian group in the graph but have not done any statistical analysis including Indians as a separate group due to the small number.

A one way analysis of variance revealed a difference in the way Black and Coloured learners responded for the Problem tasks (F = 3,643 df = 2, p = 0,029) and the Natural Science test (F = 5,303 df = 2, p=0,006). This is further illustrated in the following bar graph.

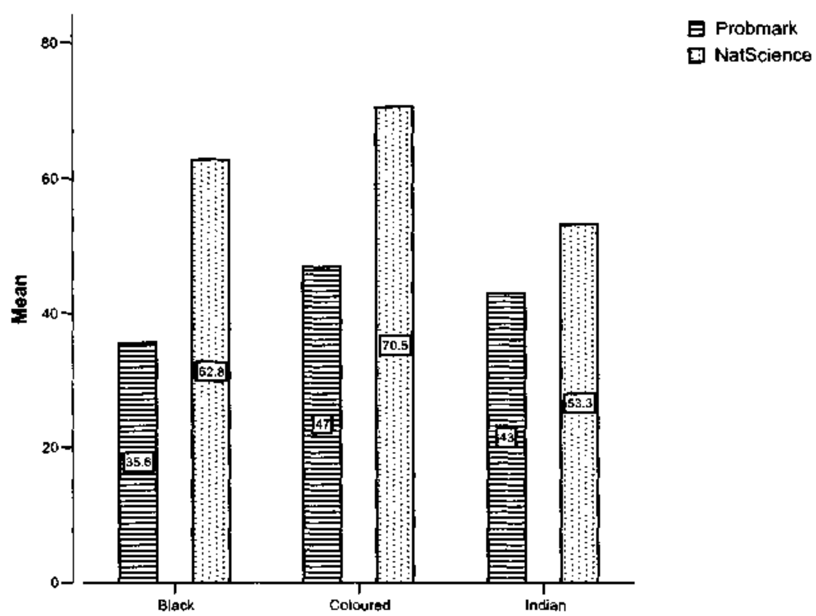


Figure 5.8: Bar graph showing the different races response to the Problem tasks and the Natural Science test

The difference in marks for Natural Science is small but larger for the Problem tasks. It appears that where there is opportunity to spend time and learn by rote and study there is minimal difference. However, for the Problem tasks the difference in marks suggests that maybe Black learners might have difficulty due to a language problem. These findings support those in the study conducted by Howie (2003). Black learners have limited proficiency in English, which results in them scoring low marks for science tasks.

These tests were also done individually and it seems that learners having difficulty with English experienced further difficulty when formulating their explanations. Many individual responses were incoherent and thus difficult to interpret. Although it has been maintained that it is better to learn scientific concepts in the learners' mother tongue language there are limitations to this (Dlodo, 1999; Jegede, 1998). This is not always possible because certain science concepts might not have the equivalent translation in the learners' mother tongue and direct translations may obscure the meaning intended. Teachers are not trained to teach in the learners' mother tongue. However, this study also acknowledges the issue of language as being serious, which cannot be ignored especially in the present multicultural classrooms (Rollnick, 1998). Although language seems to be an issue related to achievement it should be noted it is not the only reason to influence learners' success. Other factors such as the nature of teaching, socio-economic variables and the level of cognitive demand in classroom interactions in whatever language used could also contribute to learners' success (Reddy, 2006).

5.7.3 Gender

There is no difference in the marks for boys and girls scores for the Problem tasks but there is a difference in their scores for the Natural Science. To find out if there is a difference between the genders a t-test (Independent Samples test) was carried out. Within the sample of all the learners, we have two independent groups i.e. the boys and the girls. The variables we are looking at are the marks in the tests which are numbers from 1 to 100 i.e. ratio level data. Table 5.7 reports the means from which it is evident that there is little difference between means for the Problem tasks (about 5%) but double that for the Natural Science test (about 11%).

Table 5.7 Statistics for male and female learners

	Gender	N	Mean	Std. Deviation
Problem task	Male	43	34,95	19,104
	Female	73	40,53	19,983
Natural Science	Male	43	57,47	10,764
	Female	73	68,37	12,158

This difference can be shown more easily in Figure 5.9.

