LEARNING SCIENCE IN A SECONDARY SCHOOL IN PAPUA NEW GUINEA

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ABSTRACT

This study investigated teaching and learning, and the classroom learning environment in which the electricity topic was taught by the regular class teacher within the prescribed Grade 9 syllabus in a Secondary School in Papua New Guinea. The study was motivated by the perceived problems students had with understanding science concepts and the lack of classroom-based studies that provide a better understanding of teaching and learning science and the influence of the classroom learning environment on students' learning. An interpretive with embedded case study was conducted in a Grade 9 class over a period of 12 weeks in which data was gathered using mixed and multiple methods. Findings of the study revealed the presence and influence of aspects of the indigenous traditional teaching and learning approach impacting on the formal modern Western oriented teaching and learning approach in this particular classroom. The study recommended that in order to maximise students' learning and understanding of science concepts in the classroom observed, cultural sensitivity should be incorporated in the pedagogy.

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PAPER ARISING FROM THE RESEARCH

Najike, S., McRobbie, C. J., & Lucas, K. B. (2002, December) *Learning science concepts in a secondary school environment in Papua New Guinea.* Paper presented at the Australian Association for Research in Education, Brisbane, Australia.

STATEMENT OF ORIGINAL AUTHORSHIP

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The work contained in this thesis has not been previously submitted for a degree or diploma at any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

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Chapter 1

Introduction

1.1   What was the study about?

The study reported in this thesis investigated the teaching and learning of a topic in science in a secondary school classroom in Papua New Guinea. The focus was on investigating and providing insights into classroom practice, the learning environment, and the influence of the learning environment on teaching and learning under natural conditions. The students' and class teacher's interactions, and the nature of the classroom learning environment climate were examined.

The study was conducted during normal instruction of a Grade 9 class by the regular science class teacher on a unit of work on electricity as prescribed in the Papua New Guinea Teachers Guide Grade 9 Unit 2 (PNGNDOE, 1987). The unit on electricity was selected because it was a topic that was abstract and was typical of the science content taught that was conceptually difficult for most students. As such, it did provide a window through which the researcher looked into the learning process to understand how learning occurred in this particular classroom environment. The study presented the opportunity to examine the relationship between teaching and learning, and the teaching and learning conditions within the particular classroom environment; and more broadly, the learning process as it unfolded in its natural environment. This was accomplished by focusing on the classroom environment and following very closely the approaches students' and the class teacher took in their learning and teaching strategies. Consequently, outcomes of the study provided insights and meaning about the way students in this secondary school in Papua New Guinea reached the scientifically accepted understandings of science concepts and principles in a social classroom setting. Social constructivist perspectives in a Papua New

Guinea specific context informed the study.

1.2   Why was the study done?

This study was aimed at addressing a number of concerns and issues connected with the learning process applied by students in the particular secondary school in Papua New Guinea when developing their understanding of electricity. In selecting this area of research the researcher was influenced by two main concerns. The first of these was his first hand experience as a science teacher with high school students' difficulty in understanding school science in Papua New Guinea. Many students seem to have difficulty in understanding abstract science concepts such as those found in learning electricity. The other was the researcher's experience in this area through a masters degree project conducted in the field of study in 1993 at Curtin University of Technology in Perth, Western Australia (Najike, 1993). In that study the researcher identified, documented and compared students' conceptions of electric current in simple dc circuits with secondary students from an Australian high school and first year pre-service trainee science teachers from a university in Papua New Guinea.

The literature over the past few decades on students' alternative conceptions and learning in science education, and the researcher's experience in working with secondary school students and trainee science teachers, did convince him to arrive at the notion that there was a great deal to be done to address difficulties with conceptual understanding in science classrooms in Papua New Guinea. In particular, it seemed there were serious problems associated with the development of conceptual understanding of the physical sciences by students in high schools, especially when most students in Papua New Guinea lived in rural, agrarian, subsistence societies. Students in Papua New Guinea have had a relatively brief exposure to the modern world and advanced technologies that were becoming increasingly indispensable to improvement in living standards for people around the world. The findings from a masters degree study by the researcher did indicate some alarming results with respect to the understanding of electricity of Papua New Guinean

students at an elementary level.

The level of alternative conceptions uncovered was high in a topic, which was first taught in Grade 6 and 7 in Community Schools. For example, 64 percent of pre-service trainee science teachers from a university in Papua New Guinea believed that electric current was 'consumed' by the load (light bulbs) and therefore current flow was not constant in magnitude throughout an electric circuit (Najike, 1993, p. 54). With other similar findings, this fundamental misconception about the nature of electricity current flow in circuits prompted the researcher to arrive at the conclusion that many students in Papua New Guinea have difficulty in developing appropriate understandings of abstract topics in the physical sciences.

1.3   The aim of this study

The principal aim of the research study was to investigate and interpret teaching and learning as they unfolded in a classroom learning environment in which a Grade 9 class was taught a unit on electricity in Papua New Guinea, by the regular class teacher. The Papua New Guinea context of the study, to be elaborated in Section 1.5, was considered to be that of a young developing non-Western country whose political, economic and education systems were adapted from Australia and the Western world. The following objectives have been adopted for the study:

The study aimed to:

- Document and interpret teaching and learning, and the learning environment landscape inherent in the education practice of one secondary school science classroom in Papua New Guinea.

- Provide salient aspects of the teaching and learning approaches employed by students and their class teacher in one secondary school science classroom in Papua New Guinea.

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Accordingly, four research questions were explored.

1. How did the students in this classroom view science in the context of teaching and learning?

2. How did the students perceive their learning environment and the teacher's interpersonal interactions?

3. What were the students' prior knowledge and experiences about electricity before instruction?

4. What were the cultural referents displayed by the teacher and the students that impacted on teaching and learning?

As a result of this study it was envisaged that science education in Papua New Guinea will benefit in the following ways by enabling the researcher to:

1. Establish a foundation for productive science education research at the university where he is employed in Papua New Guinea.

2. Contribute to the development of science instruction in secondary schools to foster improvements in students' learning of science.

In order to achieve these objectives the study adopted interpretive and naturalistic methods of data collection, resulting in an interpretive, embedded case study that provided meaning to the learning process and activities of a Grade 9 science class in Papua New Guinea. The methodology of the study is discussed in detail in Chapter 3.

1.4   The context of the study

The context of the study was Papua New Guinea specific. As expressed by Deutrom and Wilson (1986), Papua New Guinea was a young nation in a number of senses. First, it was geologically young, which meant that the

interior was dominated by mountain ranges, while the coastal regions were swampy. This had caused considerable communication difficulties. The communication difficulties, in turn, had meant that for millennia small communities within the country had been largely isolated from one another. Consequently for a population of over 5 million people there were over 800 distinct languages, and cultural groupings, which represented a quarter of the known languages of the entire world. The result of this was that the educationally desirable policy of starting school in a child's mother tongue proved quite impractical and all children started formal schooling in English, which for almost all was a second or even third language. Students had difficulty learning in a foreign language. There were no equivalents to many English or scientific terms in many of the indigenous languages of Papua New Guinea. This was a significant factor in the development of science and other curriculum.

Papua New Guinea as a nation state was also young socially and politically. Self-government came in 1972 and full independence from Australian colonial rule in September 1975. Significant parts of the country had no contact with the outside world until after the Second World War, a further direct result of geological youth and rugged terrain. Australian colonial policy was to encourage gradual social and political development of all the people through universal primary education. This was changed by a number of political pressures in the 1960s with a push for independence, and hence secondary and tertiary education had to be developed quickly to play a crucial role in indigenous manpower development (Smith, 1975). The formal Western education system was therefore also young. Schooling became a direct concern of government only after 1945, and secondary and tertiary education was established in the late 1950s and 1960s, respectively.

The education system in Papua New Guinea was pyramidal and competitive. Until the education reforms of 1992, the pre-tertiary formal education system in Papua New Guinea was organised in three tiers on a 6-4-2 basis. That is, six years (Grades 1-6) of primary (community) school, followed

by four years (Grades 7-10) of provincial high school (PHS), and two years (Grades 11-12) of national high school (NHS). There was a major exit point from the system at the completion of each of the three tiers, and an additional one between Grades 8 and 9. There was a common nationally prescribed science curriculum for all students throughout Grades 1-11. Science was optional only in Grade 12. In the following, each of the three tiers and the nature of the science curriculum prescribed for each tier is briefly discussed.

According to Deutrom and Wilson (1986), the role of primary education was to equip the child with basic knowledge and skills which would be of use to him or her in the local community, regardless of whether or not he or she proceeded onto secondary school. Thus, primary schools were renamed community schools. Children enrolled in the six-year community school program at age 7. The curriculum included a core of English, mathematics, and science, controlled by the national government, alongside community based subjects including community life, expressive arts, health, Christian religious education, and physical education, which are under the control of provincial governments. Science received only a small allocation of time - 30 minutes per week in Grades 1 and 2, 40 minutes in Grades 3 and 4, and 60 minutes in Grades 5 and 6, out of a total school weekly time allocation of 1,600 minutes. The science lessons were activity-based, designed to expose students to a range of science-related experiences which stressed the immediate environment. Radio broadcasts related the science concepts introduced in the activities to broader issues and applications. There was also a health program for community schools, and practical work in agriculture was undertaken. At the end of the community school program there was a selection examination for entry into secondary schools.

The broad aim of the four-year lower secondary education program (Grades 7-10) offered by provincial high schools (PHS) was to provide adequate preparation for post-Grade 10 training courses, direct employment, and responsible participation in community life (Deutrom & Wilson, 1986; Maddock, 1983; McLaughlin, 1995; Vulliamy, 1988). The core curriculum

included English, mathematics, science, and social science. Optional subjects made available were expressive arts, commerce, design and technology, physical education, home economics, and agriculture. Science was taught as an integrated subject for five 40-minute periods out of a total 40 periods per week, throughout the four years. All PHSs have at least one laboratory provided with running water and gas. Teaching was based on a syllabus and detailed teacher's guides produced by the Curriculum Unit of the Papua New Guinea National Department of Education (PNGNDOE). A school certificate was awarded after Grade 10 (Deutrom & Wilson, 1986; Wilson, 1989). Up to 1981 this was largely internally assessed and moderated by an external Mid-Year Rating Examination, applied across all schools in the country except for international schools. This moderating examination, in multiple-choice format, covered English, mathematical thinking, and scientific thinking, and was intended to be content free. On the basis of the moderating examination, schools were awarded an appropriate number of distinctions, credits, upper passes, passes and fails. These grades were then awarded to individual students in the respective schools across the country. From 1982 on, students have sat for four end-of-year multiple-choice papers covering English, mathematics, science, and social science, based on the stated syllabus objectives. The results of these examinations were used to moderate the internal assessments, which were then combined with the external marks. These combined results were then used to rank and apply a national distribution of distinctions, credits, upper passes, passes, and fails to individual students. About 15 % of Grade 10 students are selected on the basis of School Certificate results to enter the four national high schools (NHS), each of which enrols about 200 students in Grade 11 each year.

National high schools provided Grades 11 and 12, primarily with an academic preparation for tertiary study (Deutrom & Wilson, 1986). The curriculum involved all students in English, mathematics, science, social science, and expressive arts in Grade 11, while in Grade 12 a system of options operated whereby students chose from offerings in all of the five areas. All were required to take English and at least minor mathematics in Grade 12. As

alluded to by Deutrom and Wilson (1986), at the end of Grade 12 over 60% achieve matriculation to the universities and 80% continue with some form of post-secondary education. At Grade 11, therefore, there was a very radical change in curriculum philosophy. As students entered NHSs the curriculum became explicitly quantitative, academic, and highly selective. The compulsory Grade 11 and optional Grade 12 science courses contained separate strands of physics, chemistry, and biology (each usually taught by a different teacher). At Grade 11 each of the three strands had two 50-minute lessons per week while at Grade 12 each strand had three 50-minute lessons per week. The minor Science and Society course offered in Grade 12 consisted of a range of suggested modules grouped under the three main themes of (a) human biology, (b) evolution, and (c) technology, and was allocated a total of four lessons per week. It was a qualitative "Science for All" type course taught to a very small number of students (about 20%). Due to university entry requirements a majority (about 60%) were taught the major science program (comprising biology, chemistry, and physics) in Grade 12. A higher school certificate is awarded after Grade 12. The science examination consisting of three separate parts covering biology, chemistry, and physics is set by external examiners from the universities, while teachers are involved through the provision of questions. The examinations are based on the detailed syllabus objectives. The results of the external examinations are used to moderate the schools' internal assessment which is then combined with the external marks. The major purpose of these procedures is to provide a selection mechanism for entry to further education. Grade 11 and 12 science is thus traditional and highly selective in its student intake. It is very much academically oriented, quite quantitative and designed explicitly to prepare students for further study of science.

This section has provided a context for the study. In general, the Papua New Guinea cultural and educational system differed significantly from those in the countries in which most science education research was conducted and reported. Consequently, the review of prior research needs to take account of

this feature of the context in which this study was situated.

1.5   The significance of the study

The research study was one of the first of its kind to be conducted in a Papua New Guinea specific context by an insider. The study was, in the main, informed by current literature relating to epistemological and ontological stances taken in science, learning and teaching of science, world views of science and science education, social constructivism, classroom learning environments, nature of science, and the development of science education in Papua New Guinea after it attained independence from Australia in 1975. The methodology and research design incorporated into the study lead the way in generating data resources that were extensive and in-depth for interpreting a naturalistic and dynamic learning environment with its inherent learning activities.

This study was significant both at a theoretical level and a practical level. From a theoretical perspective, the study added to at least three areas of the literature. They were: (a) learning physical sciences in a non-Western classroom learning environment; (b) the nature of the learning environment and its impact on learning; and (c), learning in an environment where learners' conceptions are influenced by conceptual change conditions which are socially and culturally mediated.

The study also described and contributed to the modification of current beliefs and practices based on research conducted in locations that differ in important details from Papua New Guinea. From a practical perspective, findings from the study provided clues that enabled the researcher to understand how students learned new concepts in this particular classroom in Papua New Guinea. This understanding will be crucial to developing ways of improving teachers' instruction of science and students' learning with understanding in Papua New Guinea. The findings will point the way to

developing and enacting classroom practices that take into account students' experiences and prior knowledge as well as providing a holistic learning experience in the classroom environment. This study will add to information about the external environmental factors that can influence teaching and learning in a non-Western developing country.

This study will also make a contribution to overall research efforts in science education in Papua New Guinea by providing an insight into the nature of the current science teaching practices at pre-tertiary school levels. Consequently, the study will contribute to establishing a foundation for productive science education research at a university in Papua New Guinea.

1.6   Overview of the thesis

Chapter 1 has provided an overview of the study that was undertaken in a secondary science classroom in Papua New Guinea. The nature of the study, why the study was undertaken, the context in which the study was situated, and its significance at both theoretical and practical levels were discussed. The objectives and research questions for the study and potential benefits from it for science education in Papua New Guinea have been briefly discussed.

Chapter 2 examines the literature base for the study. Five areas of research are presented. They cover the rhetoric and reality of science education in Papua New Guinea, the nature of science and individuals' world views, the changing trends in science education research, research about the teaching of science in schools, and research in science education in Papua New Guinea

Chapter 3 discusses the research design and methodology incorporated in the study for data collection and analysis. Due to the nature of the research, an interactive model of research design (Maxwell, 1996, p. 5) provided a framework to conceptualise and describe the research plan and strategies.

Chapter 4 presents the results in three major sections. The first section focuses on science teaching and learning from the perspective of the class teacher and his colleagues who have recently taught the unit on Electricity at Grade 9 level. The next section considers data from the whole class of 43 students. These data are pertinent to students' views on science, the description of classroom climate, and students' and class teacher interpersonal relationships, in accordance with research questions 1 and 2 outlined earlier in Section 1.3. The last section reports the perspective of four selected focus students. This section goes further to extend understanding of interpretations from the preceding sections of the existing nature of the dynamics of learning in this particular science classroom in Papua New Guinea including cultural referents displayed by the teacher and students, and students' prior knowledge; thus, focusing mostly on research questions 3, and 4 presented earlier in Section 1.3.

Chapter 5 discusses the results presented in chapter 4, and Chapter 6 provides an executive summary and recommendations for further research arising from the study.

Chapter 2

Literature Review

2.1 Introduction

This chapter introduces the theoretical framework that provides the basis for the aims of the research and informed the methodology that follows in the third chapter. It begins by discussing the science education scene in Papua New Guinea in Section 2.2, to establish that much has been expected of science education but many expectations remain unfulfilled. Literature relating to outcomes of science education in other countries, both developed and developing is reviewed next in Section 2.3 with emphasis on students' attitudes, knowledge of science concepts, and views concerning the nature of science. Findings, which are common to developed and developing countries, and those which relate to one or the other, are identified and discussed in Section 2.4. There follows a review of the changing focus and methods of science education research over the past 25 years particularly in developed countries and a discussion of the implications of such trends for science education research in developing countries such as Papua New Guinea in Section 2.5. The final section of the chapter in 2.6 describes and analyses research in science education in Papua New Guinea in order to identify major issues in relation to pressing questions and appropriate methodologies to provide a context and justification for the research objectives of the present study. The summary section of the chapter (Section 2.7) presents the key objectives of the research, which emerge from, and are grounded in the literature reviewed. It concludes with a restatement of the broad aim and research questions of the study.

2.2 The rhetoric and reality of learning school science in Papua New Guinea

2.2.1 Background

The development of formal secondary education in Papua New Guinea had its genesis in the late 1950s, and the early 1960s saw the establishment of science education at the lower secondary level. As in most developing countries, the early syllabuses were imported, and in this case Papua New Guinea's science syllabuses were modelled very closely on those in use in Australia, notably in New South Wales. In 1966 a science syllabus for Grades 7-8 was designed within Papua New Guinea by the Papua New Guinea National Department of Education (PNGNDOE) was released for use in schools. This was followed by a Grade 9-10 science syllabus a year later. The new syllabuses were laboratory-based and were taught by teachers recruited from Australia, New Zealand and the U.K. in multiple laboratories built in high schools by the colonial government (Maddock, 1983).

From primary to upper secondary school levels, science has been included in the syllabus as a core subject for all students (PNGNDOE, 1977; Wilson, 1989). Science education featured prominently in the Papua New Guinea education system because it was considered by the Papua New Guinea Government to be an important tool for achieving national goals and objectives for development and prosperity (Matane, 1986). A highly trained workforce was considered crucial to the needs of industry and the technological advancement of a newly independent nation of Papua New Guinea, in a modern competitive world. The government also considered that improvements in scientific literacy would enhance personal standards of primary health care, nutrition, and safety with respect to using technology, as well as assist individuals to understand the problems associated with environment degradation.

This was similar to the situation in many other countries that have been developed as colonies of Western industrialised powers. The majority of their emerging institutions, including education have been modelled on Western nation institutions. However, in Papua New Guinea, this transition of science education has not been without its problems and today there are significant discrepancies

between the rhetoric and practice of science education in schools (Vulliamy, 1988; Wilson, 1989).

2.2.2   The rhetoric about school science

The aim of secondary science education in Papua New Guinea, as published in the 1977 science syllabus, has been largely taken from the 1967 syllabus. The current syllabus states that:

> The science course should aim to develop certain attitudes, concepts, intellectual skills, and manipulative skills that will help the pupil to understand and solve problems in his (sic) world, recognising their particular significance in the changing society of Papua New Guinea. (PNGNDOE, 1977, p. 1)

These aims have been interpreted in the science syllabus by identifying five areas for development. The areas which the syllabus requires students to develop are:

- An awareness of, interest in and curiosity about the natural phenomena of their environment, and a commitment to seek a scientific explanation of those phenomena.

- An understanding and appreciation of their relationship to the environment and confidence in their ability to effect changes and improvement in the environment.

- An understanding of a selection of significant scientific facts and theories, and the ability to apply them in relevant situations.

- Students' critical thinking ability and a reduction in tendency to adopt opinions based on unsupported or unreliable evidence.