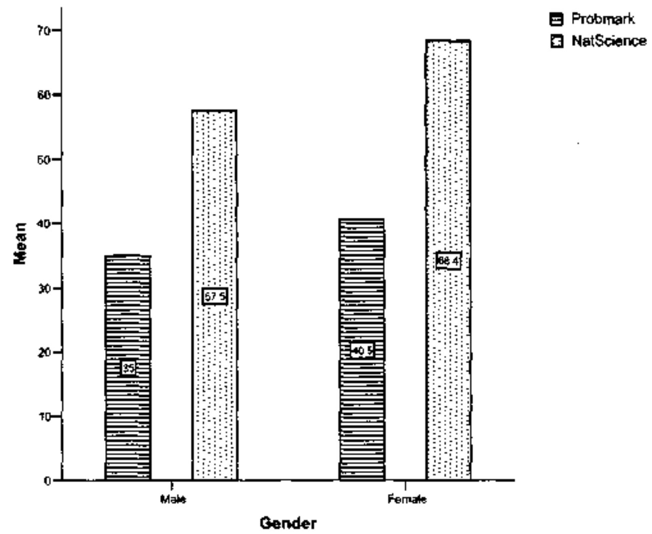


Figure 5.9 Bar graph to show the difference between males and females marks

These differences were then tested to see if they were statistically significant. From the statistics we can see that there is no significant difference between the boys and girls marks on the Problem tasks (t = 1,476 df = 114, p = 0,143). However, there is a significant difference at the 0,01 level between girls and boys for the Natural Science test (t = -4,863 df = 114, p <0,000). This difference was not apparent in the TIMSS study. It was found that for the 2003 assessment the science average scores were not statistically different for boys and girls (Reddy, 2006). Perhaps this was because the TIMSS test had a variety of types of item and not only those dealing with problem-solving.

The possible reason for this difference between problem-solving and normal school tests is that boys do not spend as much time as girls learning so they do not do as well as girls on formal tests, which require them to learn content. However, when it comes to tests, which rely on skills, then they perform as well as girls. Within the tests, another reason could be that the problem-solving tasks had a multiple-choice component to each question. These findings are not in keeping with that of the study conducted by Beard, et al. (1993) where it was found that boys do better in multiple-choice questions as they are more self confident. However, there is a difference between boys and girls scores for the Natural Science test marks. From this, it appears that where there is an opportunity to learn girls do better which would indicate they are more diligent. However, where natural ability is involved and minimum learning boys and girls do equally well.

5.7.4 Age

In general, learners within the 11 year age group had greater success with the Problem tasks. The average age of the learners, in this case study was 11 years. The age distribution is reflected in Table 5.8.

Table 5.8 Summary of descriptives for the Problem tasks by age groups

Ages		N	Percent	Mean	Std. Deviation
Total out of 28	11	59	50,9	11,83	5,537
	12	43	37,1	10,28	5,320
	13	11	9,5	7,64	5,500
	14	2	1,7	5,00	1,414
	15	1	0,9	18,00	
Total		116	100,0	10,79	5,576

A learner in the 11 age group obtained the highest score of 26 out of 28. It seems the younger learners have more success with the Problem tasks. Some of the older learners could have either spent two years in this grade or could have started school late. It does not seem as though their maturity and experience were of help to them when answering the Problem tasks. However, this could imply that younger learners are more enthusiastic about problem-solving than older learners are and therefore do better. This is in keeping with the findings of the study by McGhee (1997) were it was found the younger learners provide quality ideas to problem tasks.

5.8 CONCLUSION

From the summary and discussion of the findings it was found that learners' success was uneven. Generally, learners were more successful at problems, which contained all the information required to solve it, and only involved simple one step reasoning. Learners were not good at judging their own success at problems.

Overall, they appear to have less success than that reported in other studies and success at normal class tests was not a predictor of success in the Problem tasks. From the comparisons carried out between the three classes for the Problem tasks and the Natural Science test, no significant differences were found. Comparisons within the class showed that Black and Coloured learners had different levels of success with the Problem tasks. It was found that there was no difference in the marks for boys and girls scores for the Problem tasks but there was a difference in their scores for the Natural Science test. In general, learners within the 11 year age group had greater success with the Problem tasks. In the following chapter, the findings of the complete study are presented together with their implications for practice and future research.