- An understanding and appreciation of the methods of science, and the past, present and possible future contribution of science to mankind. (PNGNDOE, 1977, pp. 2–3)

In revising the science secondary syllabus, the Syllabus Review Committee (PNGDNOE, 1977) extended this interpretation of the aims by incorporating two important, but conflicting needs. School science had to prepare for the needs of those few students, who progressed on to further academic studies, and at the same time, to cater for the majority of students, approximately 85%, who returned to community life to engage in subsistence farming (AusAID Report, 2000, p. 4; Matane, 1986). Those returning to community life required skills, not only to adapt meaningfully to the village environment, but also to be able to maintain a sustainable lifestyle. This pattern of student behaviour is bewildering to decision makers and others concerned with education in Papua New Guinea because over 80% of the students came from the village environment in the first place.

2.2.3 The reality of school science

After 27 years of nationhood and of development of science education in the primary and secondary school system in Papua New Guinea, it would be reasonable to expect that, to some degree, the intended outcomes of the science syllabus would be observable. That is, if the rhetoric had become reality then there should be some noticeable improvements in the health and general standard of life of the general population. The high proportion of students who had returned to rural life would have settled in well to become useful, productive members of their communities. However, contrary to these expectations, Papua New Guinea has experienced social and economic problems that have threatened its very survival as a young emerging nation. Consequently, the non-fulfilment of the expected outcomes of the science education syllabus may be one key contributing factor to the social problems attributed to unemployed school leavers congregating into towns and cities (PNGNDOE, 1993).

According to PNGNDOE (1993), each year there are an ever-increasing number of students dropping-out of the education system and returning to community life, to the towns and cities, in search of formal employment

opportunities, adding to law and order problems. It seemed these school leavers were not successful in utilising knowledge of science and other skills gained at school in their communities. What had been covered by the syllabus appeared, to a great extent, irrelevant to meeting the desired goal of making rural life attractive to students. Below is a prophetic extract from the Groves report (Groves, 1936) for the then Australian New Guinea Administration, highlighting what has now become a reality in Papua New Guinea, as well as in many other developing countries.

> The tendency has been to divorce the schools from native life and thus to bring about a division of interests and outlook between the educated few and their village confreres…It is certain that the road being followed is not the one that will lead to social progress, and will not serve the needs of the mass of the people…Schools for natives should be true native schools, and not just imitations – and poor imitations at that – of European educational institutions, which tend in a tragic way to wean the young people away from their natural life and heritage. (pp. 75-76, 80)

For the fortunate minority who progress on to further academic studies and vocational training, their knowledge of the physical sciences appears to be superficial and naïve in many instances. A small number of studies on alternative conceptions of science involving Papua New Guinean students (Awei, 1992; Boeha, 1988; Najike, 1993; Tulip & Lucas, 1993) have provided important evidence that significant levels of alternative conceptions of science concepts prevail in students who had studied school science. These trends in research findings have significant implications for pedagogical practice but science syllabuses and classroom practice have not changed much in Papua New Guinea despite these research findings. For instance, the Science Teacher's Guides for Grades 7-10 presently in use were written more than 20 years ago (PNGNDOE, 1977).

There is a substantial body of research into the occurrence and persistent nature of alternative science conceptions held by students in developed countries (Duit, 1991; Mintzes, Pfundt & Duit, 1994; Wandersee & Novak, 1998). This research has spanned a period of more than 20 years. However, the development of such alternative conceptions and, more importantly, appropriate teaching strategies to address them remain poorly researched in Papua New Guinea and similar developing countries.

2.3 The nature of science and individuals' worldviews

2.3.1 Introduction

The previous section examined the failure of school science to meet expectations of policy makers in government and parents, and outlined some of the problems that arose. In many ways, these problems stemmed from internal and external constraints on students and teachers over which they had limited control. For example, instruction in science was carried out in English, the language of the textbooks, but many students had limited facility in English. Similarly, Australian science courses and texts assumed that students were living in an English speaking industrialised society, but in Papua New Guinea most students and teachers had been raised and continued to live in rural communities without many of the artefacts of science and technology familiar to their Australian counterparts. For science education to be effective, it must take more explicit account of the cultural context of the society which provides its settings, and whose needs it exists to serve (Aikenhead, 1996; Aikenhead & Jegede 1999; Cobern & Aikenhead, 1998; Maddock, 1981; Wilson, 1981). Accordingly, cultural contexts and influences on learning science, students' attitudes and knowledge of science concepts are discussed. This section also reviews different views of the nature of science, and the links with ways that science is taught in schools.

2.3.2   The classical view of the nature of science

The classical view of the nature of science is concerned with the uncovering of the invariant laws of science that have their own set rules and language. It is based on the philosophical principle of positivism, that knowledge must be based on the evidence of the senses, rather than on external pronouncements. Accordingly, the purpose of science is to find correlations between the events perceived through the senses (Cromer, 1997; Woolgar, 1988). Nott and Wellington (1998) agree that there is a strong belief among proponents of classical science that scientific knowledge is more valid than other forms of knowledge. Furthermore, Nott and Wellington state that the laws and theories generated by experiments are the descriptions of patterns observed in a real, external objective world.

Experimental inquiry is central to the classical approach to science. Many school science programs purported to reflect this, particularly in the 1970s and 1980s in developed countries, and also to some extent in Papua New Guinea. Even so, most showed little evidence of inquiry on the part of students and teachers (Tobin & Gallagher, 1987; Tobin, Kahle, & Fraser, 1990). Rather, they emphasised learning of basic facts and definitions from science textbooks and relatively little emphasis was placed on inquiry, applications of knowledge in daily life, or the development of higher-order thinking skills. Thus, curricula that reflect the classical view of the nature of science and promote transmissive teaching with limited involvement in inquiry are still common in both developed and developing countries.

2.3.3   The relativist view of the nature of science

In direct contrast to the classical view of the nature of science is the relativist view. According to Nott and Wellington (1998), a relativist view denies that things are true or false solely based on an independent reality. The truth of a theory will depend on the norms and rationality of the social group considering it, as well as the experimental techniques used to test it. Judgements as to the truth of

scientific theories will vary from individual to individual and from one culture to another. A relativist view of the nature of science posits that truth is relative and not absolute. A number of science educators have taken this notion of social groups and the influence of culture on learning in science education further by developing viewpoints that science is a cultural enterprise which existed to varying degrees in all types of societies (Aikenhead, 1996; Cobern & Aikenhead, 1998; Maddock, 1981). In so doing, they hold a position that is consistent with a social constructivist theory of learning (Bereiter, 1994; Driver, 1989; Gergen, 1995; O'Loughlin, 1992; Shapiro, 1989). There is a lively debate, which has been sustained for a considerable period, about the influence of culture on science (Cobern & Aikenhead, 1998; Maddock, 1981; O'Loughlin, 1992; Pomeroy, 1994; Waldrip & Taylor, 1999) and the implications for science education. This is discussed in the next section.

2.3.4   The cultural influence on the nature of science

A definition of culture by Geertz (1973, p. 5) is used in this chapter where culture means "an ordered system of meaning and symbols, in terms of which social interaction takes place." Attributes of culture, namely communication, social structures, skills, customs, norms, attitudes, values, beliefs, expectations, cognition, conventional actions, material artefacts, technological know how; and worldview provide other definitions of culture and have guided research in science education (Cobern & Aikenhead, 1998).

According to Cobern and Aikenhead (1998), over the past few decades, perspectives on science education have evolved from earlier psychological perspectives on the individual learner, such as those provided by Piaget (1978), Ausubel (1968), and Mintzes, Wandersee, and Novak (1997), to encompass sociological perspectives that contextualised learning in social settings, science for specific social purposes, and situated cognition (Brown, Collins, & Duguid, 1989; Waldrip & Taylor, 1999).

The next stage in the evolution regarding perspectives on science education was an anthropological one that contextualised learning in a cultural milieu, which extended on findings by Maddock (1981), Wilson (1981), and others. Maddock (1981) developed the viewpoint that science and science education are cultural enterprises which form a part of the wider cultural matrix of society and that educational considerations concerning science should be made in the light of this wider perspective. About the same time, Wilson (1981) emphasised the cultural context of the learner of science as a complex web of linguistic, social, political, economic, philosophical, and religious factors after reviewing literature on the subject. Since then, gradual acceptance of the influence of culture (contexts) on learning began to gain acceptance amongst researchers in the field. For instance, Cobern and Aikenhead (1998) perceive science itself as a subculture of Western or Euro-American culture that symbolised great prestige, power and progress. The anthropological perspective proposed by Aikenhead recognises conventional science instruction as an attempt at transmitting a scientific subculture to students (Aikenhead, 1996).

> If the subculture of science generally harmonises with a student's life-world culture, science instruction will tend to support the student's view of the world (enculturation). On the other hand, if the subculture of science is generally at odds with a student's life-world culture, science instruction will tend to disrupt the student's view of the world by trying to replace it or marginalise it (assimilation).
>
> Enculturation appeals to students who are science enthusiasts while assimilation attempts to dominate the thinking of students. Both enculturation and assimilation require border crossings into the subculture of science. (p. 5)

Aikenhead's perspective is well suited for consideration of science education in non-Western developing countries such as Papua New Guinea, as it has been, in relation to the science education of the Canadian First Nation

(Aikenhead, 1996) and Australian Aborigines (Aikenhead, 1996; Mitchie & Linkson, 1999).

Another facet of cultural influence on the nature of science and science education is the influence of indigenous science (knowledge) or ethnoscience, commonly of particular significance in developing countries. The influence is stronger because of the way knowledge systems are perceived. In the Western system, knowledge is partitioned into areas or subjects and Western science is a segment of that body of knowledge acquired through particular ways and identified by participants as belonging to the area. On the other hand, in indigenous knowledge systems, knowledge is perceived as holistic and purposeful to the participants (Aikenhead & Jegede, 1999; Fleer, 1999; Waldrip & Taylor, 1999). For example, in a South Pacific Melanesian country that was very similar to Papua New Guinea in many ways, Waldrip and Taylor (1999) found that traditional worldviews and knowledge are perceived by village elders and high school students as an integrated whole unit useful for improving the knowledge and skills for survival in the village. Pauka and Treagust (1999) report that traditional knowledge of non-Western cultures is organised and based on integration, and not on analysis into parts. This is because traditional knowledge is derived from a wide diversity of experience in nature, from teaching and apprenticeship, working with the land, absorbing the feel of the wild animals and plants, and by listening to legends and stories.

Vlaardingerbroek (1990) examined the opinions of trainee Papua New Guinean secondary science teachers on ethnoscience and its actual and potential role in science education. He defined ethnoscience as the study of knowledge in its cultural context as a cultural adaptation to the world in which the people practicing it live. Vlaardingerbroek was able to show that in spite of the presence of a significant minority with very negative views towards traditional knowledge, a great deal of potential positive feelings towards a more active role for ethnoscience in high school science teaching existed amongst the trainee body. Vlaardingerbroek further highlighted the fact that there was limited research on

ethnoscience in Papua New Guinea and the extent to which traditional knowledge is honoured, or even acknowledged, by students and teachers in formal science lessons in Papua New Guinea is very minimal. Waldrip and Taylor (1999) find a similar situation in a neighbouring Melanesian country where traditional knowledge is almost rejected as having no significance or relevance to the formal science lessons taught in schools.

The dilemma faced by non-Western developing countries such as Papua New Guinea, in adopting a suitable school science, is dependent on a number of factors that include costs, relevance and perceived benefits. The next section discusses the issues involved in adopting a particular science curriculum by developing countries and specific indigenous communities in developed countries.

2.3.5 Traditional Western science or an alternative approach?

The issue of a mismatch between traditional Western science with all its cultural baggage and the apparent lack of practical relevance for many students in a developing country such as Papua New Guinea, and an alternative approach that attempts to provide some of the useful outcomes of science and technology for the benefit of citizens without damaging their culturally diverse understandings of the physical and biological world is a very important one for science education planners in non-Western countries (Maddock, 1981; Ogawa, 1986; Ogunniyi, 1988).

A study conducted in Papua New Guinea showed that outcomes of a traditional Western science education in a developing country context led to further alienation of students from their culture, resulting in an inability of students to return to community life usually in a rural environment with old traditional styles of living (Maddock, 1983). Such students have assimilated into the foreign subculture of science that is an integral part of Western culture (Aikenhead, 1996). Waldrip and Taylor (1999) suggested that in developing countries, the process of enculturation into a Western school view involves an

implicit devaluation of students' traditional worldviews which govern their village lifestyles; and a Western world view is of limited viability in relation to traditional values and practices.

The Papua New Guinea school curriculum began encouraging local examples in its science syllabus, which came out in 1967. It consisted of three sections - a core section emphasising a narrower range of academic basic principles considered essential, a developmental section where teachers were given the option of selecting a technological area of interest familiar in the region in which they taught, and exploring the science related to it and a research area where open-ended exploration could be conducted into an interesting phenomenon of importance to the local people and easily found in the area round the school (Maddock, 1983).

It appears feasible that students from developing countries, and indigenous and minority groups in developing countries need to be given access to the full range of Western science and to understand its underlying philosophy, as well as retaining their cultural worldviews. In brief, a dual view of the world may become necessary. Ogunniyi (1988), and Mitchie and Linkson (1999) argue that an indigenous cosmology conflicting with Western science thinking should not preclude an understanding of science. Rather, it is possible to hold simultaneously an indigenous view and a scientific view of the world.

2.3.6   Summary

In considering the nature of science and individuals' worldviews, Section 2.3 commenced with a discussion on the classical view of science, highlighting the fundamental characteristics that distinguish it from other views of science. The classical view of science was then contrasted with the relativist view that emphasises the relativeness of what is perceived as the reality. Next, due to the prominence given to the influence of culture in the proposed study, current studies on the influence of culture on the nature of science in the context of non-Western

developing countries such as Papua New Guinea was discussed in some greater detail.

The notion of students possessing dual views of science, the Western school views and the traditional cultural worldview has yet to be researched to assess its viability and benefits to learners, especially those coming from a non-Western cultural background. Much research by indigenous researchers is required in non-Western developing countries and first nation communities to provide first hand insight and meaning to the way in which students from such non-Western cultures view the world and how their worldview influences their learning in schools. Today's trends and shifts in research methods from traditional research techniques that withstand a variety of statistical tests to present day research methods that include description of phenomena in rich and systematic ways (Kelly & Lesh, 2000) make the kind of research advocated above feasible. The change in research trends and shifts in science education are discussed in the next section.

2.4   Changing trends in science education research

2.4.1   Introduction

In a recent major review of the field of science education, Keeves (1998) made the following observation:

> Research in the field of science education has undergone a marked transformation during the 50 years since the termination of World War II due to: (1) the emerging understanding of the nature of science; (2) the marked expansion throughout the world, in both developed and developing countries alike, of secondary and higher education in which science education has played a significant role; (3) the rapid growth of scientific knowledge during the 20th century, which needs to be disseminated to students at all levels of education; (4) technological developments, particularly the electronic computer and opportunities for the

storage and transmission of information and the analysis of
large bodies of data; and (5) the support provided, particularly
in the USA, for research into educational problems. (p. 1127)

Keeves further pointed out that methods employed in research are
contingent not only on the research methods available, but also on the nature of
the research problem under investigation. This in turn is dependent on the theories
that have emerged from previous research. It is through the development of
theory, notably as proposed by luminaries such as Piaget, Ausubel, Von
Glasersfeld, Novak, and Driver that the changes that have occurred in science
education research have been greatest. After an in-depth analysis of research
articles in the Educational Research Information Clearinghouse (ERIC) and
Research in Science Education (RISE), White (1997) showed trends in the style
of research over the period 1975-1995. The move was from brief well-designed
and controlled laboratory-style experiments to lengthy observations and
descriptions of classrooms. Reliance on inferential statistics declined, interviews
became common and research became more theory driven and more relevant to
practice (White, 1997). According to Kelly and Lesh (2000):

In the past few number of decades, educational researchers
have moved into school systems, classrooms, and work places
and have found a complex and multifaceted world that they
feel is not well described by traditional research techniques. In
the past, educational phenomena derived their status by
surviving a variety of statistical tests. Today, nascent
educational phenomena are accorded primacy, and the onus is
on research methods to describe them in rich and systematic
ways. (p. 35)

Many researchers in science education were interested in research which
ventured beyond the positivistic quantitative procedures that underlie the majority
of early science education research (Spector & Glass, 1991). Thus, fewer and
fewer evaluative and aptitude-treatment interaction studies were conducted in the

period surveyed by White from mostly developed countries such as USA, Canada, UK, Australia and New Zealand as researchers adopted more qualitative methodologies. A brief account of the changing fashions in science education research reported in the literature is provided, together with some recent studies. Finally, conclusions are drawn concerning appropriate research strategies that might be applicable to contemporary research problems in science education in Papua New Guinea.

2.4.2   Evaluative and aptitude-treatment interaction studies

The evaluative and aptitude-treatment interaction studies have traditionally involved a positivist epistemology, applying quantitative methods, and largely patterned on research in the physical and biological sciences. The focus is on independent and dependent variables, causal relationships and control, with little attention or regard to individual students' learning. Analyses of data were usually done through statistical packages with findings generalised to populations (Cohen & Manion, 1992; Wiersma, 1991). The types of research under the category of evaluative and aptitude-treatment interaction studies as reported by White (1997) cover experimental, curriculum evaluation, correlational, and comparison of groups. Experimental studies lead to findings which provide causal inferences that can be made from carefully designed studies. An experimental study has four important characteristics: the subjects chosen for experimentation are randomly selected from a target population; subjects chosen are assigned randomly to the groups formed for study in the experiment; there is an intervention where a treatment is administered to the treatment group and not to control group (these groups are randomly selected); and the effects of the treatment are reliably measured to form the dependent variable in the analysis of data.   The evaluation research category includes evaluation of student achievement, instructional methods, curriculum materials, science education programs, and educational organisations (Cohen & Manion, 1992; Keeves, 1998).

Evaluative and aptitude-treatment interaction studies were appropriate for the kinds of questions being asked by educators of the period and did provide evidence to support or call into question theories that were current at the time. Research findings from such studies led science education researchers eventually to ask different kinds of questions, which required different methodologies with different sets of assumptions about the nature of knowledge, and of inquiry.

2.4.3 Interpretive studies

Interpretive studies, according to Gallagher (1991) form a sub-category of qualitative research studies that use approaches which include ethnographic, participant observational, case study, phenomenological, symbolic interactionist, and constructivist research. In some references used, the terms qualitative research and interpretive research have been to a certain extent used synonymously (e.g., Spector & Glass, 1991).

The purposes of interpretive research are to document in detail the conduct of everyday events and to identify the meanings that those events have for those who participate in them and for those who witness them (Erikson, 1998). Interpretive researchers may be interested in understanding the specific detail of interactions that constitute effective teaching and learning which occur between teachers and students, as well as among students, and with the world outside (Gallagher, 1991). Cohen and Manion (1992) further elaborate that interpretive studies involve a relativist epistemology, although ontologically, some, perhaps most, researchers adopt a realist position. The methods used allow subjective observations and interpretations, with appropriate measures being taken to establish authenticity of the findings. Frequently such studies are clinical, and involve few students (Hanrahan, 1998; Roth & Lucas, 1997; Roth, Lucas, & McRobbie, 2000; Shapiro, 1989).

Interpretive research has attracted some criticism. Erickson (1998) observed that the criticisms of interpretive research come from both 'hard science,' positivist advocates outside such research and from inside, those who

are interpretive researchers. The internal criticism refers to an overly researcheritative voice in some forms of interpretive research, particularly ethnography. To some extent, these criticisms may be addressed by taking care to show clear evidence for assertions. The external critics question the entire interpretive research movement on the grounds that it does not meet their rationalist expectations. One aspect of this is that traditional interpretive research is open to abuses of 'researcherity' by researchers (including those of self-deception in data identification and analysis). As Erickson points out, a response to this has been for researchers to attempt to check imbalance of power by sharing it more fully with those who are studied. With researcherial researcherity comes professional responsibility, and those internal critics have increased a sense of this among the most thoughtful interpretive researchers.

Despite their limits, interpretive methods make important contributions to science education research (Erickson, 1998; Gallagher, 1991; Maxwell, 1996). Erickson (1998) aptly highlights the immense benefits of interpretive studies, especially to "make sense of, or give meaning to" the specific and diverse nature of daily life in classrooms, as follows:

> Interpretive research most essentially addresses issues of the literal and metaphoric meaning of actions to social actors, while it also documents those actions in the concrete details of their routine enactment. It is the most fundamentally constructivist research method available to us. It enables us to see and understand how, in the conduct of daily life, all persons are busy, active, and making sense. (p. 1172)

Interpretive research has become an accepted part of the methodology in science education because it allows researchers to ask and answer questions that cannot be answered fully or satisfactorily by other methods. The most obvious contribution of interpretive research methods to visualise has been to detail the nature of practices in science classrooms. Most interpretive research contributes to knowledge of the events of practice (Erickson, 1998; Gallagher, 1991; Maxwell, 1996). Findings from such studies have more potential to inform

improved classroom practice than do traditional evaluative and aptitude-treatment interaction studies (Denzin, 1996; Erickson, 1998; Maxwell, 1996).

2.4.4   Classroom-based studies

The emerging popularity of interpretive studies in science education as noted by Gallagher (1991), Maxwell (1996), and Erickson (1998), has contributed to an increase in classroom-based studies conducted in the natural learning environment setting. One notable example of this is that international research efforts involving the conceptualisation, assessment, and investigation of perceptions of aspects of the classroom environment have firmly established classroom environment as a thriving field of study (Fraser, 1998; White, 1997).

Recently there has been substantial growth in the number of science classroom-based studies (Chin & Brown, 2000; Fraser, 1998; Henderson, Fisher & Fraser, 2000; Roth, Lucas, & McRobbie, 2000; Stephens, McRobbie, & Lucas, 1999). Such studies can be seen as a natural extension of clinical studies and as growing out of theoretical considerations, especially constructivist theories of learning (Tobin, 1998; White, 1997). Similar studies provide insights into the complex teaching and learning processes that constitute the dynamic transactions within a typical classroom. Other areas of focus for science education in recent years include computer-assisted instruction (Teh & Fraser, 1994), and teacher interpersonal behaviour in the classroom (Wubbels, Creton, Levy, & Hooymayers, 1993).

Frequently, a combination of traditional quantitative descriptive strategies and interpretive methods are employed in classroom-based research. Maxwell (1996), Keeves (1998), Tobin and Fraser (1998), and others agree that more consideration should be given to the methodological aspect about recognising the very many variables and dynamics which must be understood if significant changes are to be made in classrooms that will enhance student learning

outcomes, both cognitive and affective. For example, Henderson, Fisher, and Fraser (2000) have conducted a study that investigated the associations between students' perceptions of their biology teachers' interpersonal behaviour and their laboratory learning environments and their attitudinal, achievement, and performance outcomes. A combination of methodologies is therefore appropriate for addressing research questions involving classroom-based studies of recent years (Keeves, 1998).

2.4.5 Summary

The section has considered the remarkable transformation in science education research over the past few decades, in terms of methods employed as well as the nature of the research problems under investigation. Research in science education has undergone changes from brief, well-designed and controlled laboratory-style experiments to lengthy observations and descriptions of classrooms. The use of inferential statistics declined and interviews became more popular to address the emerging research questions which fell more in-line with the relativist view of the nature of science.

The chapter proceeds to review recent, relevant international research in science education, highlighting actual and potential links with developing countries such as Papua New Guinea when appropriate. It concludes with a consideration of the present state of research in science education in Papua New Guinea and the objectives and research questions of the research study.

2.5 Research about the teaching of science in schools

2.5.1 Introduction

This section discusses the research concerning the outcomes of science courses in secondary schools and current theories and debates concerning them. An international perspective is taken. Links to developing countries, and Papua New Guinea in particular, are made where possible. Subsections within this section cover the following themes:

1. The changing perspectives of learning paradigms

2. Cultural aspects of learning science

3. Classroom learning environments

2.5.2 The changing perspectives of learning paradigms

2.5.2.1 From behaviourism to social constructivism

Research on the learning of science in a formal classroom setting has been underpinned by learning theories of one kind or another. Constructivism had the ascendancy among learning theories in the 1990s, though this has not always been the situation. Research conducted prior to the late 1950s especially in the USA had a predominantly behaviourist tone, although cognitively based research did occur without becoming mainstream (Duit & Treagust, 1998). Behavioural and cognitive theories acknowledge that the learner and environmental variables influence learning but differ in the relative emphasis given to these variables. For example, behavioural theories stress such environmental factors as the arrangement of stimuli and the consequences (reinforcements, punishments) of given behaviours. Learning in behavioural theory requires that responses be performed and therefore, assign less emphasis to the learner variables than do cognitive theories. Cognitive theories acknowledge the role of environmental conditions as facilitators of learning. Teachers' explanations and demonstrations of concepts serve as environmental cues for students. Student practice of skills, along with corrective feedback, promotes learning. However, cognitive theories emphasise the way learners mentally process information to determine the what and how of learning, as well as the role of learners' thoughts, beliefs, attitudes, and values (Schunk, 1991).

Behaviourism had its origins in functional psychology or functionalism. As stated by Bredo (1997), Novak (1997) and others, at the turn of the 20th century, the dominant orientation in American psychology was functionalism, and not behaviourism or cognitivism. Common themes in functionalism, which has

been largely forgotten today (Bredo, 1997), included the notion that evolution selects individuals according to their mental capacities, and that human development progresses through successive stages reflecting those stages of social evolution, and that there is continuity between animal and human learning. In short, functionalism offers the view that mental processes and behaviours of living organisms assist organisms to adapt to their environments. Behavioural theory views learning as a change in the form or frequency of behaviour as a consequence of environmental events (Schunk, 1991).

The 1950s and 1960s saw the domination of cognitive theories over behavioural theory. By the late 1960s, the influence of behaviourist theories of learning in science education was waning and Piaget's ideas of intellectual development came into prominence. Piaget's research examined his constructs of concrete and formal thinking and attempted to create conditions and design convenient measuring systems so that the learner could move from the concrete to formal thinking in optimal ways. Novak (1978) challenged whether students develop general cognitive structures or cognitive operations to make sense out of experience. Novak argued that Ausubel's theory of meaningful reception learning, depended on the framework of specific concepts and integration between these concepts, therefore provided a better analysis and explanation of learning than did Piagetian stages. Thus, emphasis was placed upon the active person reaching out to make sense of events by engaging in the construction and interpretation of individual experiences (Pope & Gilbert, 1983). Nussbaum (1989) contended that it was a combination of a greater awareness of the paradigm shift in the philosophy of science away from positivism, along with the new emerging theories of cognitive psychology which finally led to the major drive in science education for a new approach to teaching that emphasised student internal cognitive processes.

The new approach to teaching was one that perceives students as active thinkers who construct personal meaning that will in turn help them form conceptions. This constructivist view of learning is defined as the acquisition of

knowledge by individuals through a process of construction that occurs as sensory data are given meaning in terms of prior knowledge (Tobin, Kahle, & Fraser, 1990). Learning is an interpretive process and involves individual constructions. Therefore, to learn science from a constructivist perspective implies direct experience with science as a process of knowledge generation where prior knowledge is elaborated and changed on the basis of fresh meaning negotiated with peers and teachers. The modern constructivist approach has already assimilated the sociocultural perspective (Driver, 1989; Shapiro, 1989), in so far as it applies to science as a discipline. The sociocultural perspective in personal constructivism made a lot of sense to researchers and science educators to an extent where social constructivism evolved, an off-shoot of personal constructivism. According to Staver (1998) constructivism falls into two camps, namely, personal constructivism, or radical constructivism as referred to by von Glasersfeld (1996), and social constructivism (Bredo, 1997), where the latter evolved from the former.

Personal constructivism or radical constructivism is identified by several defining ontological and epistemological characteristics outlined below (von Glasersfeld, 1996). In the first instance, knowledge is actively constructed from within by a thinking individual. It is not passively received through the senses or by any form of communication such as the transmissive approach to teaching and learning. Knowledge does not exist independent of the individual learner who has constructed it. Social interactions between learners are central to the construction of knowledge by individuals. The character of cognition is both functional and adaptive. The purpose of cognition is to serve the individual's organisation of his or her experiences of the environment in which the individual is situated. In other words, the purpose of cognition is not the discovery of an objective ontological reality, but to make sense or meaning of his/her world.

Social constructivist views centre on the making of meaning and sense of the world by any one group of individual learners through social interactions of which language is a vitally important component (Bereiter, 1994; Driver, 1989;

Gergen, 1995; O'Loughlin, 1992; Shapiro, 1989). Driver (1989) emphasised the role of language and social negotiations in the science classroom. Shapiro (1989) and others enriched the social constructivist perspective by including a student's personal orientation towards, for example, the science content, the teacher, and the school or institutional context. Accordingly, for social constructivists, knowledge is constructed and legitimised by means of social interchange between individuals (Bredo, 1997; Driver, 1989). Similar to personal constructivism, there are defining ontological and epistemological characteristics, described below, which distinguish social constructivism. Social interdependence enables individual learners to make meaning in language. Through language individuals co-ordinate their activities and therefore, at least two individuals are required to make meaning understood by others. Within language, meanings are dependent upon the context in which the social interdependence is situated. Language lies within sociological and historical occurrences, and that local agreements about connections between language and referent are not necessarily generalisable to other contexts (Gergen, 1995). Gergen (1995) further reported that the purposes served by language are primarily communal, and are important in continuing and fostering relationships between individuals in social groups, and, similar to personal constructivism, social constructivism's primary role does not lie in discovering an objective ontological reality. Social constructivism attempts to make sense or meaning of the social group's world.

Many researchers involved in science education, including Bereiter (1994), Cobb (1994), and Duit and Treagust (1998) agreed that these varying views of aspects of personal and social constructivism should complement each other as science learning should be viewed both as a process of individual construction and enculturation into the scientific practices of wider society. Moreover, Staver (1998) pointed out that both variations of constructivism, personal and social constructivism, have much in common. They share the same view of learning, as individuals actively construct knowledge and make meaning for themselves. They both consider social interactions between individuals as central to the construction of knowledge, and they see the character of cognition

and a language used to express cognition as functional and adaptive. However, according to Staver, the primary difference between personal and social constructivism lies in the foci of study, which ultimately lead to substantive differences in direction and problems for study. In personal constructivism, the focus is on cognition and the individual learner, while with social constructivism, the focus is on the language and the group of learners.

Sociocultural ideas have gained growing attention in science education over the past years, especially in Western developed countries. However, in non-Western developing countries similar to Papua New Guinea, the situation is not the same.

2.5.2.2 Developing country learning contexts: The case of Papua New Guinea

One of the major reasons for developing countries not responding positively to the benefits of social constructivist perspectives is due to the significant contextual differences in non-Western developing countries that render some recommendations based on research in developing countries inappropriate. For example, if teachers lack certain skills and experiences, or do not have access to specific apparatus and facilities, it will be impossible for them to comply with some research based recommendations. Moreover, differing cultural norms and worldviews result in different learning outcomes compared with those reported in Western cultural settings. In Papua New Guinea, for example, students attend science classes with traditional Melanesian worldviews that conflict with the Western worldviews. Pauka, and Treagust (1999, p. 3) contended that "the Melanesian worldview incorporates human and animal, the seen and the unseen, the living and the dead in a way that is vastly different from the Westerner's outlook."

Teaching and learning activities in developing countries that are similar to Papua New Guinea are usually teacher-centred, very bookish and use didactic approaches (Taylor, 1997). The primary aim is for students to pass external examinations, and learning in such environments involves low-level cognitive

structures (Maddock, 1983; Waldrip & Taylor, 1999). In Papua New Guinean schools today, teaching styles still reflect the behaviourist learning paradigm which was introduced into the country in the 1960s with an Australian education system (Maddock, 1983). Each science topic taught is included in the Teachers' Guides which has behavioural objectives explicitly stated for teachers to adhere to (PNGNDOE, 1977; PNGNDOE, 1987). The predominant teaching style in Papua New Guinean schools at present involves "chalk and talk," some teacher demonstration of concepts and principles using science apparatus, and individual student group experiment work. It seems there is a lack of up to date research activities to inform practice, and consequently enhance science education in Papua New Guinea. A trend in the science education scene in both developed and developing countries throughout the world is the research focus on the cultural aspects of learning science (Cobern, 1993, 1996; Cobern & Aikenhead, 1998; Jegede, 1995, 1997; Maddock, 1981; Ogawa, 1986; Okebukola & Jegede, 1990; Waldrip & Taylor, 1999) which is discussed in the following section.

2.5.3 The cultural context of learning science

As previously discussed in Section 2.3.4, in the past few decades, views on learning science have shifted from earlier psychological perspectives on the individual learner to encompass sociological perspectives that contextualised learning in social settings (Cobern & Aikenhead, 1998). Many researchers in science education believe that the cultural background of a learner plays a central role in learning. For example, Maddock (1981) proposed that "science and science education are cultural enterprises which form a part of the wider cultural matrix of society and that educational considerations concerning science must be made in the light of this wider perspective" (p. 1). Accordingly, research on cultural aspects of learning science has increased over the past years to shed light on how a students' culture can affect his or her learning of science in school (Cobern, 1996; Cobern & Aikenhead, 1998; Jegede, 1995, 1997; Ogawa, 1986; Waldrip & Taylor, 1999).

In African studies, Jegede and Okebukola (1989, 1991) believed that the socio-cultural interferences in science learning arise through students' traditional worldview. Similarly, in Papua New Guinea the students attend class with traditional cultural views that often are not in conformity with the school science view (Boeha, 1988; Pauka, Treagust & Waldrip, 2000). The epistemological and ontological stances of students in developing countries are not the same as those for Western developed countries. As mentioned briefly earlier, the traditional Papua New Guinean worldview includes human and animal, the seen and the unseen, the living and the dead in a way that is very different from the Western view (Pauka et al., 2000). Pauka et al. (2000) further elaborate on what the Western world refers to as the "supernatural categories." For Melanesians, these are simply the non-visible parts of a single continuum of life which are eminently natural and form a normal part of everyday life activities. In the Western system, knowledge is partitioned into areas or subjects and Western science is a segment of that body of knowledge acquired through particular ways and identified by participants as belonging to the area. On the other hand, in indigenous knowledge systems, knowledge is perceived as holistic and purposeful to the participants (Aikenhead & Jegede, 1999; Fleer, 1999; Waldrip & Taylor, 1999).

2.5.3.1 Students' traditional worldviews

In general, Papua New Guinean students' traditional worldviews remain much the same as they were generations ago because of the strong ties to land and the environment for survival. More than 85 % of the people in Papua New Guinea live in rural villages with very limited comforts of modern life such as running water and electricity. Traditional beliefs, stories and ideas to explain natural phenomena exist in every community in Papua New Guinea (Pauka et al., 2000), and these form the students' alternative conceptions prior to the systematic study of science in schools.

Working in Papua New Guinea, George (1991) identified examples of traditional views which he referred to as traditional science that are more influential in students' thinking than the Western science viewpoint. For example, traditional taxonomies of plants and animals seldom agree with the Western scientific taxa. This is illustrated by the grouping of snakes and scorpions in a single primary taxon in the particular non-Western science view. In another example, pregnancy, according to one clan, occurs when a spirit child enters a woman and is not directly related to sexual intercourse which is viewed as playing only an indirect part in preparing a woman for pregnancy. Frequent intercourse would, by sustained knocking on the womb, assist in producing the overflow of blood which is required before any woman could be possessed by the spirit child (Shea, 1978).

Elsewhere, in developing countries similar traditional views which differ from the Western scientific views abound. Working in the Caribbean, George (1989), and George and Glasgow (1989) developed a database which consisted of 236 items of what they call "street science." These items consist of beliefs and sayings that deal with the same content areas that are dealt with in school science, but which sometimes offer different explanations to those offered by school science. For example, human hair will grow longer if it is cut when the moon is full. The items have been collected through personal interviews with farmers, elderly citizens, medical personnel, and graduate researchers in the areas of bush medicines, and Creole and oral traditions, and have been cross-referenced with high school students' alternative conceptions in an attempt to establish a source for these conceptions. Data obtained indicate that fifteen year olds have some commitment to street science, and George and Glasgow (1989) believe that this is likely to be a powerful source of conceptions in science for Caribbean students.

Teachers from developing countries also exhibit evidence of conceptions contrary to school science (Ogunniyi, Jegede, Ogawa, Yandila, & Oladele, 1995; Vlaardingerbroek, 1991; Waldrip & Taylor, 1999). After conducting an extensive study amongst 283 Papua New Guinean trainee teachers, Vlaardingerbroek (1991)

revealed that 60 % of the trainee teachers expressed qualified or unconditional belief in the power of sorcery and in malevolent spirit beings called Masalai in the Papua New Guinean Pidgin language. A wide-ranging study of science teachers from five non-Western cultures (Ogunniyi et al., 1995) indicated that these teachers did not make clear demarcation between the scientific and non-scientific view. As such the researchers suggested that non-scientific viewpoints might influence their teaching of science. This implied that they might also help reinforce or fail to correct their students' inadequate notions of science or the universe. The situation described above raises the important issues of students' and teachers' views on the nature of science, which have implications for learning.

2.5.3.2 The nature of science

The phrase "history and philosophy of science" has been used to describe the interplay of disciplines that inform science education about the character of science. However, in recent times, a more encompassing phrase to describe the scientific enterprise for science education is the "nature of science." McComas, Clough and Almazroa (1998, p. 4) aptly refer to the nature of science as:

> A fertile hybrid arena which blends aspects of various social studies
> of science including the cognitive sciences such as psychology into a
> rich description of what science is, how it works, how scientists
> operate as a social group and how society itself both directs and
> reacts to scientific endeavours. (p. 4)

These researchers also suggest that a better understanding of scientists and the scientific community will enhance an understanding of the strengths and limitations of science, interest in science and science courses, and social decision making. Furthermore, knowledge of the nature of science fosters interest in science and the instructional delivery of teachers.

Understanding of the nature of science is critical to effective science education as a number of studies have documented students' alternative

conceptions regarding scientists, how science works, and the nature of scientific knowledge (Rowell & Cawthron, 1982; Rubba, Homer, & Smith, 1981). The significant misunderstandings that both students and teachers hold regarding the nature of science are particularly damaging to general scientific literacy because they affect students' attitudes towards science and science classes (McComas et al., 1998; Rowell & Cawthron, 1982). Nevertheless, it is highly likely that the lack of understanding of the nature of science has an impact on student learning and the selection of further science courses by students.

The only recorded study available at the time of writing, on the nature of science carried out in Papua New Guinea was by Mackay (1970), titled *Understanding of the Nature of Science of Some Teachers' College Students in the Territory of Papua and New Guinea.* This study is described in Section 3.2.4.3. Mackay used the Test of Understanding Science (TOUS) which comprised three scales of understandings about the scientific enterprise, scientists, and the methods and aims of science. The findings of his study indicated that students' understanding of the nature of science did not change significantly in their first year at teachers' college. Furthermore, the students' understanding of the nature of science at the completion of high school studies was considerably less than expected. What has been described above reinforces the need for more studies to be conducted in Papua New Guinea, especially in the classroom-based research and learning environment areas, and how views of nature of science influence learning.

2.5.4 The classroom learning environment

Over the past two decades, considerable interest has been shown internationally in the conceptualisation, measurement, and investigation of perceptions of psychosocial characteristics of the learning environment of primary and high schools (Fraser, 1998). As a result, several instruments have been developed to assess classroom environment. For example, the Learning Environment Inventory (Fraser, Anderson & Walberg; 1982), the Classroom

Environment Scale (Moos & Trickett, 1974) and the Individualised Classroom Environment Questionnaire (Rentoul & Fraser, 1979) have been used widely to assess classroom environments at the secondary school level. For use at the primary and tertiary levels respectively, My Class Inventory (Fisher & Fraser, 1981) and the College and University Classroom Environment Inventory (Fraser & Treagust, 1986) were developed.