CHAPTER 6

SUMMARY, IMPLICATIONS AND CONCLUSION

The purpose of the study was to determine Intermediate phase learners' success with science problem-solving tasks. This was achieved by attempting to answer the research question, "How successful are learners with science problem tasks at the end of the Intermediate Phase?" In order to answer the main research question, the study focussed on answering a number of sub questions, which contributed to answering the main research question. These sub questions were

1. How successful are learners at solving problems?
2. What types of problem tasks can they solve?
3. Is there any relationship between their ability at solving problems and their normal science achievement?
4. Are they any differences between groups such as male and female or across different classes?
5. What opportunities enabled them to develop problem-solving skills?

An evaluative case study was the approach used in this study. Grade six learners were evaluated on how successful they were at solving problems given that problem-solving features significantly as part of the new curriculum. This approach involved participant observation during a one-year period with a class that I taught. The study was approached within a post positivist/ realist paradigm. A variety of instruments was used to enable me to collect both qualitative and quantitative data. What follows is a summary of the main findings with limitations and implications.

6.1 SUMMARY OF STUDY FINDINGS

The summary of the findings of this study will be presented as answers to the research questions. This section will conclude with the findings to the main research question.

How successful are learners at solving problems?

In general, learners' success was uneven. They were able to do well on one or two Problem tasks but in general were unsuccessful.

What types of problem tasks can they solve?

Learners seemed to have more success with closed, inside type problems requiring one step simple reasoning compared to open, outside type problems requiring multiple step linked reasoning. The way the problems were presented seemed to affect learners' success. Learners had more success when the problems were presented as tables than as diagrams. They appeared to have more success when answering the multiple-choice component of the question but had little success explaining their choice of answers. Learners had most difficulty when tasks involved reasoning while manipulating numbers. When interviewed it seemed that there was little relation between what problems learners thought they had success in solving and the problems that they performed poorly in.

Is there any relationship between their ability at solving problems and their normal science achievement?

In general, the learners did not do as well in the Problem tasks as they did in other tests. This could be related to learners experiencing difficulty in manipulating more than one variable as well as language skills required to explain their reasoning in the Problem tasks. On the other hand, the school test was very straight forward mostly requiring recall of learnt work or replication of taught procedures. Overall, it would appear that although some learners did well on both tests, in general it appears that there is not a strong relationship between learners doing well at their normal school tests and being able to solve problems. Learners' success was also uneven when compared to the TIMSS items and learners performed better in the school Natural Science test compared to the Problem tasks.

Are they any differences between groups such as male and female or across different classes?

There was no difference in the marks for boys and girls scores for the Problem tasks but there was a difference in their scores for the Natural Science test. Black and Coloured learners had different levels of success with the Problem tasks. In general, learners within the 11 year age group had greater success with the Problem tasks.

What opportunities enabled them to develop problem-solving skills?

As seen from the analysis of documents, learners had very limited opportunities to develop their problem-solving skills. Learners' inadequate experience with solving problems could have contributed to their lack of success with the Problem tasks.

How successful are learners with science problem tasks at the end of the Intermediate Phase?

Learners' success with science problem tasks at the end of the Intermediate Phase was uneven. They were able to solve some problems and not others. Learners limited success could be attributed to them not being explicitly taught problem-solving skills. However, some learners were able to solve the problems despite not having being taught the skills.

6.2 LIMITATIONS

As this is a case study, it highlights a single case and therefore it is imperative to realise that the same practice might not be the practice throughout South Africa. When teachers read this study, they need to reflect on their own practices. The types of Problem tasks given invariably affected learners' success.

Maybe the context of the Problem tasks chosen for this study was not the ideal. The resources used were also limited to the context of the school. The context of the school and the background of learners are specific to this case study and might or might not be the case in other situations. At worst, these finding would be useful to many similar classrooms. However, my belief is that the findings of this study will be of use to a much wider community of teachers as there is little evidence from TIMSS and other studies that other more resourced or under resourced schools are producing learners who have problem-solving skills.

6.3 IMPLICATIONS

The findings of this research may be relevant to all the stakeholders in the education process especially at the primary school level. The analysis of the data obtained in this study draws our attention to the fact that no single reason can be given for learners' success or lack of it. A number of implications arise from this case study that needs to be addressed.

This study was carried out during the implementation of the RNCS. The philosophy underpinning the RNCS was that of outcomes-based education. The curriculum can be viewed as having three aspects: the intended curriculum, the implemented curriculum and the attained curriculum (Reddy, 2006). It seems the curriculum that is intended by the RNCS is not implemented the way it should be, resulting in the attained curriculum not meeting the expectations of the RNCS. This is evident in learners' general lack of success with problem-solving. If learners attained the curriculum as prescribed by the RNCS then they would have more success with problem-solving. Hobden (2000) points out, "there is little value in having published curricula which are difficult for teachers to implement and are never experienced by the learners as originally intended by the curriculum planners" (p.79). He also maintains, in the end what really matters is the experienced curriculum.

Learners' uneven success with the Problem tasks could have stemmed from their insufficient experience with problem-solving during the Intermediate Phase. As evident from the analysis of the documents, learners were given just seven opportunities during the entire three years spanning the Intermediate Phase (Table 4.10). All the activities were directly from textbooks and in many cases not relevant to the learners. The context of problem tasks have to be "embedded in the natural world" to make it more realistic to learners especially at the primary school level. If the Problem tasks are from "real situations familiar to learners," they will then "learn more effectively" as they can make the connections required for successful learning (Hobden, 2000, p. 71).

Problem-solving is now a major part of the RNCS and as such should be given the status it deserves. Chin, et al. (1994) also believes teachers need to make problem-solving the "focus of their instruction" (p. 41). From this study, it appears that learners' limited experience with science problem-solving indicates that insufficient time is spent on this. Teachers need to realise that it takes time to develop problem-solving skills in young learners but once this is done it lays the foundation for the future and saves time as well (Wallace, 2002).

Some teachers especially in the primary school who teach all Learning Areas have limited content and pedagogical content knowledge. It would be difficult for them to set challenging problem-solving tasks that have higher cognitive demands (Chin, et al., 1994). Problems that focus on particular skills need to be designed. It was found from the TIMSS study that "South African mathematics and science teachers are among the least qualified" (Reddy, 2006, p. 15).

Teachers would need to be trained in this field of teaching problem-solving. Teacher support groups could also be set up.

It maybe that during teacher training, time could be spent on familiarising teachers with the scientific terminology and concepts in other African languages. These concepts could be incorporated in science lessons. This would ensure the science taught is understood by the majority of our learners who experience limited proficiency with the English language. This would also make science relevant to learners using the South African context as a platform.

Although teachers attended many workshops to ease in the implementation of outcomes-based education, this does not seems adequate. These workshops have to be properly monitored and evaluated to see if they are meeting the demands. Workshops on assessment are also essential. Teachers need training on how to assess group work. It is difficult to get an objective score for each learner. Different methods of assessment need to be incorporated into the science lesson. This is evident from this study as learners had different levels of success with the different types of Problem tasks. Learners doing well in the Group tasks did not necessarily do well in the Natural Science test or Problem tasks. Professional development courses could be offered to educators to help bridge the gap between the old and the new education system assessment strategies.

More attention needs to be paid to learner activities during science lessons. Daily scientific activities need to involve reasoning and analysis. It was reported that the international average and the prevalence of scientific inquiry activities in South Africa were similar in nearly all categories except for watching a demonstration of an experiment or conducting an experiment. However, it would seem that in South Africa less than a third of the learners watched a demonstration or conducted an experiment (Reddy, 2006, p. 104). A reason for this could be that many disadvantaged schools have little or no resources. However, primary science affords the teachers the opportunity to include more "hands on" and "make and do" science activities. The activities tend to be more susceptible to being practical and using improvised apparatus.

Learners' unrealistic view of success appears to indicate they have not thought about the task or their responses carefully. Learners need to be taught problem-solving strategies involving reflection so that they can be assured of success. Schoenfeld (1985) suggests that for learners to be resourceful they have to be "familiar with a broad range of heuristics" (p. 12). He also maintains they need coaching in how to manage the resources at their disposal and reflect on their problem strategy.

Group work seems to be a good way to introduce problem-solving as learners get to experience success. Care needs to be taken when selecting groups to avoid personality clashes to create an optimum learning experience for all learners in the group. Although it is not always possible as the teacher may not be aware of such instances. An option could be to allow learners to form their own groups. It is also noted that learners will have to eventually learn to work with all types of people in society irrespective of any differences they might have. However, for the younger learner their initial experiences with group work needs to be encouraging and fruitful. The group situation works well but needs to be monitored closely to maintain control and to ensure learners are working on the task at hand. Once the logistics of group work is sorted out it becomes an invaluable approach to teaching problem-solving.