Fisher and Waldrip (1997) reported a more recent instrument developed to assess culturally sensitive factors in the learning environment of science classrooms. Early indications show promise, especially when schools are becoming increasingly diverse in scope and clientele. The instrument, provisionally identified as the Cultural Learning Environment Questionnaire (CLEQ), was guided by the following criteria, in its development (Fisher & Waldrip, 1997):

1. Consistency with previous learning environment research.

2. Consistency with the social psychology, organisation sociology and anthropological literature.

3. Consistency with the important cultural dimensions in the unique environment of multicultural organisations literature.

4. Coverage of Moos' general dimensions.

5. Salience to teachers and students. By interviewing teachers and students an attempt was made to ensure that the CLEQ's scales and individual items were considered salient by teachers and students.

6. Economy. The CLEQ was designed to have a relatively small number of reliable scales, each containing a small number of questions.

The outcome was a questionnaire containing eight scales of Gender Equality, Collaboration, Risk Involvement, Competition, Teacher Researcherity, Modelling, Congruence, and Communication.

An instrument that provides a convenient method of graphically describing the nature of student-teacher interaction in the classroom learning environment is the Questionnaire on Teacher Interaction (QTI) (Wubbels, 1993). Students' and teachers' perceptions of classroom interactions are mapped onto separate charts that are easier to read and interpret compared to similar conventional instruments. The QTI is one of the instruments to be used in the proposed study and is discussed further in Chapter 3.

2.6   Science education research in Papua New Guinea

2.6.1   Introduction: A young history of science education

Papua New Guinea, a relatively young developing Pacific Island nation of more than five million people, has a very young science education system, even by Third World standards. Primary school science was first introduced into the school curriculum in the early 1950s where it evolved into a natural science course with increasing emphasis on the physical sciences (Maddock, 1983). According to Maddock the first high schools were established in the then Territory of Papua and New Guinea (TPNG) in 1957 using Queensland (Australian) courses. No science was offered at the time. Science was introduced later, following the change to affiliation with New South Wales in 1960, and was examined for the first time in 1963 with two schools participating in the New South Wales Intermediate Certificate examinations. Research in science education commenced in the late 1960s when research grants were made available by the Education Ministry to researchers from Australian universities to conduct research in schools in Papua New Guinea.

An extensive and in-depth search of the literature reveals that the number of research studies undertaken in the area of school science in Papua New Guinea from the late 1960s, during Australian colonial rule, to the present time has been limited. For instance, Wilson and Wilson (1977, 1986) and Eyford (1992), whose bibliographies on science education in Papua New Guinea covered the periods

from the 1960s to 1990, are able to list 205 articles collectively. Of the 205, less than 70% are reports of research studies while the rest are articles and general reports on issues and developments in science education.

Much of the early research can be broadly classified as quasi-Australian as it was dominated by researchers from Australia, with emphases on issues that related strongly to Australian science education research. The research included studies of: student attainment and learning difficulties (Mackay, 1969b, 1973; Mackay & Gardner, 1969; Marshall & Gilmour, 1990) attitudes (Maddock, 1982); and student cognition based on the work of Piaget (Kelly, 1971a, 1971b; Prince, 1968; Shea, 1978).

To facilitate the review of this literature on science education research in Papua New Guinea four major categories of research have been created. They are research:

1. that focus on student learning,

2. that accommodate students' cultural perspectives,

3. that is classroom-based,

4. by indigenous researchers.

These categories have been chosen because they not only cover most of the science education research in Papua New Guinea, but also because they reflect the dimensions of the present study. Research from each of these categories will be discussed in the following sections. Where research fits into more than one category, it will only be described once and subsequently referred to only by the researcher's name.

2.6.2   Research on student learning

When the University of Papua New Guinea was set up in 1966 (as part of a program by the Australian administration to prepare a skilled indigenous workforce to take over the running of the country on independence), research by academic staff was modelled on studies conducted in Australia. More than 50% of studies on student learning conducted in the 1960s and 1970s focused on Piagetian conservation related to school science (Price & Nidue, 1974; Prince, 1968). A handful of studies on student learning focused on areas of difficulty in the teaching of physical science concepts in Papua New Guinea. For instance, Mackay and Gardner (1969) linked their work on conceptual and language difficulties to learning problems associated with science. In this study, Mackay and Gardner administered standardised tests measuring concept attainment and principle learning in the physical sciences to 762 students in Grade 10 in Papua New Guinea. In addition, tape-recorded group interviews conducted by class teachers as well as individual interviews by Gardner yielded information on conceptual and vocabulary difficulties. The difficulties encountered in the topics of Measurement; Physical Quantities of Volume, Mass, Weight, Density; Force; Atoms and Molecules; and Light were significant and provided useful insight into students' learning difficulties for teachers. The findings were useful to most teachers at the time who were able to incorporate them in their teaching. These teachers were recruited on short-term contracts from Australia and other Western countries, and they had limited knowledge and experience of teaching in a developing country similar to conditions in Papua New Guinea. A few years later, Gardner (1971) did an extensive follow-up investigation into language problems which identified an extensive list of important non-technical vocabulary difficulties in Papua New Guinean high school students.

Three studies on learning will be discussed below. These three are selected because they illuminate possible examples of learning difficulties that feature prominently in an average Papua New Guinean science classroom. The first study by Marshall and Gilmour (1990) was carried out on Papua New Guinean students' comprehension of non-technical words used in science classes. The study was conducted on first year students at the Papua New Guinea University of

Technology in Lae. The findings pointed to the fact that many of the problems of comprehension experienced by students in physics classes arise not from technical words used but from the non-technical words used. The English language itself is not the first language Papua New Guinean students learn as infants because of the huge diversity of culture and languages in Papua New Guinea. Many students do not fully comprehend the non-technical words used regularly by science teachers. In this study Marshall and Gilmour tested 2111 students from Grade 7 up to first year university level. Of these, 629 were female, 1477 were male and 5 students did not indicate their gender. Forty-five non-technical words used in science classes in Papua New Guinea were included in the testing program. They were presented in four formats representing a different context each time:

1. A synonymous expression without context,

    For example: "Effect" can mean

    a) attack

    b) result

    c) frequent

    d) change

2. The word appears in a sentence describing an everyday event,

    For example: Which one of the following sentences uses the word "effect" correctly?

    a) The teacher could not effect the work of the pupils.

    b) The effect of heating the water was that it boiled.

    c) It took considerable effect to move the large rock.

    d) He thought that his smiling would effect everyone.

3. The word appears in a science context stem,

    For example: If you were asked to find the effect of adding acid to a metal, this would mean you would try to find

    a) the reason for adding the acid

       b) what happened

       c) how long the reaction took

       d) the quantity of acid used.

4. The word appears in a non-science context stem,

       For example: Putting the car brakes on had no effect. This means the car

       a) stopped

       b) did not stop

       c) went faster

       d) skidded.

For many words the results indicated that students lacked the required comprehension and often confused the words with others. Marshall and Gilmour further found that, in a number of cases, students actually selected the opposite meaning to that intended, for example, "take from" for "accumulate"; "simple" for "complex." There was also a tendency for students to confuse words with graphologically or phonetically similar ones such as "complex" with "compound," and "consistent" with "constituent." There was also a tendency to confuse words with others in the same or similar semantic field, for example, "detect" with "project"; "devise" with "do" or "make." In other cases words were selected which seem to fit grammatically but which did not capture the sense intended, for example, "methods" for "devices," and "insulate" for "isolate." In concluding their findings Marshall and Gilmour state that many students in Papua New Guinea do not fully comprehend the non-technical words used regularly by science teachers.

The second study on learning to be considered is by Boeha (1990), titled "Aristotle, alive and well in Papua New Guinea science classrooms." Boeha is an indigenous researcher who was one of the first Papua New Guinean academics employed at the Papua New Guinea University of Technology in Lae in the

1980s. In this study Boeha reports some Aristotelian views in situations involving the concept of force, held by 17 and 18 year old Grade 12 students in an upper secondary school in Papua New Guinea. It was part of a larger study conducted on alternative frameworks of Papua New Guinean students at upper secondary school levels. The larger study used a mixture of pencil and paper, and interview instruments similar to the interview-about-instance used by Osborne and Gilbert (1980). The instruments were used to evoke 21 Grade 12 (17 – 18 year old) Papua New Guinean students' Aristotelian-like views about natural phenomena that they bring with them to science classrooms. The Aristotelian ideas about force tested are listed below as:

1. Designed forces. Forces are assigned to objects that will cause events to occur. For example, humans are centres of forces. Also forces are inside bodies which cause events.

2. Motive forces. Forces are seen as acting upon a body moving in the direction of the movement.

3. Operative forces. Forces are actions that produce an effect.

4. Encounter forces. These forces act together to affect movement of a body. For example, a softball moving into the air appears to stop when it reaches maximum height due to encounter forces.

5. Impact forces. For example, when moving forces collide, the collision itself is considered a force.

6. Configuration forces. If bodies are stationary in a position, then they have force by virtue of the body's height from the reference plane. (p. 21)

Boeha's findings show that, similar to students in other countries, Papua New Guinean students have naïve views about the physical world. These views emerge from the everyday processes / experiences of living. The fact that these

views are similar to those described by Aristotle supports the idea that children construct their own understanding.

One study which moved somewhat in this direction concerning students constructing their own understanding of the physical world through their everyday living experiences was reported by Najike (1993). He investigated conceptions of electric current in simple direct current circuits held by first year students (19-20 year olds) at the University of Goroka in Papua New Guinea and Year 9 students (14-15 year olds) at a high school in Perth, Western Australia. Using a mixed quantitative (questionnaires) and qualitative (interviews) methods he was able to test the three key concepts in current electricity listed below.

Concept 1. The load in a closed loop or series electric circuit determines the magnitude of the current. If the load has a high resistance, a low current will pass through and vice versa.

Concept 2. Current flow is constant in magnitude in a series circuit at any one time. What-ever current is passing in a circuit as determined by its load remains the same value at every point in the closed loop. Current never gets used up.

Concept 3. In a parallel circuit, current depends on load while voltage drop (across loads) remains the same as source voltage.

Some common alternative conceptions identified were:

1. Determination of current in a series circuit

    - The length of wire determines the magnitude of current passing through it to complete circuit. The longer the wire, the less the current passing through it.

    - Two light bulbs will draw more current than a single light bulb in a series circuit.

2. The nature of current flow in a series circuit

- Current is used or consumed by load.

- Current is not constant or does not have the same magnitude at different points of the series circuit.

- Current progressively decreases in magnitude as it passes through more light bulbs.

- Current decreases in magnitude as more energy is used up by the light bulbs.

3. Current and voltage in parallel circuits

For light bulbs connected in parallel, most students' conceptions were very close to the canonical science ones. The majority of students from both groups indicated that total current divides equally between different paths (loops) with identical loads connected in parallel.

Similar to Boeha's research, the findings of Najike's study demonstrated that students' alternative conceptions relating to a particular domain in physical science are similar in Papua New Guinea and other countries such as Australia, United Kingdom and USA. Nevertheless, one might reasonably expect regional differences due to different cultural and educational experiences among countries. This is an under-researched area in Papua New Guinea.

The foregoing discussions provide a brief overview and status of research on student learning in Papua New Guinea from 1960-1999. International science education research journals in recent years have published many reports of interpretive studies of classroom-based learning. Such studies seek to understand teaching and learning in the context of local cultures, student characteristics, contemporary theories of learning and other factors perceived to be relevant. However, there is a lack of in-depth up-to-date research in Papua New Guinea

that attempts to interpret the processes of learning in such fine detail. The research by Marshall and Gilmour (1990), Boeha (1990) and Najike (1993) all identified culture as an important factor related to learning science. The next section looks at research that is accommodating cultural perspectives in the context of learning.

2.6.3. Research accommodating cultural perspectives

Science education research that accommodated students' or teacher's cultural perspectives in Papua New Guinea is limited. Of the few studies available, the first reported such study conducted in Papua New Guinea was in 1970 by Mackay of Monash University in Australia (Mackay, 1970). Mackay used the Test of Understanding Science (TOUS) to investigate whether changes in the understanding of science had occurred in high school teacher trainees during their first year pre-service training at a teachers' college in Papua New Guinea in 1968. According to Mackay (1970), TOUS was developed at the Harvard University Graduate School of Education by Cooley and Klopfer after having conducted considerable pre-testings. Form W of TOUS comprised 60 multiple choice items with four alternatives per item yielding three major areas derived from Cooley and Klopfer's analysis of the nature of science and scientists. These were:

Scale 1. Understandings about the scientific enterprise

Scale 2. Understandings about scientists

Scale 3. Understandings about the methods and aims of science.

These scales were used by Mackay. The results of his study indicated that students did not change significantly in their understanding of the nature of science during their study of science in their first year at teachers' college. In addition, as measured by TOUS, the trainee teachers' understanding of the nature of science at the end of their high school years was considerably less than would be desired. However, a weak point of the study was that TOUS considered the situation from the frame of reference of the (Western) professional scientist and

used the medium of English not modified for the Papua New Guinea context. Although the findings of such research provide insights into the difficulties in achieving the objectives of school or college science courses, they reveal little about the specific culture of the students.

Maddock conducted in-depth studies that were more culturally appropriate in 1972, and again in 1974, using an instrument based on Papua New Guinea culture known as the Environment Phenomena Attitude Scale (EPAS) (Maddock, 1974). EPAS was developed, refined and field-tested in English and included four Papua New Guinean language versions by Maddock. The test was administered in a number of indigenous languages as well as English. The study looked at the attitude towards investigation, control and manipulation of natural phenomena, in an attempt to evaluate stated aims in the Papua New Guinea syllabus, which purported to develop confidence in the students' ability to investigate their environment by scientific approaches and to develop the capacity to change opinions in the light of experimental evidence. Many of the items in the attitude scale used situations from Papua New Guinean cultures and others were based on the use of modern and traditional technology by Papua New Guineans. In 1972, the instrument was administered to Grade 9 and 10 students at high school and to a sample of village people about the same age, from the same language groups as the students, but having had less schooling. In 1974 a much larger sample of students was tested, as well as a wider counterpart sample of village people ranging from those with no schooling at all to those who had six years of primary schooling, and ranging in age from twelve to mature and middle aged people.

The results indicated a statistically and very socially significant rise in attitude scores from the lowest level of formal education through to the highest level, the difference between the top and bottom levels in the 1974 study being greater than 1.5 standard deviations. When students were asked to predict what responses uneducated villagers would give to the same questions, the mean for their predictions was more than two standard deviations lower than the mean for the students' own scores. Follow-up open-ended interviews revealed that the

students viewed the village people as being ignorant and tradition bound, and many attributed their own enlightened status to their having been taught science at school.

In a second followed-up study in 1980, Maddock (1982) further evaluated the performance of EPAS as a research instrument and assessed any changes in attitudes that may have occurred since the earlier studies. The studies described above show students' attitudes and impact on students' behaviour after school but seem to fail to provide understandings from cultural perspectives that may influence classroom teaching and learning of science. Research that is classroom-based in which the learning contexts are examined and interpreted to provide rich meaning should be encouraged as a means to improve learning in the classroom.

2.6.4 Classroom-based research

Much recent research published in international science education journals focuses on teachers' and students' activities in classrooms. Classroom-based studies could be seen as a natural extension of clinical studies and as growing out of theoretical considerations, especially constructivist theories of learning. The emerging popularity of interpretive research methodology has been a dominant factor that has led to the increase in classroom-based research. Interpretive research has addressed methodological considerations about recognising the very many variables and dynamics which must be understood if one is to make significant changes in classrooms that will enhance student affective learning and cognitive learning outcomes.

This type of research in Papua New Guinea science classrooms is not reported. Much has yet to be understood of the nature of learning and teaching activities in its naturalistic setting in Papua New Guinea schools. It is clearly desirable for this kind of research to be conducted, if for no other reason than to provide authentic contexts in which to assess the relevance of other (widely accepted) research findings for teaching and learning science in Papua New Guinea.

Implications for the research methodology adopted in the present study are significant in a number of ways. According to Erikson (1998), Gallagher (1991) and Maxwell (1996), most interpretive studies similar to the present one contribute to knowledge of the events of practice and their findings have more potential to inform improved classroom practice then do traditional evaluative and aptitude-treatment interaction studies in science education. The methodology of the present study involves a careful detailed documentation of everyday events and to identify the meanings that those events have for those who participate in them and for those who witness them (Erikson, 1998). The present study is not only enriched by the use of an appropriate theory driven methodology in place but it is further strengthened by the inside knowledge of the researcher who is indigenous and was educated under the education systems of both Papua New Guinea and Australia. The researcher is a member of a small growing group of indigenous researchers in science education in Papua New Guinea.

2.6.5   Research by indigenous researchers

Research by indigenous researchers in Papua New Guinea was non-existent in the 1970s. From the late 1980s and up to the present time such research activities still remain low in volume. Eyford (1992) made 34 entries for science education in the bibliography of education in Papua New Guinea from 1986 to 1990 when she compiled a bibliography of education for the research branch of the PNGNDOE. Out of the 34 entries on science education studies conducted in Papua New Guinea, 13 were on teaching strategies, 2 were on students' alternative conceptions, 5 on curriculum, 5 on science education issues, 2 on student attitudes, 3 on language and 4 on ethnoscience. Of the 19 researchers 2 were indigenous (Boeha, 1990; Kappey, 1983, 1989) and the rest were expatriate researchers mostly from developed English speaking countries. The majority of them were either academics from universities and teachers' colleges or curriculum

staff with the PNGNDOE. Recent additions to the list of indigenous researchers include Awei (1992), Kelontii (1996), Najike (1993), and Pauka (1988).

In the majority of cases, the research conducted by indigenous researchers is largely replication of studies conducted elsewhere with only the element of comparison between two different countries (see for example; Awei, 1992; Boeha, 1988; Najike, 1993). Many of these replication studies fall under the research field of the alternative conception movement popular internationally in the 1980s to the early 1990s (Wandersee, Mintzes, & Novak, 1994).

These indigenous researchers added a unique dimension to science education research in Papua New Guinea because, as insiders who have been educated through their own country's education system, they have an in-depth first hand knowledge of the context of learning and the cultural norms and belief systems of Papua New Guinea. Thus, research conducted by indigenous researchers is most meaningful as they have inside information and insights which researchers from other countries would not normally have.

2.6.6 Conclusion

Science education research in Papua New Guinea is in its infancy. The majority of research studies conducted in the past twenty years have been quasi-Australian and replication studies from English speaking developed nations set in the local context. After Papua New Guinea gained independence and more jobs were localised by indigenous staff, most skilled expatriate researchers left and there was a drop in research activity. In order for school science teaching and learning to improve significantly, research that strives to interpret and document practice and provide data on the influences of culture and the numerous dynamic forces at play in the classroom learning environment is urgently required. The present study has been conceived with this imperative in mind.

2.6.7 Summary and research questions

The review of the literature has drawn the reader's attention to the problems associated with students' learning of science in a Papua New Guinean high school classroom environment in relation to their poor grasp of abstract science concepts. Students' poor understanding of abstract science concepts, and teaching and learning in general, in formal classroom environments have been shown to be influenced by the students' and the teacher's cultures and worldviews. Students' learning might be improved if teaching and learning strategies acknowledged awareness of these cultural aspects.

The individuals' worldviews and the cultural context in which learning occurred has been highlighted, together with the complexity and importance of the shifts in learning paradigms in science education research, the nature of the learning environments, and the changing fashions in science education research.

The review of the research literature ends by drawing the reader's attention to the contextual issues related to the present teaching practices that generally employ low-level cognitive skills of students, and the incongruity of educational objectives with actual outcomes of science education in Papua New Guinea. Moreover, science education research in Papua New Guinea has been shown to be limited in scope and volume, and therefore there is the need for research to be increased to inform practice and decision-making for all stakeholders of education in Papua New Guinea.

The broad aim of the study was to investigate and interpret teaching and learning as they unfolded in a classroom learning environment in which a Grade 9 class was taught a unit on electricity in Papua New Guinea, by the regular class teacher. This broad aim gave rise to four research questions mentioned earlier in Section 1.3 to which this research attends. These questions were:

1. How did the students in this classroom view science in the context of teaching and learning?

2. How did the students perceive their learning environment and the teacher's interpersonal interactions?

3. How did the students' prior knowledge influence teaching and learning in this learning environment?

4. What were the cultural referents displayed by the teacher and the students that impacted on teaching and learning?

The next chapter reports the design and methods utilised to study these research questions.