From this study, it was found that not one but many issues could affect learners' success with problem-solving tasks. However, it is apparent that teachers especially need to:

- be aware of teaching problem-solving as an explicit skill;
- be attentive to learners language proficiency;
- use a variety of problem-solving assessment techniques;
- develop large numbers of appropriate and relevant problems that can be used;
- present problems in an unambiguous manner using visual stimuli as well as text;
- link Natural Science with technological problems thus incorporating "make and do" activities; and

- continue with research at primary school level laying the foundation for higher level of GET.

This study has paved the way for future studies in primary science problem-solving.

6.4 CONCLUSION

Incorporating problem-solving into the science curriculum is mandatory. I am of the belief that once the initial problems of learners' enthusiasm or lack of it is addressed problem-solving will fall into its rightful place. If learners are being taught problem-solving skills from the early grades onwards this would not be an issue as it becomes a way of teaching and learning. Teacher training will produce teachers with problem-solving pedagogical content knowledge which would assist them in developing problem tasks, teaching and assessing problem-solving.

I am now in a better position to explicitly teach problem-solving and help design problem tasks. This study has also motivated me to pursue a doctoral degree as it has brought to the fore many areas within primary science problem-solving that still need to be researched.

Returning to the literature review, McGhee (1997) highlighted the need to teach problem-solving, "young children not only have the enthusiasm to tackle problems, but the ability to master many of the skills and strategies of problem-solving (p. 109). Children are naturally inquisitive about their surroundings. We as teachers need to take advantage of this and build on this inquisitiveness to ensure children are being nurtured to develop into problem solvers that could benefit the society within which they live.

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APPENDICES

A- Problem-solving tasks

B- Aquarium Problem task

C- Construction Problem task

D- Learner questionnaire for Aquarium task

E- Learner questionnaire for Construction task

APPENDIX A PROBLEM-SOLVING TASKS

Problem-solving Tasks
Problem-solving in Natural Science

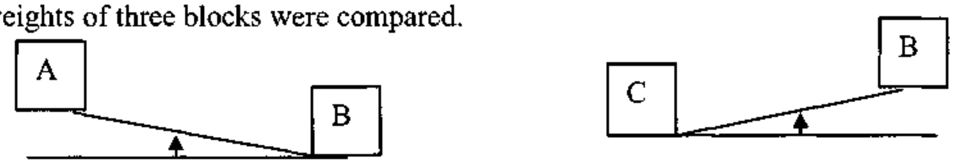
Please complete the following details. Place a cross (x) were applicable.

Surname				
Name				
Grade				
Age				
Gender	Male		Female	

Complete the problem tasks by firstly place a cross at the answer you see as being most correct. Then in the space provided, supply reason/ s for your choice

Problem: 1

The weights of three blocks were compared.



1.1 Which one of the three blocks weighs the most? (A, B or C)

A. Block A ☐
B. Block B ☐
C. Block C ☐

1.2 Give a reason for your answer.

____

____

Problem: 2

This table shows the temperature and precipitation (either rain or snow) in four different towns on the same day.

	Town A	**Town B**	**Town C**	**Town D**
Lowest Temperature	13 ° C	-9 ° C	22° C	-12° C
Highest temperature	25 ° C	-1 ° C	30° C	-4 ° C
Precipitation (either rain or snow)	0 cm	5 cm	2, 5 cm	0 cm

2.1 At which town did it snow?

A. Town A ☐
B. Town B ☐
C. Town C ☐
D. Town D ☐

2.2 Give a reason for your answer.

____

____

Problem: 3

Four learners went to a party. After the party, three of the learners were feeling unwell. They were Thembi, John, and Musa. Sally was perfectly well and did not feel sick. This is what they each ate during the day.