Chapter 3

Methodology

3.1 Introduction

This chapter builds on the literature reviewed in Chapter 2 and discusses the methodology that were employed to investigate and interpret the teaching and learning of science in a secondary school in Papua New Guinea. The word methods as applied in this research "encompasses the range of approaches used in educational research to gather data which are to be used as a basis for inference and interpretation, for explanation and prediction" (Cohen & Manion, 1989, p. 41). Cohen and Manion state that traditionally, the word methods refers to those techniques associated with the positivistic model, eliciting responses to predetermined questions, recording measurements, describing phenomena and performing experiments. They extend the meaning of methods to include not only normative research but also that associated with the interpretive paradigm, participant observation, role-playing, non-directive interviewing, episodes and accounts. Furthermore, these authors stress that the aim of methodology is to describe and analyse these methods, throwing light on their limitations and resources, clarifying their presuppositions and consequences, and relating their potentialities to the twilight zone at the frontiers of knowledge. Put simply, Cohen and Manion regard the aim of methodology as one that is to help researchers and practitioners understand, in the broadest possible terms, not the products of scientific inquiry but the process itself.

The nature of the research study, as reflected in the objectives in Chapter 1, required an investigation and interpretation of classroom teaching and learning activities and landscapes. Consequently, the research was essentially qualitative,

but some quantitative techniques were included to support description and assist in the identification of students for more detailed study.

The research was conducted in Papua New Guinea because that was where the researcher was normally located professionally and that was the focus of his research interests. The location selected was a large government-run secondary school located in a highland town. The selected school had a student population of over 1,000 and a predominantly indigenous teaching staff of 50 teachers. Students enrolled at the school came from all parts of the country and had diverse cultural and socio-economic backgrounds. Participants in the research were members of a Grade 9 class of 43 students and their regular science class teacher. The participants' interactions in the teaching and learning process occurring during normal instruction in a unit on electricity within the school's teaching program were carefully observed and described. The researcher assumed the role of a non-participant observer.

3.2   Philosophical considerations

Guided by the objectives and research questions in Chapter 1, the study employed predominantly interpretive research methods (Gallagher, 1991; Kelly & Lesh, 2000; Tobin, 2000) that were underpinned by a constructivist framework (Bereiter, 1994; Bredo, 1997; Driver, 1989) in examining teaching and learning in a secondary school science classroom in Papua New Guinea. Among the conceptual change conditions (Duit & Treagust, 1998) that influenced students' learning and understanding in the classroom environment, the cultural backgrounds of students and the teacher are of importance (Aikenhead, 1996; Aikenhead & Jegede, 1999; Maddock, 1981). A major component of this study placed emphasis on the nature and impact of cultural referents exhibited by the students and their teacher on teaching and learning in the classroom environment.

Interpretive research, as described in earlier in Section 2.4.3 focuses on the immediate and local meanings of actions, as defined from the actors point of view (Erickson, 1998). Kelly and Lesh (2000) note that today's educational researchers

have moved into school systems, classrooms, and work places and have found a complex and multifaceted world that they feel is not well described by traditional research techniques where educational phenomena derived their status by surviving a variety of statistical tests. Nowadays, nascent educational phenomena are accorded primacy, and the onus is on the researcher to use research methods to describe them in rich and systematic ways.

The study was conceptualised within a constructivist epistemology, as discussed previously in Section 2.5.1.1. The researcher holds a constructivist view in seeing students as being purposive, and therefore constructing knowledge through social interaction and their interactions with the physical environment. Or, as stated by Tobin, Kahle, and Fraser (1990):

> Within a constructivist framework, learning is defined as the construction of knowledge by individuals as sensory data are given meaning in terms of prior knowledge and experience. Learning is an interpretive process, involving construction of individuals and social collaboration. (p. 411)

Hence, the central premise of the constructivist epistemology is that knowledge, whether public or private, is a human construction within a social setting. A key feature of this perspective is that learners construct mental models of their environment and new experiences are interpreted and understood in relation to existing mental models and schemes (Driver, 1989). Millar (1989) highlights the valuable contribution this view has made to thinking in science education by acknowledging that the constructivist approach offered an insight that was enormously valuable in emphasising that any knowledge is necessarily reconstructed by the learner in the learning process. A body of knowledge cannot be taught by direct transmission; the learner is always involved in reconstructing the meaning personally.

Although constructivist epistemology has not been universally accepted (for example, Mathews, 1993), Duit (1994) argues that it has been a most

powerful and fruitful driving force in research on students' and teachers' epistemological stances. Summers (1992) contends that it is now widely valued as a theoretical basis for developing learner's ideas in science. Constructivist thinking has influenced science educators' views on curriculum development and teaching and learning in the science classroom (Driver, 1989). However, in many developing countries it appears that constructivist inspired strategies are rarely implemented in the teaching of science at any level. While it could be argued that this is also true for many Western classrooms (Tobin & Gallagher, 1987), the earlier discussion in Section 2.5.2.2 would indicate that the situation is far more serious in Papua New Guinea and other developing countries. In Fiji, a developing country very similar to Papua New Guinea in many ways, most teachers do not realise the potential of questioning and discussion, and as a result miss out on understanding the ideas their students have about important concepts (Muralidhar, 1989). Often a transmissive approach to science teaching predominates, with teacher exposition being the major method in the delivery of the curriculum. Ingle and Turner (1981) argued that this approach has been singularly unsuccessful in encouraging students in developing countries to think scientifically. They contend that straight forward teaching by telling with an emphasis on rote learning cannot be an effective method of achieving this end, as the facts and ideas are simply absorbed without any process of internalisation. A more active method requiring the students to experiment and discuss, to observe and interpret at their level is likely to be more fruitful.

Many researchers in science education believe that the cultural background of the learner plays a central role in learning as discussed previously in Section 2.5.3. Maddock (1981), who had conducted a number of pioneering studies in Papua New Guinea in the 1970s and 1980s, noted that science and science education were cultural enterprises which formed a part of the wider cultural matrix of society and educational considerations concerning science had to be made in light of this wider perspective. Research pertaining to cultural aspects of learning science has increased over the past years to shed light on how

a learner's culture can have an effect on learning science in school (e.g., Cobern & Aikenhead, 1998; Pauka et. al., 2000; Waldrip & Taylor, 1999). In Papua New Guinea and other Melanesian Island nations, the peoples' traditional cultures are still strong and influence their daily lives despite the strong Western influences. More than 85% of the population of Papua New Guinea live as subsistence farmers in rural communities, having strong ties to the land and their traditional cultures (numbering over 700 distinct cultures and languages). Thus, students in Papua New Guinea attend school with traditional cultural views that conflict with the school science view (Boeha, 1988; Najike, 1993; Pauka et. al., 2000). Students' epistemological and ontological stances of these countries are not the same as for Western countries. For instance, indigenous cultures of Papua New Guinea view knowledge systems as holistic and purposeful to the participants (Pauka et. al., 2000; Waldrip & Taylor, 1999). On the other hand, in the Western system, knowledge is partitioned into areas or subjects and Western science is a segment of that body of knowledge acquired through particular ways and identified by participants as belonging to the area (Aikenhead & Jegede, 1999; Fleer, 1999).

Teachers from developing countries have been shown to display evidence of conceptions based on their cultural viewpoints that were contrary to school science (Ogunniyi et al., 1995; Waldrip & Taylor, 1999; Vlaardingerbroek, 1991). This implies that teachers might reinforce or fail to correct students' inadequate understanding of science taught in schools. The situation highlighted raises the important role culture plays in learning. The researcher in this study is an insider, familiar with the context in which the study was conducted in Papua New Guinea.

3.3   The researcher as non-participant observer

The researcher was a non-participant observer throughout the duration of the study in the classroom. It was anticipated that the researcher's familiarity with the context as an insider having received education both in Papua New Guinea and Australia would minimise the possibility of participants making misleading or

inaccurate assertions, and displaying contrived behaviour for the researcher's benefit (Stake, 1994; McRobbie & Tobin, 1995), thus enhancing the credibility of the study. It was also expected that as an insider the researcher would have a better understanding and appreciation of the participants' views, expectations, actions, and involvement in classroom transactions, which are influenced by the culture of the participants.

Finally, the researcher was not concerned with quantitative outcomes as traditional researchers might have been, but with processes and interactions which are susceptible to influences of unfamiliar factors. A feature of the research design was that the researcher was aware of this and indeed was looking for evidence of irregular classroom behaviour of any of the participants in order to probe more fully.

3.4 Research as case study

In keeping with the epistemological underpinnings of the research an interpretive case study approach was adopted (Stake, 1994; Wittrock, 1986). In particular, the case study strategy used in this research study constituted an embedded case study (Stake, 1994, p. 237) in which a "particular case," a selection of students, "was examined to provide further insight into an issue," the aspects of culture associated with the views, experiences and interactions of the students' and teacher's that influence learning in the classroom environment. The choice of a case study approach is also congruent with the decision to use both qualitative and quantitative research methods because as Stake (1994, p. 236) notes, "case study is defined by interest in individual cases, not by the methods of inquiry used." In support of such a position he adds:

> The case is of secondary interest; it plays a supportive role, facilitating our understanding of something else. The case is often looked at in depth, its contexts scrutinised, its ordinary activities detailed, but because this helps us

pursue the external interest…The choice of case is made because it is expected
to advance our understanding of that other interest. (p. 237)

Embedded case studies require that cases be selected. This is because as
Verma and Mallick (1999) claim, embedded case studies are characteristically
examples of research in depth rather than breadth. In order to select the case for
this research, it was necessary to address an important issue concerning the
selection of students for intensive study. The four students selected were, in the
view of the researcher representative of the range of variations between students
with respect to their upbringing (rural, town, city), view on science (crude/naïve,
transitional, canonical), and prior knowledge of electricity. The four selected
students constituted the embedded case study to amplify data gathered from the
class of students and were reported in this study.

The ongoing scrutiny of these four students was deemed necessary to
ensure that the research remained responsive to the implications of emerging
assertions. The consideration of a range of students' perspectives assists readers in
the construction of their own understanding regarding a case (Stake, 1994).

3.5   The research context

3.5.1   Site details

The school selected for the research study was located in a valley in the
highlands of Papua New Guinea at an altitude of 1500 metres above sea level.
Surrounded by beautiful blue mountains with all-year-round spring weather, the
Government co-educational school of over 1000 students served a growing urban
centre that was the administrative and economic capital of a highland province.
The students attending this school were characterised by their predominantly
Melanesian origins but showed a wide-ranging diversity in socio-economic status
and cultural ethnicity. Papua New Guinea has more than 800 languages and
cultures. Some of the students' parents were uneducated subsistence farmers who

had no regular income. While, on the other hand, there were some parents where both spouses received regular incomes from paid employment in the town where the school was located. Many students who lived in villages and outlying rural areas travelled as much as 20 kilometres each day to school. The school enjoyed a high reputation as the premier secondary school in the province.

The school science curriculum was nationally prescribed by the National Education Department in Port Moresby for all Grades except for Grade 12 where science was optional. The science class involved in this study was Grade 9.2 comprising 21 boys and 22 girls of ages ranging from 14 to 18 years, which was fairly typical of secondary schools in Papua New Guinea. For each unit taught there was a corresponding Teacher's Guide that provided a clear descriptive guide for teachers to adhere to comprising behaviourist objectives to be achieved, theory, and specified practical laboratory work.

3.5.2   Access provisions

The School Board of Governors granted access to the school after correspondence between the School Principal and the researcher. The request for entry was negotiated on the basis of: (i) past collaboration between the school and the researcher in his capacity as Lecturer in Science Education, and Practicum Supervisor for teaching practice of trainee teachers whilst attached to the local university; (ii) involvement in in-service and professional development for teachers at the school; and (iii), for the professional and personal development of the researcher.

Parents and guardians were requested in writing to give their consent for the research. Students were made aware of their option to not participate in the research study. All parents and students agreed to support the study. The research proceeded on the understanding that all data collected were confidential and pseudonyms would be used to conceal the identity of all participants.

3.5.3   Ethical considerations

The research met ethical quality guidelines (Altrichter, 1993), that is, it was "compatible with the educational aims of the situation under research" (p. 44) and attempted to "build on democratic and cooperative human relationships and contribute to their further development" (p. 44). The researcher sought informed consent of students, the class science teacher, parents and the School Board of Governors in writing by appropriate informal and formal means thus achieving a high level of cooperation and support in the research study. The researcher had two meetings with science teachers in which they were informed of the role and requirement of the class teacher in the research study before accepting a teacher who volunteered to participate.

Throughout the research it was assumed that participants' words, actions and interactions in class were intentional, meaningful, and voluntary and that students, class teacher, and the researcher maintained truthfulness in all communications. Students willingly spoke openly to the researcher and on a few occasions Pidgin English, a common local vernacular was used in interviews when the researcher encountered students' having difficulty in expressing themselves in English. Students' responses to the researcher were open and friendly. This may have been, to a large extent, due to his unique position as an insider who understood the participants in a more holistic way and as a result could relate to them on a personal level. The researcher sought to solicit, respect and, in the writing of this thesis, present without prejudice the range of different constructions and the underlying value structures of the participants. Confidentiality was maintained through the use of pseudonyms in reporting research findings and also ensuring that data were removed from the research site and kept in a locked room at the researcher's residence during the period of fieldwork.

3.5.4   Authenticity issues

It may be thought that any tangible evidence of learning in a classroom environment took longer than three months in most cases, the duration of the study. However, the researcher was less concerned about the amount of learning than he was with the quality of learning. He was more interested in the processes and influences that enhanced or inhibited learning.

The novelty of the involvement of the researcher in the classroom might be thought to be another threat - the so-called Hawthorne effect. However, as this study did not involve an intervention there was no danger of claiming an effect due to an experimental treatment. Certainly the presence of the researcher in the classroom may have influenced the behaviour of some students in an unpredictable fashion but the extended period for which the researcher was present lessened the impact on class behaviour. In an interesting discussion of the Hawthorne Effect, Brown (1992) pointed out that in studies such as the one proposed here, the students were in some ways being treated as co-investigators of their learning. The fact that this collaboration might lead to some improved performance was not an undesirable educational outcome, and can be accommodated by the researcher in analysing data and reporting the research findings.

Finally, the researcher was concerned with processes and interactions which were susceptible to influences of unfamiliar factors; as well as with some quantitative outcomes from a variety of test instruments. A feature of the research design was that the researcher was aware of this and indeed was looking for evidence of unusual classroom behaviour of any of the participants in order to probe more fully.

3.6   Research methodology

3.6.1   Introduction: Use of mixed research methods

In the context of this research, the term research methodology involved a consideration of research design, data collection, data analysis and theorising, together with the social, ethical and political concerns of the social researcher (Burgess, 1984). It was in this broad sense that the term methodology was used, which was distinct from the research methods that represented a part of the overall methodology. Accordingly, in this research, research methods referred specifically to the strategies and instruments used for data collection within the methodology. As such the methods for data collection were encompassed within the broader methodology.

The collective aim of the research methods was to investigate and interpret the learning occurring in a naturalistic environment, hence providing insight and understanding of students' interactions in this classroom in Papua New Guinea. In support of the use of multiple methods, Cizek (1995) had suggested that a renewed awareness that quantitative and qualitative methodologies were often investigating similar phenomena was necessary. Similarly, Erickson (1998) advocated the use of a range of research methods in interpretive research. He noted that qualitative research that relied solely on interview data did not resolve criticism of such research from both advocates of objectivist approaches to research and those who also employ such research. In this study, qualitative information obtained using interpretive methods was complemented by quantitative information obtained from a variety of test instruments. This approach (Fraser & Tobin, 1991) was similar to that used by Tobin, Butler-Kahle, and Fraser (1990) in the exploration of students' perceptions of classroom learning environments and their science learning. While the primary focus was on the use of qualitative procedures for data collection and analysis, there was also a quantitative aspect to the data collection. The complementary nature of the research methods was consistent with the recursive and divergent nature of constructivist inquiry in which findings were "created social constructions" (Guba & Lincoln, 1989, p. 263) that were subject to continual reconstruction.

The research conducted was very much in the tradition of much of the classroom-based science education research in recent years, which had focused on detailed descriptions of teaching and learning strategies and attempts to interpret them in light of contemporary theories. By contrast, tightly controlled classical quantitative research designs have been employed less frequently than in the past because they have been judged to be inappropriate to address the kinds of questions now being asked. Erikson (1998) provided an excellent description and justification for the use of qualitative research methods in science education:

> Qualitative research most essentially addresses issues of the literal and metaphoric meaning of actions to social actors, while it also documents those actions in the concrete details of their routine enactment. It is the most fundamentally constructivist research method available to us. It enables us to see and understand how, in the conduct of daily life, all persons are busy, active, and making sense. (p. 1172)

3.6.2   Research plan

3.6.2.1 Design features

Maxwell (1996) likened "research design to a philosophy of life; no one is without one, but some people are more aware of theirs, and thus are able to make more informed and consistent decisions" (p. 3). Yin (1994) stated, "every type of empirical research has an implicit, if not explicit, research design" (p. 19).

For this study it was important that the design was outlined clearly so that its strengths, limitations and implications could be clearly understood. Geertz (1976) defined design in qualitative research similar to this study as an iterative process that involves tacking back and forth between the different components of the design, assessing the implications of purposes, theory, research questions, methods, and validity threats for one another. Maxwell (1996) emphasises that

such an interactive model was more compatible with the definition of design as the arrangement of elements governing the functioning of a study than it was with design as a pre-established plan for carrying out the study or as a sequence of steps in conducting that study.

Thus, the research design adopted for this research had the characteristics of being appropriate, flexible, functional, as well as reflecting the need for the research study design to be not linear but interconnected and recursive (Keeves, 1998; Kelly & Lesh, 2000; Maxwell, 1996).

3.6.2.2 Appropriateness of research design

The research design was structured to adequately address the needs of the research objectives. Thus, as stated by Tobin (2000), this study sought to investigate and interpret teaching and learning of students in the classroom environment from data sources gathered from the periphery of a community as well as from assertions, or what Tobin (2000) refers to as central tendencies. The four students who participated as focus group members where selected on the criteria of being very different to each other (maximum variation) and the average student in that class of 43 students who participated in the study. For instance, the focus students represented variations in gender, socio-economic status, exposure to modern conveniences, age, and personality. In other words, a dialectic principle was applied in the selection of focus students so that the diversity of the class was reflected in the data sources scrutinised during the study. The research design enabled the researcher to use methods that appropriately interpreted the teaching and learning in the selected classroom from different participants' perspectives and with the use of multiple data sources and strategies to ensure that the common themes and central tendencies surfacing were supported by a number of sources as well as methods.

3.6.2.3 Flexibility of research design

The research design needed to be flexible in order to respond to emerging understandings and unexpected circumstances. This would be so if the research was being conducted in a science classroom in a developed country such as Australia even though many similar studies have been conducted in such situations. It is even more so for research planned in Papua New Guinea where so many features of the educational context are different and susceptible to change. The research commenced with some very tentative assertions based on research conducted largely in developed countries. A number of possible unexplained events were anticipated because of the nature of the research being based on a Western European culture in a developing country culture. Flexibility was also essential to enable the recursive process of reviewing evidence, and generating and testing new assertions to arrive at new insights.

3.6.2.4   Functionality of research design

Research plans comprise different components such as data collection, data analysis, interpretation and drawing of conclusions, identifying and accounting for potential threats to the integrity of the research outcomes. In the design of this research all these components must blend and function together. For example, early data collection was analysed and informed later data collection and so on. Since there was less emphasis on statistical control measures that are characteristic of quantitative research, on-going attention to trustworthiness of data and analysis was necessary.

3.6.2.5 Use of an interactive research model

In order to satisfy the requirements of this study, Maxwell's Interactive Research Design Model depicted in Figure 3.1 (Maxwell, 1996 p. 5) was selected to provide a framework to conceptualise and describe the research design.

Purpose

- Improve student science learning in secondary schools in Papua New Guinea.
- Apply and assess the applicability of contemporary literature principally from developed countries to science education research in Papua New Guinea.
- Interpret the teaching and learning strategies employed by students and their teacher in one science classroom in Papua New Guinea.
- Establish a foundation for a productive science education research program at the University of Goroka in Papua New Guinea.

Conceptual context

- Contemporary literature related to science learning (prior knowledge, social constructivism, conceptual change strategies); learning environments. teaching strategies, and ethnoscience.
- Relative lack of research in developing countries similar to Papua New Guinea.
- Researcher's personal experience.
- Science curriculum imperatives in Papua New Guinea.

Research questions

- How did the students in this classroom view science in the context of teaching and learning?

- How did the students perceive their learning environment and the teacher's interpersonal interactions?

- What were the students' prior knowledge and experiences about electricity before instruction?

- What were the cultural referents displayed by the teacher and the students that impact on teaching and learning?

Methods

1. Data sources
Observations (video / audio recording; field notes)
- Semi-structured interviews (teacher and selected students)
- Probes of students' science knowledge (class tests; interviews)
- Questionnaires on teacher interaction, nature of science knowledge, classroom environment.
- Artefacts of teacher's and students' work.
- School records, work programs etc.

2. Data analysis
- Prompt transcription & verification of recorded data.
- On going coding, categorising and interpretation of data to test tentative theories and pose new questions.
- Quantitative data analysed in SPSS to provide descriptive data and inform selection of target students for interview.

Validity and related issues

- Use of multiple sources of data, methods, and theories to cross check / triangulate where appropriate.
- Use of prolonged intensive indepth study time on research site.
- Researcher as an insider with expertise.

Figure 3.1. An interactive model of the research design

Five important components of purpose, conceptual context, research questions, methods and validity are shown in Figure 3.1 to form an integrated and interacting whole. The lines between the components represent two-way ties of influence or implication. Although there are also connections other than those emphasised in Figure 3.1 (example, between purposes and methods and between conceptual context and validity), the ones shown are generally the most important according to Maxwell. They emphasise that the research is not linear but interconnected and recursive, which reflects the nature of the study. For instance, the purpose of the research study depends on the conceptual context of the study as well as the research questions. The research questions are linked to the other four components of purpose, conceptual context, methods, and validity issues.

The top three boxes highlighting the purpose, conceptual context and research questions respectively in Maxwell's Interactive Model of Research Design shown in Figure 3.1 have been alluded to in the introduction and literature review in Chapters 1 and 2. The last two components of the model in Figure 3.1 pertaining to methods and validity related issues are addressed in Chapter 3.

3.6.3   Structure and procedures of the macro research design

Figure 3.2 provides an overview of the four phases that comprise the structure of the study. Table 3.1 further amplifies this figure with a description of the aims and the focus topic, as well as the roles played by participants and the sources from which data were gathered for the four phases. Across the four phases, the foci of data gathering, analysis and conclusions, or the development of theoretical propositions, were: (a) the existing nature and understanding of the classroom learning environment; and (b), students' and the class teacher's understandings about teaching and learning. Section 3.8 provides an explanation of how these understandings were recognised and analysed. Identification of these propositions directed attention throughout the study period (Yin, 1989).

In Figure 3.2 and Table 3.1, Phase 1 indicates a pilot study conducted with two out of the four questionnaires used in the study. The two questionnaires piloted were the Views on Science, Technology, and Society (VOSTS) (Aikenhead et al., 1989) and the Questionnaire on Teacher Interaction (QTI) (Wubbels et al., 1993) because they were developed and used in contexts (Canada and Europe) with great variations to that of the location of this study. The pilot study trialled the questionnaires with students in Papua New Guinea in order to develop and validate adaptations that would be suitable for application in the local context. This was achieved through the assistance of an experienced tertiary science educator from the local university who administered the questionnaires to different Grade 9 students at the school where the study was conducted a few months later.
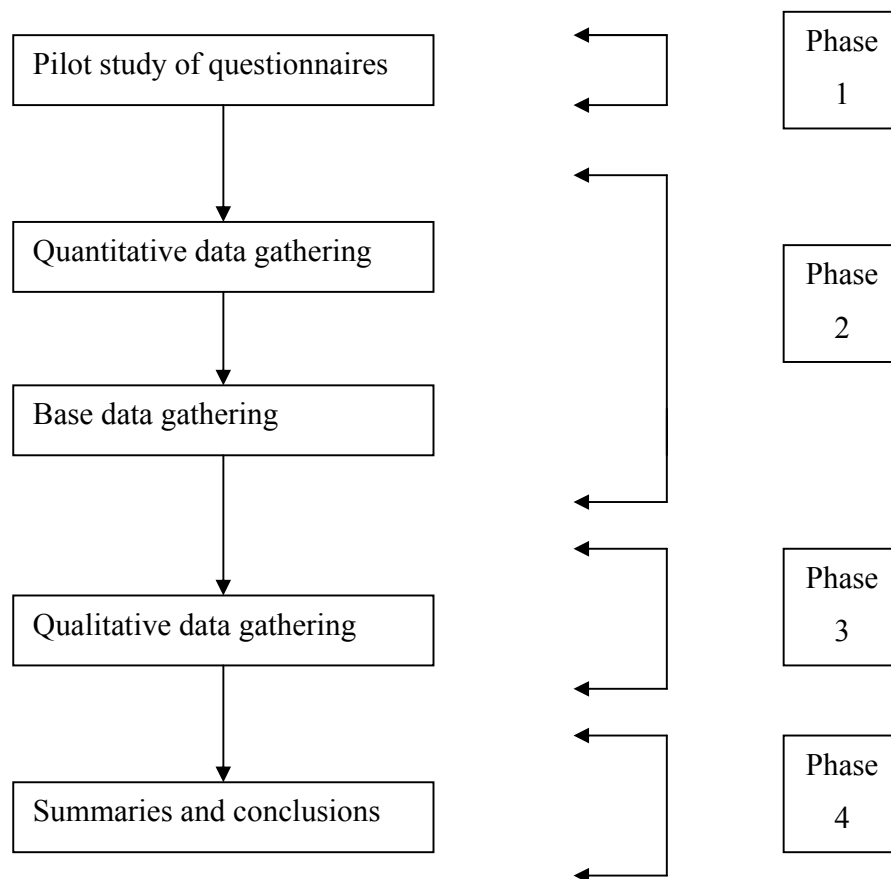
Figure 3.2. An overview of the major stages of the study

Table 3.1

A Detailed Overview of the Study

Phase	Aim	Focus topic for data gathering	Roles	Data Sources
1	To conduct a pilot study of questionnaires for adaptation to local conditions.			
2.1	To gather quantitative data about the classroom learning environment, and important aspects of teaching and learning.	Understanding of students' actual and preferred learning environment, interpersonal relationships with the class teacher, views of science, and students' prior knowledge of electricity.	Students as participants.	• MCI questionnaire (Fraser & Fisher, 1994); • Questionnaire on Teacher Interaction (QTI) (Wubbels et al., 1993); • Views on science, technology and society (VOSTS) questionnaire (Aikenhead et al., 1989); • Two tier diagnostic test (Treagust & Zadnik, 1991)
2.2	To gather base data about students, their background, classroom environment and the wider learning context.	Students' background, teaching and learning, and their learning environment.	Researcher as interviewer.	• Interviews with some students.
3	To gather qualitative data from students and teachers about their teaching and learning, and their learning environment. To probe into specific areas of students' and class teacher's understanding and perception. For the researcher to monitor and record developments in students' views and perceptions about teaching and learning, and their learning environment.	Students' views about science, teaching and learning, and interactions in the learning environment. Teachers' perceptions about teaching and learning. Students' and the class teachers' thinking and practices concerning references to prior knowledge and culture.	Researcher as non participant observer. Researcher as interviewer	• Observations of lessons; • Review of video and audio tape recordings of lessons; • Interviews with students and teachers; • Collection of student artefacts; • Audio tape recordings.
4	To conclude and summarise data gathering	Review perceptions and developments in understanding of learning environment, and teaching and learning by students, class teacher, and researcher.	Researcher as interviewer and knowledgeable about own experiences. Focus students and class teacher knowledgeable about their views and perceptions of teaching and learning, and the learning environment.	• Interviews • Audio tape recordings

Phase 2 indicates the quantitative data gathering phase in which information about the learning environment was gathered. This occurred through the administering of four questionnaires which provided information on students' preferred and actual classroom environment, interactions in class, views on science, and students' prior knowledge of electricity. These questionnaires are discussed fully in Section 3.7.3. In addition, students were interviewed for base data concerning their background, upbringing, perceptions about science, teaching and learning, and their learning environment. In this period of time, the researcher became familiar with students and was able to select focus students as described previously in Section 3.4.

Phase 3 in Table 3.1 incorporated lesson observations by the researcher as a non-participant observer, which is described in Section 3.7.1. that follows. The lessons observed were from the Grade 9 syllabus for students to study, and were complete lessons on an electricity unit taught by the class teacher. Interviews with students and teachers, and video recordings of lessons also became major data sources to gain insight into students' views about science, teaching and learning, and their learning environment. Students' and teachers' perceptions about teaching and learning, and practices concerning references to prior knowledge and culture were further probed with follow up interviews. During this phase the researcher interviewed four other teachers who had recently taught the electricity unit toYear 9 classes on at least three different occasions each.

Phase 4 was the concluding and summarising phase, during which final data concerning students' and the class teacher's perceptions of their learning environment, and teaching and learning were collected and reflected on by the researcher. During this time the final data emerging from several sources and methods of gathering were compared and discussed with four teachers who recalled their experiences of teaching the unit on electricity in Grade 9.

After the data gathering period, made up principally of both quantitative and qualitative data gathering strategies, the case study was written which was aimed at extending the research in depth rather than breadth (Verma & Mallick, 1999; Yin, 1989), as discussed in Section 3.4.

3.7   Data sources

Due to the nature of this research study, which was based on an interpretive framework with case study (Keeves, 1998; Maxwell, 1996; Gallagher, 1991; Erickson, 1998), rich data were gathered from a variety of sources using multiple data gathering strategies. In research of this nature it is important not to rely on one perspective, or approach, to indicate the consensual understandings of reality as perceived by participants in the study. Thus, strategies of multiple triangulation or data collection should be implemented (Denzin, 1996; Erickson, 1998) to ensure that more than one perspective is acquired. Denzin (1996) highlights four types of triangulation: data, investigator, theory, and methodological.

Data triangulation refers to the use of strategies that elicit the effects or influences of such attributes as time, space, and person upon the interpretation of an event or occurrence. In this study, data were collected at different times, but consistently, across the period of its three months duration of field work. They were collected by and/or from specific participants within the study, namely, the students and the researcher; from other specially selected individuals, for example, teachers who have recently taught Grade 9 science; and from ideas gleaned from viewing and experiencing whole class activities and responses during lessons on the electricity unit taught by the class teacher.

Investigator triangulation incorporates the views of multiple rather than single observers. In this study those closely involved in the research task, that is, the researcher, as well as those less closely involved, for example, teachers were all sources of data.

Theory triangulation refers to the need to apply different theoretical understandings to particular events or occurrences during the process of interpreting their meaning/s. A major data collection strategy implemented in this study was the holding of semi-structured and un-structured interview sessions with students and the class teacher in which they were given the opportunity to discuss specific topics at length. The purpose of this process was to expose and encourage different theory bases (not necessarily in explicit philosophical terms, however) to be applied to experiences as the participants discussed, compared and contrasted their varying perspectives.

Methodological triangulation means that the strategies to gather data should emanate from a variety of methodological bases. In this study a range of methods were used to collect data. These methods included observations, interviews, questionnaires, and classroom interactions.

3.7.1 Observations

In his role as a non-participant observer, the researcher took field notes with specific attention given to focus students. By using two unobtrusive mini-video cameras fixed at suitable locations, the activities of all class members were recorded for the duration of the research period. One video camera focused on the selected four students who sat as a group with three others near the front of the science laboratory. The other video camera was focused on the whole class of students in a wide angle shot configuration. The teacher's remote radio microphone output was fed directly to the video recording in the storeroom area where the recording equipment was set up.

The analysis of data occurred simultaneously with data collection. Thus, the researcher made initial analyses of the data immediately after the lessons, and before the transcriptions were completed. This led to an iterative process that became an integral component of interpretive studies the aim of which was to

"make sense of, or give meaning to" the specific and diverse nature of daily life in the learning environment (Gallagher, 1991, p. 8).

3.7.2   Interviews

All students in the class and a select group of Grade 9 teachers including the class teacher were interviewed using structured and semi-structured interview techniques (Osborne & Freyberg, 1985; White & Gunstone, 1992). The interview of students was approached from three perspectives. First, it was necessary to build a profile of each student. Thus, each student's personal details including parents' education and work background information was sought through interviews to build a profile for each of the students in the class. The purpose for creating a profile for each student in the class was to assist in the categorisation of students into rural, town and city; and the selection of four focus students for in depth study. Next, students' worldviews and prior knowledge were obtained through interviews, to establish the students' initial knowledge of the topic, their beliefs about the nature of science, and learning in their classroom environment. Finally, interviews were also directed at probing more deeply into issues that emerged from data made available through the multiple data gathering strategy applied in the study. Four other Grade 9 science teachers who had recently taught the unit on electricity were also interviewed.

3.7.3   The research instruments used

Four questionnaires were used to provide the researcher with quantitative data on the classroom environment and participants' perceptions for the entire class. Data from these instruments were useful for descriptive purposes, and thus they did not undergo thorough statistical analysis, as was typically the case with most quantitative data. They served to determine the basis for purposeful sampling in the research and allowed connections to be made with other research in which the same instruments have been employed in different contexts. Purposeful sampling (Maxwell, 1996) was conducted in order to study particular kinds of

students more intensely as indicated by the researcher's emerging understanding of the classroom. Furthermore, the data collected using these instruments enhanced rich data collected from the activities in the classroom and participants' qualitative data.

The quantitative data collected tested students' views on science-technology-society; students' preferred and actual classroom learning environment; teacher's interpersonal interactions in the classroom, and students' content knowledge of electricity prior to instruction. The instruments employed in the study were, Views on Science-Technology-Society (VOSTS; Aikenhead et al., 1989); My Classroom Inventory (MCI; Fraser, 1993); Questionnaire on Teacher Interaction (QTI; Wubbels et al., 1993); and a two tier diagnostic questionnaire on electricity (Treagust & Zadnik, 1991).

3.7.3.1 Views on Science-Technology-Society (VOSTS) questionnaire

An adapted version of a questionnaire that measured students' views on science-technology-society referred to as VOSTS (see Appendix A) was used to test for students' views on issues dealing with science-technology-society. Developed and validated in Canada at the University of Saskatchewan by Aikenhead, Ryan, and Fleming (1989), VOSTS was created from a large inventory of student viewpoints about science, and how science was related to technology and society. Canadian high school students' ideas were catalogued in a logical way to seek students' views (Aikenhead et al., 1989). Each question of the VOSTS inventory began with a statement about a science-technology-society topic. Several positions on the issue raised by the statement were then made available for students to choose from according to their viewpoints.

The use of the VOSTS questionnaire was designed to be an entry point for ascertaining personal worldviews of individual students. A number of criteria for development were considered. The wording was revised to suit the English literacy skill level of students in Papua New Guinea. The attention span of

respondents was considered especially in the light of reports that VOSTS materials tended to require a lengthy response time and that reader fatigue became a factor (Carlsen & Hussain, 1997).

The researcher selected eight items from the VOSTS inventory on the basis of their relevance to key elements of the intended study which included students' understanding of science concepts prior to formal instruction, students' viewpoints on the nature of science and learning, and the influence of students' cultural contexts on learning. The adapted VOSTS questionnaire yielded data that facilitated purposeful sampling, and provided initial starting points for data analysis. This questionnaire was not intended to be an end in itself but it was planned to use the initial responses as spring boards to fuller pictures of the students views, to be uncovered in subsequent investigations by the researcher.

Table 3.2 shows the content addressed by the VOSTS questionnaire items.

Table 3.2

Classification of Survey Items in Adapted VOSTS Questionnaire

General nature of science	Epistemology and ontology of science	Science and technology	Science and society	Science and cultural belief systems
Item 1				
	Item 2			
			Item 3	
		Item 4		
	Item 5			
			Item 6	
				Item 7
				Item 8

With input and validation checks from two experienced tertiary science educators, students' views on science-technology-society were grouped under three distinct categories (a) crude/naïve, (b) transitional, and (c) canonical. The crude/naïve views were defined as those explanations/views about science-technology-society offered by people who had not attended school under the Papua New Guinea formal education system. Such crude/naïve views of science were based on the individual's understanding and experiences of the world around her or him in direct contrast to scientifically acceptable views expressed in textbooks. A transitional view comprised some elements of high school science and those found in textbooks, but excluded views of science commonly presented in school science in Papua New Guinea. The canonical view was based on textbook science or conventional sciences which were universally scientifically acceptable. The canonical view also extended to the presentation of new developments in science and technology by experts in their fields in the media. For instance, astronomers releasing information on comets to inform people or NASA scientists explaining what the surface of nearby planets were like from recent space probes. It takes time for most new developments in science and technology to find their way into school textbooks and curriculum but this information is easily and readily disseminated in both the print and electronic media including the Internet.

Figure 3.3 shows as an example, the first item in the adapted VOSTS instrument. The exemplar shows the choices that students were expected to select for the definition of science. Based on the definitions for categories elaborated above, choices f) and g) were canonical views, choices c), d), and e) were transitional views, choices a) and b) were crude/naïve, and h), i), j) were regarded as other responses.

All students in the class were systematically classified as rural, town or city, according to their backgrounds or origins. A student considered to have a rural background would have attended primary school in a rural area isolated from

any major modern development such as mines or plantations which used modern machinery and equipment. The rural student's parents were likely to be subsistence farmers who had had limited formal education.

Item 1. Defining science is difficult because science is complex and does many things. But mainly science is:

(Your position)

a) a study of fields such as biology, chemistry and physics.

b) a body of knowledge, such as principles, laws and theories which explain the world around us (matter, energy and life).

c) exploring the unknown and discovering new things about the world and universe and how they work.

d) carrying out experiments to solve problems of interest about the world around us.

e) inventing or designing things (for example, artificial hearts, computers, space vehicles).

f) findings and using knowledge to make the world a better place to live in (for example, curing diseases, solving pollution problems and improving agriculture).

g) an organization of people called scientists who have ideas and techniques for discovering new knowledge.

h) I do not understand.

i) I do not know enough about this subject to make a choice.

j) none of these choices fits my basic viewpoint.

Figure 3.3. Item 1. of adapted VOSTS questionnaire

This type of student would have had very little contact with the outside world, especially exposure to the understanding and use of modern technology. Television, for example, is part of everyday life experience in most homes and schools for town and city students but a rural student would have limited access to it. The student with town background would have attended primary school in an urban centre but not in a major city. His or her parents would most likely have

had some formal education. For the city student, he or she would have attended primary school in a city or large town and have at least one parent who would usually have been highly educated and in paid employment. The home of a city student would be modern with at least a television set. A few of these households would have a personal computer. There were major differences between the city student and the rural student in terms of their respective exposure and interactions with the everyday modern technologies in the environment that are taken for granted in the developed countries.

These classifications (12 classified as rural, 20 as town and 11 as city) were arrived at after careful consideration of students' background data gathered through lengthy one-on-one individual interviews with all students in the class and teachers, and input from two experienced science educators who had extensive experience and exposure to the context in Papua New Guinea. The selected four focus students discussed earlier in Section 3.4 were 2 rural, 1 town, and 1 city. The researcher's inside knowledge of the Papua New Guinea education situation was also useful in this regard.

3.7.3.2 My Classroom Inventory (MCI) questionnaire

To gain an insight into students' actual and preferred classroom learning environments a questionnaire known as the My Class Inventory scale (MCI) was used (see Appendix B). The MCI was a simplified version of the Learning Environment Inventory (LEI) that was initially developed in the late 1960s in conjunction with the evaluation and research on Harvard Project Physics (Fraser, 1991; Fraser, 1993). The 15 climate dimensions selected for LEI included as scales, concepts identified as good predictors of learning, relevant to social psychological theory and research, and those found useful in theory and research in education.