Thembi	John	Sally	Musa
Ice cream	Ice cream	Ice cream	Ice cream
Hotdog	Meat pies	Hamburger	Orange
Chips	Chips	Chips	Chips
Meat pies	Hamburger	Fish	Meat pies
Tomato sauce	Popcorn	Popcorn	Tomato sauce

3.1 What food do you think could have caused the three learners to feel sick? _______________

3.2 How did you work out your answer?

____

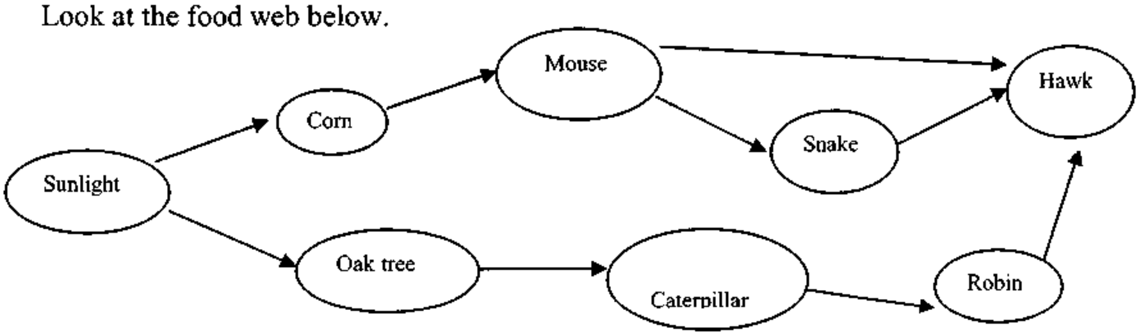
____

____

____

Problem: 4

Look at the food web below.



4.1 If the corn crop failed one year what would most likely happen to the robin population?

A. Robin population may decrease ☐
B. Robin population may increase ☐
C. Robin population would stay the same ☐

4.2 Explain your answer.

____

____

____

Problem: 5

Simone and Renata were discussing what it might be like to live on other planets. Their science teacher gave them data about two imaginary planets. The table shows these data.

	Astrid	Athena
Atmospheric conditions	21% oxygen 0,03% carbon dioxide 78% nitrogen ozone layer	10% oxygen 80% carbon dioxide 5% nitrogen no ozone layer
Distance from a Star like the sun	148,640,000 km	103,600,000 km
Rotation on Axis	1 day	200 days
Revolution around Sun	365 ¼ days	200 days

5.1 On which of the two planets would it be difficult for humans to live?

A. Astrid ☐

B. Athena ☐

5.2 Give reasons why it would be difficult to live on this planet.

____

____

____

Problem: 6

Machine A and machine B is each used to clear a field. The table shows how large an area each cleared in 1 hour and how much gasoline each used.

	Area of field cleared in 1 hour	Gasoline used in 1 hour
Machine A	2 hectares	¾ liter
Machine B	1 hectare	½ liter

6.1 Which machine is more efficient in converting the energy in gasoline to work?

A. Machine A ☐

B. Machine B ☐

6.2 Explain your answer.

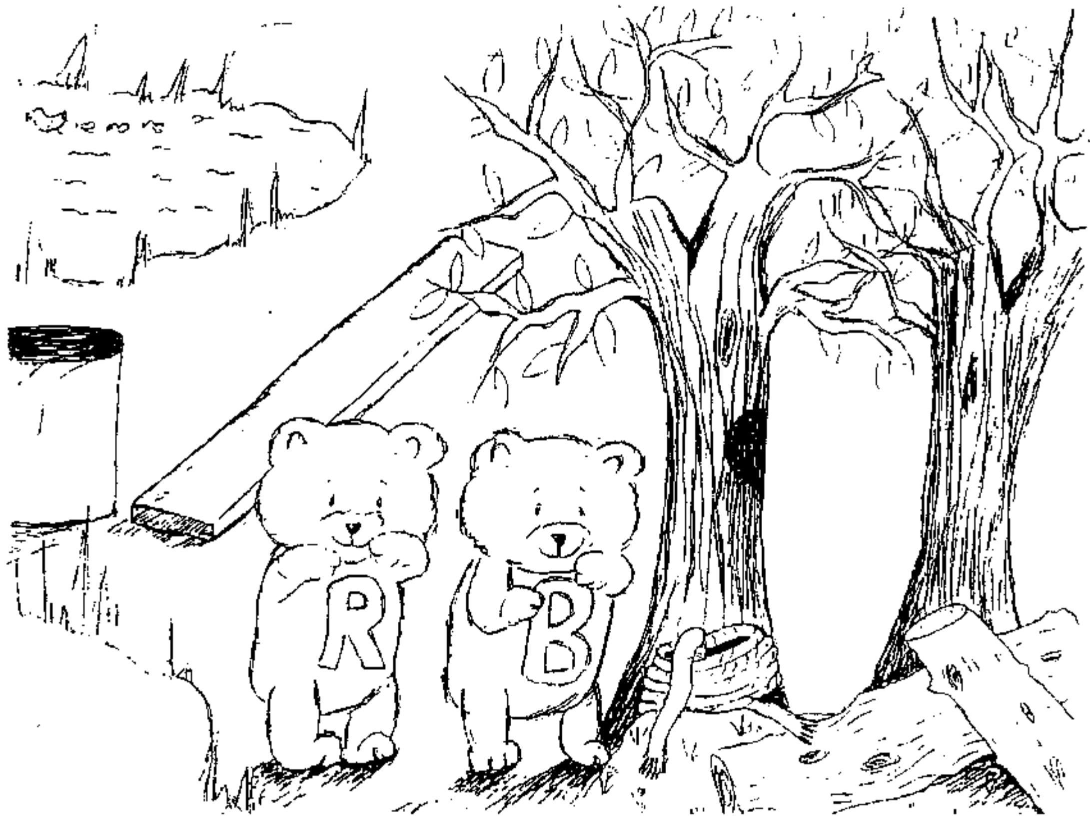
____

____

____

Problem: 7

The diagram below shows two bears in a wood, surrounded by various materials.



You are invited to suggest how two bears could prove which one was the heavier using only material found in a wooded area.

APPENDIX B

Aquarium Problem

Imagine that your science teacher asks you to do a special job and gives you these written directions:

> Your class will be getting a 135-liter aquarium. The class will have R 25, 00 to spend on fish. You will plan which fish to buy which will help you design an attractive aquarium with no problems. Use the accompanying information (Choosing Fish for your Aquarium) to help you choose the fish. The information tells you things you must know about the **size** of the fish, how much they **cost** and their **special needs**.
>
> Choose as many different kinds of fish as you can. Then complete the task sheet explaining which fish you choose.
>
> 1. Tell me how many of each kind of fish to buy
> 2. Give the reasons you choose those fish
> 3. Show that you are not overspending and that the fish will not be too crowded in the aquarium

Choosing Fish for your Aquarium

Planning Ahead

Use the information to help you choose fish that will be happy and healthy in your aquarium. To choose your fish, you must know about the **size of the fish, their cost, and their special needs.**

Size of the Fish

To be healthy, fish need enough room to swim and move around. A good rule is to have about 2,5 cm of fish for every 4.5 liters of water in your aquarium. This means that in a 45-liter aquarium, the lengths of all your fish added up can be 25 cm at the most.

Example: With a 45-liter aquarium.

Here are a few choices:

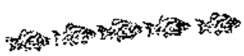
1. one 25 cm long fish, or

25 cm

2. a 17 cm long fish and an 8 cm long fish, or

25 cm

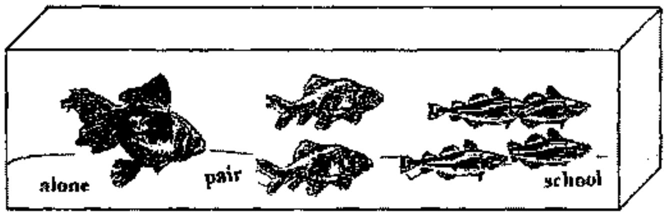
3. five fish if each is only 5 cm long

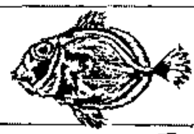
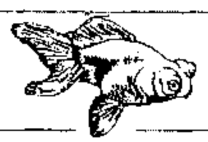


25 cm

Cost of the Fish
Some fish cost as little as one rand, others cost much more. The prices of each kind of fish are listed in the chart.

Special Needs
Use the chart to learn about the special needs of each kind of fish. Some fish need to live together in schools- a group of four or more of the same kind of fish- while others live in pairs or alone. A few kinds of fish have other special needs, which are listed, in the chart.