According to Fraser (1991, 1993) the MCI was developed originally for use at the elementary school level for students in the 8-12 years range but it has

been found to be very useful with students in the junior high school, especially with those who might experience reading difficulties with the LEI. The MCI differs from the LEI in four important ways. First, in order to reduce fatigue among younger students, the MCI contains only five of the LEI's original 15 scales. Second, item wording has been simplified to enhance readability. Third, the LEI's four-point response format has been reduced to a two-point (Yes–No) response format. Fourth, students can put their answer on the questionnaire itself instead of a separate response sheet to avoid errors in transferring responses from one place to another. A factor that influenced the researcher to use MCI was that the selected class in Papua New Guinea was at junior high school level and the English language was a second or third language for the students. Thus, it made more sense to the researcher to choose MCI in which the item reading levels were better suited to students at the primary level and students whose first language was not English. The five scales used in the MCI were satisfaction, friction, competitiveness, difficulty, and cohesiveness. According to Moo's scheme (Moos & Trickett, 1987) cohesiveness, friction and satisfaction were classified as Relationship Dimensions while the difficulty and competitiveness scales were classified as Personal Development Dimensions (Fraser, 1993). The form of the MCI used in the study contained 64 items altogether. Table 3.3 provides descriptive information for each scale of the MCI, a sample item, and Moo's dimension for that scale

A limitation of the adapted MCI used in this study was the low level of internal consistency (alpha reliability) for students' actual and preferred forms when compared to information available for an Australian sample consisting of 758 third grade students in 32 classes in eight schools located in the Sydney metropolitan area (Fraser, 1993). The reliabilities for the Australian sample (alpha coefficients) for the actual form and the preferred form are shown in Table 3.4. Fraser (1993) states these values indicate that the short form of the MCI has satisfactory reliability for scales containing only five items each. In the Australian study, both the actual and preferred forms were administered orally by research

assistants (to limit reading difficulties at this age level). These short forms of 25 items were similar to the ones used in this study.

Table 3.3

Description of Scales and Sample Items for Each Scale of the MCI

Scales	Description of scale (The extent to which students…)	Sample item	Moo's dimension
Satisfaction	…enjoy their work and class	My class is fun.	Relationship
Friction	…are in conflict with each other.	Some students in my class are mean.	Relationship
Competitiveness	…are competing with each other.	Students often race to see who can finish first.	Personal development
Difficulty	…face difficulty with their work.	Schoolwork is hard to do.	Personal development
Cohesiveness	…work together in harmony and unity	In my class everybody is my friend	Relationship

Table 3.4

Reliabilities for the Australian Sample that used the MCI

Scales	Cronbach Alpha	
	Actual	Preferred
Satisfaction	.68	.75
Friction	.78	.82

Competitiveness	.70	.77
Difficulty	.58	.60
Cohesiveness	.81	.78

3.7.3.3 Questionnaire on Teacher Interaction (QTI)

Insight into interpersonal relationships between the class teacher, David and students in the classroom environment were sought through the administering of an adapted version of the QTI (see Appendix C). The basis for the development of the QTI began when a team of researchers in the Netherlands extended classroom environment research by focusing specifically on the interpersonal behaviour between teachers and their students (Wubbels, Creton, Levy, & Hooymayers, 1993). The Dutch researchers investigated teacher interpersonal behaviour in classrooms from a systems perspective, adopting a theory on communication processes developed by Watzlawick, Beavin, and Jackson (1967). Within the systems perspective on communication, it is assumed that the behaviours of participants mutually influence each other. That is, the behaviour of the teacher is influenced by the behaviour of the students and the behaviour of the teacher in turn influences student behaviour. Circular communication processes develop which not only consist of behaviour, but determine behaviour as well.

With the systems perspective in mind, Wubbels et al. (1993) developed a model to map the interpersonal interactions of teachers and their students extrapolated from the work of Leary (1957). In the adaptation of the Leary model, teacher behaviour is mapped with a proximity dimension (Co-operation, C; Opposition, O) and an influence dimension (Dominance, D; Submission, S) to form eight sectors, each describing different behaviour aspects. Wubbels et al. (1993) labelled these sectors DC, CD, etc. according to their position in the coordinate system to describe the type of teacher interpersonal interactions in each section, labelling each section as: leadership, helping/friendly,

understanding, student responsibility and freedom, uncertain, dissatisfied, admonishing, and strict behaviour as shown in Figure 3.4.
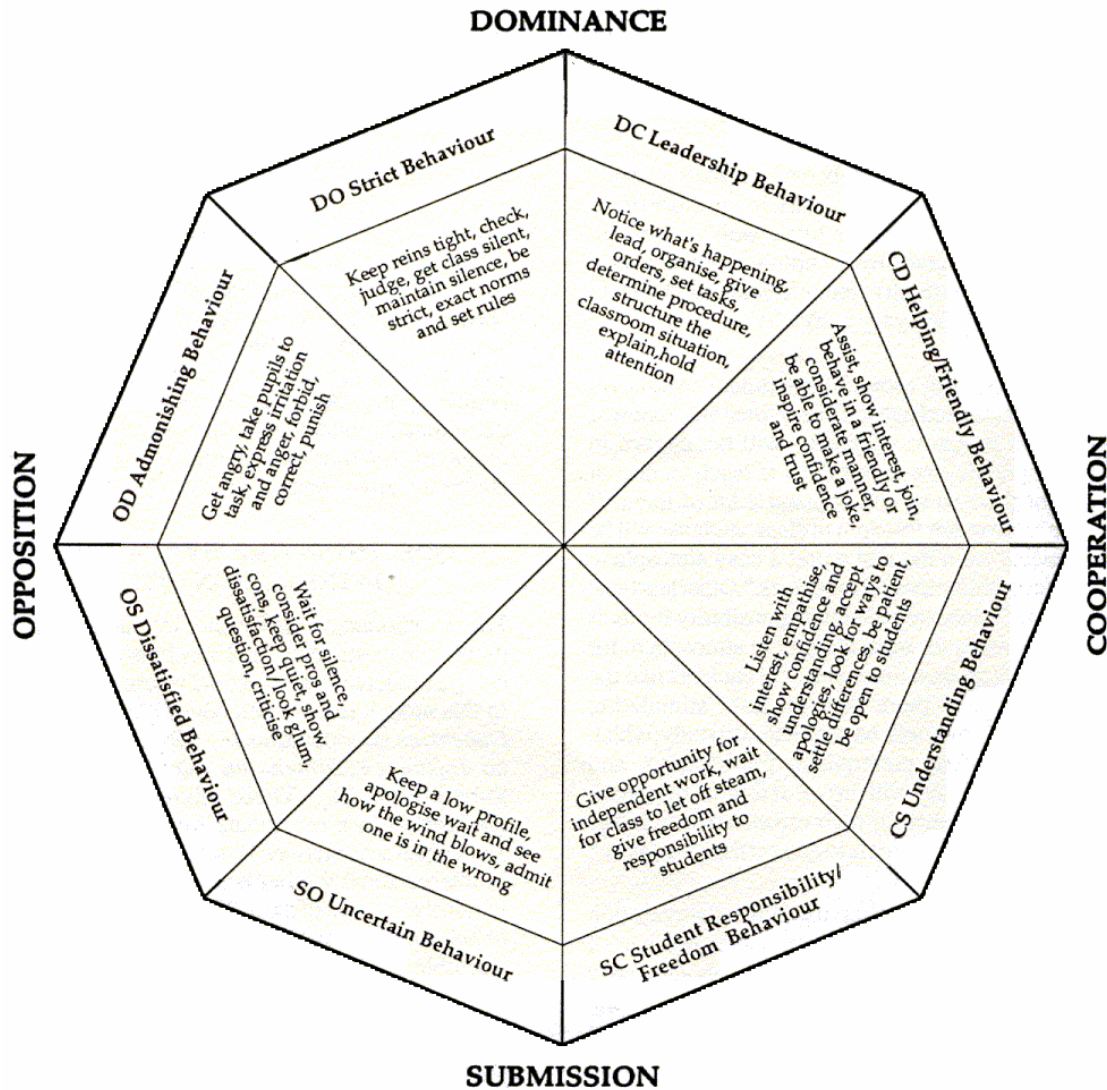
Figure 3.4. Model for interpersonal teacher interactions in class

For example, the two sectors DC and CD are both characterised by Dominance and Cooperation. In the DC sector, the Dominance aspect prevails over the Cooperation aspect, whereas the adjacent sector CD includes behaviours of a

more cooperative and less dominant character. To clarify the concepts covered by each sector, Figure 3.4 shows typical behaviours for each sector.

The QTI is based on this model and is composed of eight scales, each of six items, corresponding to the eight sectors. The scores for each item within the same sector are added to obtain a total scale score. The higher the scale score, the more a teacher shows behaviours from that sector. Scale scores can be obtained for individual students, or can be combined to form the mean of all students in a class. The researcher modified the Australian version for the Papua New Guinea contexts after having trialled the instrument with assistance from a staff member from the local university in Papua New Guinea who had experience in tertiary science education. The modifications focused on language use to ensure that they were compatible for students who spoke English as a second language as well as reducing respondent fatigue. The final version of the QTI employed for this study had 64 items which were answered on a five-point Lichert scale.

The application of the QTI in studies has been found to be valid and reliable (Fraser, 1998), including its use in a study conducted among secondary students in The Netherlands, the USA and Australia (Wubbels, 1993). The Australian version of the QTI which was used with a sample of 792 Grade 11 students and their 46 teachers, for example, showed Cronbach alpha coefficients for QTI scales ranging from .80 to .95 for students and from .60 to .82 for teachers. These indicate that each QTI scale displayed satisfactory internal consistency for scales containing only six items each.

Table 3.5 shows the nature of the QTI by furnishing a scale description and a sample item for each of the eight scales.

Table 3.5

Description of Scales and Sample Items for Each Scale of the QTI

Scale name	Description of scale (The extent to which the teacher…)	Sample item
DC Leadership	…leads, organises, gives orders, determines procedure and structures the classroom situation.	This teacher talks enthusiastically about his/her subject.
CD Helpful/friendly	…shows interest, behaves in a friendly or considerate manner and inspires confidence and trust	This teacher helps us with our work.
CS Understanding	…listens with interest, empathises, shows confidence and understanding and is open with students.	This teacher trusts us.
SC Student responsibility/freedom	…gives opportunity for independent work, gives freedom and responsibility to students.	We can decide some things in this teacher's class.
SO Uncertain	…behaves in an uncertain manner and keeps a low profile.	This teacher seems uncertain.
OS Dissatisfied	…expresses dissatisfaction, looks unhappy, criticizes and waits for silence.	This teacher thinks that we cheat.
OD Admonishing	…gets angry, expresses irritation and anger, forbids and punishes.	This teacher gets angry unexpectedly.
DO Strict	…checks, maintains silence and strictly enforces the rules.	This teacher is strict.

3.7.3.4 Two Tier Diagnostic Questionnaire

The two tier diagnostic questionnaire was adapted from a test instrument developed and validated with different groups of Western Australian students to test first-year university students' qualitative understanding of electricity and Newtonian mechanics (Treagust, 1988; Treagust & Zadnik, 1991). The questionnaire measured students' conceptions of their understanding of physics concepts. The individual items had at least two parts that catered for further probes, crosschecking and confirming of responses from participants. The adapted instrument, which investigated students' conceptions of electricity concepts, was successfully trialled and used to collect data in Australia and Papua New Guinea by the researcher (Najike, 1993).

The Two Tier Diagnostic Test items are reproduced in full at Appendix D and should be consulted in conjunction with Section 4.4.5. The key direct current electricity concepts in simple circuits tested using the questionnaire were:

- A closed electric circuit is necessary for current to flow,
- Current is never used up in an electric circuit,
- The strength of current in an electric circuit is dependent on loading when source voltage is constant,
- The strength of current in an electric circuit is dependent on source voltage given a constant load,
- Understanding of Ohm's law,
- In electric circuits where loads are connected in parallel, the strength of current flowing through each circuit path depends on the load resistance while voltage across each load in parallel remains equal to source voltage, and;
- Electrical energy is transferred from voltage source to the load.

The first item on the questionnaire was related to the scientifically accepted view that current will only flow in a closed loop so long as there was a voltage source present at any one time providing an electro motive force (emf) in the electric circuit. Any break in the circuit immediately resulted in an absence of electric current.

Items 2, 3 and 4 related to the scientifically accepted view that electric current is never used up in a closed circuit. The strength of a current can vary in an electric circuit depending on circuit parameters but a current is not consumed.

Item 5 related to current behaviour in circuits where loads were connected in series with the voltage source maintaining a constant voltage or emf. In such a situation it is scientifically accepted that the strength of the current will depend on the total resistance of the loads. The higher the total resistance the smaller is the current flowing through this circuit.

Item 6 related to a similar situation as for item five except that this time the loading of the circuit is kept constant while the source voltage is varied in a circuit where the loads are connected in series. It can easily be shown empirically that under such a condition an increase in emf will effect a corresponding increase in the strength of the current in the circuit. Items five and six comply with Ohm's law.

Items 7 and 8 related to the understanding of Ohm's law governing current behaviour in circuits where the loads are connected in series and parallel.

Item 9 specifically considered current and voltage behaviour in circuits where the loads are connected in parallel. It is scientifically accepted that load resistance determines current through each path in the parallel circuit while voltage across each load is equivalent to the source voltage.

Finally, item 10 related to the transfer of electrical energy from voltage source to load. The scientifically accepted principle of conservation of energy was tested.

3.7.3.5 Summary

In accordance with the focus of the study, research instruments used in the study were purposely selected to complement the qualitative body of data obtained through interpretive methods as discussed earlier in Section 3.6.1, as well as assisting in the selection of the focus students. The adapted VOSTS instrument (Aikenhead et al., 1989) employed in the study augmented information on students' perceptions of science and issues associated with science. On the other hand, the MCI provided information on the students' actual and preferred classroom learning environment dimensions, identified as good predictors of achievement by Fraser (1993). The use of the QTI instrument complemented information on the teacher's interpersonal interactions with students

3.7.4 Field notes and artefacts

Field notes focused on two areas of the research: the first was a record of observations especially with emphasis placed on the focus students, to build up confirming/disconfirming evidence; thus, enhancing aspects of trustworthiness and authenticity of the research. A card containing personal details, family background, socio economic status, career interests, and views on science was kept for each student in the class.

There were a number of items of students' and the class teacher's work that the researcher collected to complement the main data sources, thus enhancing the descriptions of meaning and sense making of the activities in the classroom (Gallagher, 1991; Tobin, 2000). These were

- photo copies of students' work - useful when the researcher reviewed data collected on students' learning and understanding, and;

- copies of teacher's work comprising the teacher's lesson plans, schedule for teaching the electricity unit, syllabus, and textbook pages related to the lessons all collected.

3.8 Data analysis techniques

Data analysis in this type of research is an integrated process because all data gathered are complementary. The analysis of data relied on the theoretical propositions which emerged with the review of the literature in Chapter 2. These tentative assertions guided the initial analysis as the researcher sought confirming or disconfirming evidence, new and unexpected data. As Erickson (1998) aptly stated, qualitative research analysis is a bootstrapping operation in which reflexively, assertions and questions are generated on the basis of evidence, and evidence is defined in relation to assertions and questions. Data analysis, informal and formal, according to Erikson begins as the researcher negotiates entry to the research site, and it often continues in re-study after supposedly final reports are written. Bodies of information are gathered in fieldwork and are held in documentary sources in various media such as field notes, interview tapes, videotapes and site documents. These are not yet data but regarded as resources for potential data as they appear in raw form. The documentary sources contain many thousands of information bits, not all of which are relevant to the study being conducted. Analysis consists of a recursive review of information sources with a question or assertion in mind, deciding progressively which information bits to attend to further and which not to attend to (Erickson, 1998; Gallagher & Tobin, 1991; Lemke, 1998).

For this study, data were analysed as soon as possible after collection, reflecting Guba and Lincoln's (1989) hermeneutic process. This necessitated the transcription of audio recordings of interviews and the transcription of video tapes to produce vignettes and extracts of pertinent classroom interactions, and the scrutiny of written material and other artefacts to facilitate and promote the

immediate and continual interplay of ideas and reflections with the data. The analysis was on-going; therefore interpretations about occurrences and developments in the classroom environment about students' and the class teacher's thinking and practices occurred continually, one interpretation building upon the next, one answer leading to another, one question leading to a further one. Thus, during the hermeneutical dialectical process, interpretation of the data was undertaken by the researcher as a means to reporting upon perceptions of their experienced realities.

During the course of the data collection, a series of assertions were developed that related to significant factors influencing the way teaching and learning, and the perception of the classroom learning environment was perceived by the students and the class teacher. The initial significant factors were the established school culture of emphasis on rote learning (Muralidhar, 1993; Taylor, 1999), and the cultural contexts of learning science discussed in Section 2.5.3. These factors were interpreted through: (a) the students' and the class teacher's constructions of the nature of teaching and learning science, and learning environment; and, (b) their   assumptions, views and understandings of science and science education.

To assist the researcher to make sense of the data using these two cultural areas as frameworks, summaries of ideas as they presented themselves were assembled, as the data became available. As the assertions developed, they were tested against emerging data as the study progressed. This development of assertions is integrated within the case study that is described in Chapter 3 and the discussion of them through further interpretation by the researcher is to be found in Chapter 4. Throughout, the two aspects of culture applied to the classroom learning environment, and in teaching and learning, were used to structure interpretations and finally to formulate implications about learning science in Chapter 5.

Chapter 4

Results

4.1 Overview

This chapter presents the research data and points the way for the discussion of the research findings that are discussed in Chapter 5. As an introduction to the chapter a background to the contemporary teaching and learning situation in Papua New Guinea is presented. This is necessary because there are significant similarities and differences between teaching and learning in young developing countries such as Papua New Guinea and the developed Western world. Accordingly, the introduction describes important details of the class teacher involved in the study, the classroom facility that was used by students during the study and two vignettes of lessons. The first vignette discusses a typical complete non-practical single lesson observed by the researcher in the first few weeks of the study. The other vignette covers a full double period lesson that ran as a practical session after five weeks into the study of electricity.

Following the introduction, the body of the chapter is divided into three major sections. The first section focuses on science teaching and learning from the perspective of the class teacher and his colleagues who had recently taught the Grade 9 unit on Electricity. The next section considers data from the whole class of 43 students. These data are pertinent to the whole class view of science-technology-society, perceptions of their classroom environment, perceptions of the teacher interaction in the classroom, and students' prior knowledge of electricity in accordance with research questions 1 and 2 outlined earlier in Sections 1.3 and 2.7. The last section reports data from the perspectives of four selected focus students. This section looks at the four selected students' profiles in relation to their views of science-technology-society, classroom environment, teacher interaction, and their understanding of electricity prior to the instruction on electricity. The last section also goes further to extend understanding of

interpretations from the preceding section about the existing nature of the dynamics of learning in this particular science classroom in Papua New Guinea; thus, focusing mostly on research questions 3 and 4 presented earlier in Sections 1.3 and 2.7. The principal sources from which data were drawn in the study are alluded to and referred to directly in parentheses throughout this chapter. A key to the data sources appears at Appendix F.

4.2 Introduction to the learning environment context

4.2.1 The class teacher: Participant in the study

In a meeting held at school early in the commencement of fieldwork with the Head of Science Department and teachers involved in teaching Grade 9 Science, the researcher explained details of the study and the need for a volunteer teacher to participate. Mr. David Mark (all names are pseudonyms) volunteered to participate in the study. David was in his twenties, newly married and was an indigenous member of staff of the school. This was his first year of teaching after obtaining a Bachelor of Education Degree in Science Education the previous year from the local university. The structure of the Bachelor of Education Degree allowed David to complete over 70 % subject content and less than 30 % education methodology. In the final two years of his study at university he had majored in science to teach physics and chemistry streams at high school. His minor specialisation was in teaching mathematics.