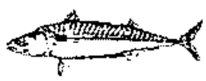
Picture	Name	Cost	Length in inches	Colour	Special Needs Facts
	Zebra Danhio	R1	4 cm	blue with gold lines	lives in schools, gets along with other kinds of fish
	Marbled Hatchetfish	R1	5 cm	yellow	lives in schools, can leap 3-5 yards
	Guppy	2 for R3	5 cm	red, blue, and green	lives in schools
	Red-Tailed Black Shark	R5	10 cm	black with red tail	fights with other sharks, but gets along with other kinds of fish
	Cardinal Tetra	R5	4 cm	red and green	lives in schools
	Blind Cave Fish	R2	8 cm	silvery rose	lives in schools, uses its sense of smell and vibration to find food.
	Ramirez Dwarf Cichlid	R5	5 cm	rainbow	lives in pairs, rarely lives longer than 2½ years, gets along with other fish
	Velvet Cichlid	R5	30 cm	olive with stripes	can be trained to take food from the hand and can be petted, must be kept only with other cichlids

Zebra Danhlo
R1
4 cm

Marbled Hatchetfish
R1
5 cm

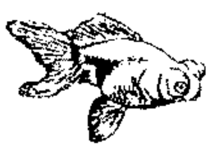
Guppy
2 for R3
5 cm

Red-Tailed Black Shark
R5
10 cm



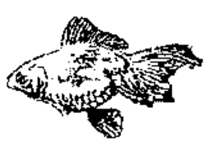
Cardinal Tetra
R5
4 cm

Blind Cave Fish
R2
8 cm



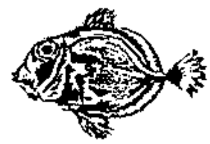
Ramirez Dwarf Cichlid
R5
5 cm

Velvet Cichlid
R5
30 cm



Zebra Danhlo
R1
4 cm

Marbled Hatchetfish
R1
5 cm

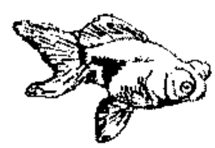


Guppy
2 for R3
5 cm

Red-Tailed Black Shark
R5
10 cm

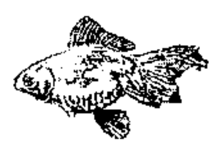
Cardinal Tetra
R5
4 cm

Blind Cave Fish
R2
8 cm



Ramirez Dwarf Cichlid
R5
5 cm

Velvet Cichlid
R5
30 cm



APPENDIX C CONSTRUCTION PROBLEM TASK

Construction Problem-solving Tasks
Problem-solving in Natural Science

Instructions

1. You are required to **construct the highest free – standing structure** from the newspaper provided and 50 cm of cello tape.

2. You have **one hour** to complete the task.

3. You can only use the newspaper and cello tape provided nothing else.

4. I will walk around every **15 minutes** to monitor your progress.

5. You are going to work in-groups **of six.**

6. At the end of the task, the group with the highest freestanding structure wins!

7. Please, answer these questions after the activity.

APPENDIX D **LEARNER QUESTIONNAIRE FOR AQUARIUM TASK**

Problem-solving Tasks
Problem-solving in Natural Science

Please complete the following details. Place a cross (x) were applicable.

Surname				
Name				
Grade				
Age				
Gender	Male		Female	

1. Which fish did you choose for the aquarium?

____

____

____

2. How many of each type did you choose?

____

____

3. Why did you choose these fish? (the type and number of fish)

____

____

____

____

4. How much of money will you be spending on the fish? (Show how you worked out the cost.)

____

____

____

5. Do you think the fish would be overcrowded in the aquarium? Why do you think this?

____

____

____

6. Are the special needs of the fish met? Explain.

____

____

____

____

APPENDIX E LEARNER QUESTIONNAIRE FOR CONSTRUCTION TASK

Problem-solving Tasks **Problem-solving in Natural Science**

Please complete the following details. Place a cross (x) were applicable.

Surname				
Name				
Grade				
Age				
Gender	Male		Female	

Instructions:

1. You are required to **construct the highest free – standing structure** from the newspaper provided and 50 cm of cello tape.
2. You have **one hour** to complete the task.
3. You can only use the newspaper and cello tape provided nothing else.
4. I will walk around every **15 minutes** to monitor your progress.
5. You are going to work in-groups **of six.**
6. At the end of the task, the group with the highest free standing structure wins!
7. Please answer these questions after the activity.

1. Did you enjoy working with your group? ________________________________

2. What was your favourite part of the activity? Tell me about this.

____
____
____

3. Which part did you not enjoy? Tell me about this.

____
____
____

4. If you could change anything about this task, what would it be?

____
____
____

5. Do you think you learnt anything from this task? If yes, what did you learn?

____
____
____
____
____