David had been educated through the Papua New Guinea education system from primary school to secondary school and on to university. This was his first posting as a specialist science teacher. He had been through six years of primary school (Grade 1-6), four years of lower secondary school (Grade 7-10), two years at upper secondary school (Grade 11-12) and four years at university (Bachelor of Education) in Papua New Guinea. The teachers who taught him in primary school, lower secondary school and many in upper secondary school

were all indigenous staff who had themselves experienced teaching and learning approaches that were highly teacher-directed.

The school he was posted to was unable to provide accommodation for him and his family within the school grounds because there was a shortage of housing for teachers. In Papua New Guinea it is common practice for schools to provide accommodation at minimal rental rates to their staff within the vicinity of the school. As a result, David was forced to live a few kilometres away in a village on the outskirts of the town. The house he lived in was a typical traditional village house made from bush materials and was without power and running water. The lack of adequate lighting in the evenings at home forced him to do all his lesson preparations at school during the day. David also had a high teaching load in his second teaching subject area of mathematics.

The teaching schedule for Unit 9.2 on Electricity, compiled by the Head of Lower Science Department is reproduced in full in Table 4.2 (Section 4.2.3). It was planned for David to teach Science Unit 9.2 (Electricity) of the High School Science Syllabus (Papua New Guinea National Department of Education, 1987) in 11 weeks, which was almost twice the time frame of 6 weeks recommended by the NDOE curriculum division. Colleagues of David interviewed by the researcher said that they did not have enough time to adequately teach students the important concepts and principles about electricity that Grade 9 students need to learn and they believed the recommended time as specified in the Teachers Guide was inadequate.

> That's what I have experienced myself. Given limited time I have to cover
> the given content. Sometimes I want to relate to new ideas but there is not
> enough time. (Teacher Interview: Albert; 11.04.01, line 21)

Albert agreed that 6 weeks was insufficient time to teach electricity topics outlined in Unit 9.2. According to the teachers, limited time and lack of equipment for experiments led teachers to spend the majority of time on writing notes on the chalkboard and explanations (talk and chalk) than experiments.

> Teachers tend to be more or less the chalkboard and textbook teacher in the science classroom. Some teachers would like to be experiment-oriented type but the time factor with the unavailability of the basic science equipment, I think ….we tend to be the chalkboard and textbook teachers. (Teacher Interview: Norman; 11.04.01, line 2)

This resulted in lessons that tended to be more teacher-directed. The next section discusses the physical facilities at school that were an important aspect of the learning environment in which David conducted his teaching.

4.2.2   The classroom facility

All science lessons for the selected Grade 9 class were conducted in standard combination classroom/laboratories. The layout of the laboratory used by the class participating in the study is described in the excerpt from the field notes below.

> The laboratory had two fixed benches running alongside the length of the room adjacent to the side walls and windows. There were four gas taps and four sinks and water taps equally spaced along each bench forming eight workstations for group experiments. In the middle of the laboratory there were other desks and stools fitted to cater for the large student numbers. The front area had a raised demonstration bench. (Field Notes, 01.03.01)

Basic science equipment such as Bunsen burners, beakers, and test tubes were available in the attached preparation and storeroom as required. Students tended to maintain the same seating arrangements for all lessons. These arrangements

were in groups as determined by the class teacher for experiments and group activity. Although there were basic science apparatus and materials available in the preparation and storeroom, the laboratory was lacking necessary equipment to conduct experiments on electricity. David confirmed this observation in this initial interview.

> We don't have enough equipment in the schools like the electrical appliances, meters, voltmeters, ammeters which I can give to the students to help them learn things better [by conducting experiments]. (Teacher Interview; David 11.04.01, line 5)

It was not unusual for David to borrow equipment for electricity experiments from the Grade 11 and 12 science laboratories as indicated in the following field note.

> I observed period 7 and 8 science lessons. This session was a practical class where students had practice with connecting series and parallel circuits and taking current and voltage readings. There was enough apparatus for only four groups so there were four experimental groups instead of the usual five. Two groups had to share a voltmeter. Students from one group moved over to join other groups. The previous afternoon David had transferred over circuit boards, ammeters and voltmeters from the senior science laboratory nearby for the lesson. (Field Notes, 09.03.01)

The laboratory used had neither the capacity to hold 43 students in the class nor were there enough sets of experiment equipment for each of the five groups of eight or nine students, let alone for groups of more reasonable size of four to five students per group. It was difficult for David to inspect individual students' worksheet exercises and experiment work because of the overcrowding of students.

A major drawback to the lesson was the overcrowding caused by the large number of students that led to the restriction of movement of the five groups around the class. Students at the fringes could not see clearly what was going on with the experiments. David had some difficulty moving around from group to group attending to students' requests for assistance with setting up of circuits. (Field Notes, 9.03.01)

The science topic taught during this study is discussed in the next section.

4.2.3   The electricity unit taught during this study

The selected Grade 9 class was taught the Science Unit 9.2 on electricity by the class teacher, David. The regular teaching and learning approach in the school was continued by David, unaltered in any way so as to maintain the usual natural learning environment that would have ensued if the study had not been conducted in this classroom. Thus, there was neither treatment nor changes in conditions introduced in this formal learning situation, in keeping with the overall intentions of the study to investigate and furnish insights into a contemporary Papua New Guinean high school classroom learning environment as earlier highlighted in Section 1.1. The suggested teaching program for Unit 9.2 was outlined in the Unit 9.2 Teacher's Guide published by the PNGNDOE (1987), a copy of which is reproduced in Table 4.1. The unit begins with a revision of circuitry taught earlier in Grade 7, followed by an introduction to the use of the ammeter as a device for measuring current, the concept of voltage and the voltmeter as an instrument for measuring this, the heating and lighting effects of an electric current and activities with electromagnetism leading to the functioning of electric buzzers and electric motors. The production of electricity is then covered with particular reference to dry cells, car batteries and the national production of electricity. The unit concludes with an investigation on household electricity and its safety aspects.

Table 4.1

Suggested Program for Teaching the Electricity Unit by PNGNDOE

Investigations	Activities	Purpose	Duration
1. Electricity revision	1. Revision	Revise some of the ideas that students should have learned in Grade 7 Unit 6 on Circuitry.	2 periods
2. Measuring electric current	1. Measuring current in a series circuit 2. Measuring current in a parallel circuit	Reinforce and build on ideas learned in Grade 7 Unit 6. Then introduce the use of ammeters for measuring electric current quantitatively. Introduce idea of electron flow and nature of an electric current.	2 periods
3. Voltage	1. Measuring voltage of different cells 2. Measuring voltage of different numbers of cells	Consider the voltage of sources of electricity and not the voltage across other points in a circuit. Differentiate between electric current and voltage.	2 periods
4. Heating and lighting	1. Heating wires 2. Lighting 3. Heating appliances	Provide students with a basic understanding of the most common uses of electricity.	2 periods
5. Electromagnetic devices	1. The shape of the magnetic field 2. The hacksaw buzzer 3. The electric bell	Extend students' knowledge of electromagnetism and investigate the application of electromagnets in devices such as electric bells and buzzers.	3 periods
6. The electric motor	1. An introduction to the electric motor 2. Constructing the electric motor	Give students an understanding of how an electric motor works and the important applications of electromagnets in electric motors.	3 periods
7. Simple chemical cells	1. The lemon cell 2. The simple cell	Show that chemical energy can be converted to electrical energy.	2 periods
8. Rechargeable cells and batteries	1. A rechargeable cell 2. Car battery – Teacher demonstration	Give students some understanding of how dry cells and car batteries function and how to use them properly.	3 periods
9. Other ways of	1. A bicycle dynamo	Show that electrical energy can be	4 periods

producing electricity	(Mechanical energy to electrical energy)	produced in a variety of ways besides chemical methods. Reinforce the	
	2. The generator (Mechanical energy to electrical energy)	ideas learned earlier on how generators function in Grade 7 Unit 6 Investigation 12.	
	3. Using an electric motor as a generator (Mechanical energy to electrical energy)		
	4. The thermocouple (Heat energy to electrical energy)		
	5. The light meter (Light energy to electrical energy)		
10. National production of electricity	1. Where is electricity produced in Papua New Guinea? 2. A power station 3. The transmission of electricity from the power station to the home 4. High voltage electricity	Give students some understanding of the production of electricity by generators on a large scale and the distribution system from the power station to the individual house.	3 periods
11. Household electricity	1. Safety measures 2. Household wiring 3. Short circuits and fuses 4. Paying for power	Look at ways that electricity is used in the home with an emphasis on using electricity safely.	3 periods

In the foreword of Unit 9.2 Teacher's Guide (Papua New Guinea National Department of Education, 1987, p. i) is a message from Secretary for Education of the Papua New Guinea Education Department; emphsising that the approach used in the guide was to engage students actively in learning science and therefore many student practical worksheets were included. Subsequently, most of the investigations are student-centred activities for which worksheets are provided with clear specified behavioural objectives that are to be met by students after

completion of the unit as evidence of learning. The first investigation titled Electricity Revision, for example, has as its behavioural objectives the following detailed requirements for students to attain after completing the investigation.

Students should be able to:

- Identify and construct electric circuits with components in series and parallel.
- State and demonstrate that increasing the number of lamps in series in an electric circuit decreases the electric current (as shown by reduced brightness).
- State and demonstrate that as more lamps are placed in parallel in a circuit, the brightness of (and therefore the electric current flowing through) each lamp stays the same.
- State and demonstrate the difference between electrical conductors and electrical insulators.
- State that a good electrical conductor allows high currents to pass through it and is said to have a low electrical resistance.
- State that a poor electrical conductor allows low electric currents to pass through it and is said to have a high electrical resistance.

There were a total of eleven practical investigations to be taught by teachers in two to four period time allocations depending on the number of activities each investigation had. As presented in Table 4.1, the total number of periods required to complete the unit was 30 periods of 40-minute lessons or 6 weeks as Grade 9 students studied 5 periods of science per week.

Table 4.2 presents a copy of the program drawn up by the Head of Department (HOD) of Lower Science, reproduced in full for teachers to adhere to in planning and teaching electricity alluded to earlier in Section 4.2.1.

Table 4.2

A Program for Teaching the Electricity Unit Compiled by Head of Lower Science

Week	Topic	Objectives
Term 1*	*Investigation 1*:	- Identify and construct electric circuits with components.
6	Revision [A short	- Identify series and parallel circuits.
	open test or quiz	- Revise common terms.
	would be suitable]	
	Static electricity	- State and establish what static electricity is, by experiment.
		- When material is rubbed – a charge is acquired.
		- State there are two kinds of charges.
		- Understand the atomic theory, i.e. charges in an atom.
		- State that rubbing removes charges, adds charges.
		- State that static electricity is electricity at rest.
7	*Investigation 2*:	-Determine what electric current is.
	Measuring electric current	-Determine source of electric current.
	Activity 1- Current in series circuit.	- Construct a series circuit.
		-Determine that as more dry cells are added in a series circuit, the current increases.
		- Define unit of current.
		- To connect and use the ammeter correctly.
		- Determine by experiments that total current is the same at all points of the circuit.
8	Activity 2- Current in parallel circuits	- Determine that as more lamps are added in parallel, the brightness (current) is the same through each lamp.
		- Connect ammeter correctly.
		- Total current in parallel circuits is the sum total of each circuit path current.
	Investigation 3:	- Differentiate between current and voltage.
	Voltage	- Determine that the unit of voltage is volt.
		- Determine by experiments that voltage can be measured.
		- Use voltmeter correctly
		- Determine that a high source of voltage will give a high voltage and vice versa.

9	Activity 1- Voltage series circuit.	- Determine by experiment the rule for voltage in a series circuit.
		- Determine that voltage across a supply is the sum total of the voltage drops across individual lamps.
	Activity 2- Parallel circuit	- Determine that voltage across all parallel lamps is the same.
10	*Investigation 4*: Effects of electricity Activity 1- Resistance	- Define resistance.
		- Confirm by experiment the factors that affect resistance; length, thickness, materials.
1 Term 2	Activity 2- Resistance in series.	- Calculate resistance in series.
		- Total resistance, $Rt = R1 + R2 + R3$.
	Resistance in parallel.	- Reciprocal of Total resistance, $1/Rt = 1/R1 + 1/R2 + 1/R3$
2	Activity 3- Heating	- Describe 4 effects of electricity: heating, lighting, magnetic, and chemical.
		- Describe heating effect as a result of resistance.
	Activity 4- Lighting	- Confirm by experiment that electrical energy can be converted to heat and light energy.
		- Explain how light is emitted from luminous substances as in fluorescent tubes.
3	*Investigation 5*: Magnetic effect Activity 1- Shape of magnetic field.	- Confirm by experiment that electricity has a magnetic effect.
4	Activity 2- Magnetic field about a straight wire carrying current.	- Confirm that a magnetic field is created by current passing through a straight wire.
	Activity 3- Magnetic field about a solenoid	- State that the magnetic field is similar to a bar magnet's field. (Stronger- more turns of wire)
	Activity 4- The electromagnet	- Describe the electromagnet as a device built to use the magnetic effect.

5	Activity 5- Electric motor	- Show that a straight current carrying wire at right angles to a magnetic field experiences a force at right angles to both the wire and the field. This results in a movement. - State energy changes. - State basic parts of a motor.
	Investigation 6: Sources of electricity (Primary Cells)	- State that electricity can be produced by chemical means. - Describe the primary cell and its composition. - Describe energy changes. - Explain electrode, electrolyte, and simple cell.
	Activity 1- The Simple cell.	- Compare and contrast a simple cell to a dry cell regarding composition and durability.
	Activity 2- The dry cell.	- Define and describe dry cells.
6	Activity 3: Car Battery (Secondary Cells)	- Describe secondary cells using old car battery. - Describe lead acid cells.

Note: * Lesson observations commenced in Term 1 week 6 , week beginning Monday 5 March 2001; and ended in Term 2 week 6.

The actual electricity content taught to Grade 9 students by teachers, based on the syllabus document is shown in Table 4.2. The actual teaching program compiled by the Lower Science HOD instructed teachers to teach Investigations 1 to 6 whilst omitting Investigations 7 to 11, which effectively reduced the content taught to Grade 9 students by half.

Furthermore, the recommended 6 week time frame to teach the full electricity program (Table 4.1) in the syllabus document was extended to 11 weeks as previously alluded to in Sections 4.2.1 and 4.3.3. It seemed teachers required more time to teach half of the content in electricity specified in the syllabus document.

The next section describes in detail two of the lessons observed in the form of vignettes in order to provide insight into classroom practice of the

learning environment of this particular secondary school in Papua New Guinea. The following vignettes, based on the researcher's field notes and transcriptions of the class video recordings, were selected at random and they represent typical lessons in David's classroom.

4.2.4   Vignettes

4.2.4.1 Vignette 1

This first vignette provides a summary, a transcript, and an analysis of a single period 40-minute lesson taught by David in Term 1 week 7 (see schedule in Table 4.2). The vignette serves two purposes. Firstly, it introduces the reader to the strategies for teaching and learning of science employed by David in this particular classroom in Papua New Guinea which has some distinct differences with his counterparts in Western developed countries. Secondly, the vignette serves to illuminate the important teaching and learning activities that were evident in David's science lessons that typified his teaching style and strategies, and the way his students learned in his class. If perceptions and beliefs are the basis of strategies by which people act (Black, 1973), then the actions described in this vignette are based on David's beliefs and those of his students. Accordingly, what David and his students perceived and believed in regarding their learning and learning environment, influenced the manner in which they interacted and participated in the classroom learning activities as illustrated by the following transcript. The transcript is based on video recordings of the entire lesson and the researcher's field notes, and they are annotated in italics to indicate what students and the teacher were doing at various points during the lesson.

The lesson occurred early in the study in the second week of David's teaching in Term 1, week 7. (Numbers in the following vignettes refer to times and sequence as each speaker take turns)

Three minutes after the bell rang, a handful of students walked into the science laboratory slowly - some whistled. It was a warm humid day. The researcher had taken his normal post at the rear of the laboratory before the students entered. Three to five minutes later a few more students made their entry. The teacher entered around this time.

1. **Teacher**: Some [students] are still coming, aren't they?

2. **Some students**: Yes

3. **Teacher**: Did I tell you about having lessons here?

Students have been using a different science laboratory for their lessons previously

4. **Most Students**: Yes

By this time half the class was present. Most of these students were slowly opening their notebooks. They seemed to be talking among themselves in low voices

5. **Teacher**: Make sure you have this sheet [referring to worksheet] with you and the homework. We'll do the corrections [to the homework] now.

David had the teacher's copy of a worksheet that had problems that was given to students the previous day for completion. The worksheets were part of the teaching activities included in the Teacher's guide for teachers to use. Students slowly opened their books. Some were mumbling. A few were looking out of the window. More students entered and found their places to sit.

6. **Teacher**: May we continue now? … Good morning class?

7. **Students**: Good morning Mr. Mark and Mr. Najike

Some more students entered. The teacher hesitated, waited for the late students to settle down. Two students had no stools to sit on so they stood leaning against the bench.

8. **Teacher**: Okay, enough of the noise. Open your books to the problems. Sit down; don't   make a lot of noise. Find a place to sit down.
9.   Okay let's start the lesson.
10.   We talked about static electricity in our last lesson.
11.   What is static electricity? How do you define the term?

There was no response from students. The teacher looked around the class for students' response. After a few seconds he tried to prompt students to respond. This was David's introduction to the day's lesson. He was attempting to review main ideas from the last lesson.

12. **Teacher**…Give a try.

David paused for a few seconds.

13. **Some students**: …electricity at rest.

14. **Teacher**: Electricity at rest, that's what we said in the previous classes.

15.   How did we define current, Peter?

There was no response for a few seconds.

16. **Peter**: …Flow of electrons

17. **Teacher**: That's what we said in the previous classes. As we discussed last time, electrons are in every thing. Metals have electrons because they are made up of atoms.

18.   What is an electron? …Yes, Joshua?

19. **Joshua**: …an electron is made up of charges

20. **Teacher**: Electrons are charges. Electrons exist in everything. What type of charge?

21. **Most students**: Negative charge

22. **Teacher**: Very good, negative charges

23.   In which direction in a circuit does the electron flow?

The majority of students neither put their hands up nor made any attempt to respond to the teacher's question. Some students appeared to be busy writing things in their books. In many cases it was only when students were called by name that they responded.

24.   …Paul?

25. **Paul**: Negative to positive

26. **Teacher**: Why is that? Paul

27. **Paul**…because negative terminal has lots of negative charges.

28. **Teacher**: We must not forget that. We say electrons are negative charges passing from negative terminal where there are lots of electrons to positive terminals where there are fewer electrons.

29.   Last lesson we did an experiment by rubbing a plastic rule.

30.   We said that like charges do attract or repel?

31. **Some students**: Repel

32. **Teacher**: Unlike charges…?

33. **Some students**: Attract

34. **Teacher**: So when we rub a ruler against the hair of our skin, hair was attracted to the ruler. Hair has surface atoms. That's what we learned in our last lesson. Now I want us to complete this Worksheet

He showed the Worksheet to the class.

35. **Teacher**: Take it out…

36.   We have corrected the first stage, now we correct the rest of the
         problems.

37.   I want a volunteer from each group to come and draw the circuit
         on the board.

38.   …Rose, good you can come and do it…that's a rep. from Group 5.

Rose was the group leader of Group 5 and took it upon herself to volunteer. Three minutes passed by where Rose copied onto the chalkboard a series circuit diagram from her notebook. Some students were talking away in little groups. Many students were writing things in their books with heads down, probably checking their work against Rose's on the chalkboard. In general, it seemed students were reluctant to respond to their teacher's questions unless they were specifically called by name to respond.

39. **Teacher**: Thank you Rose.

40.   The instruction says three dry cells connected to a light and a
         switch also in series… Does that drawing have three dry cells…?

The teacher tried to lead the students along.

41.   This is a positive terminal…

The teacher pointed at parts of the diagram while talking.

42.   We have three dry cells, what else…this is a switch…good…

The teacher talking to himself. Students paid attention but did not respond.

43.   You should have something similar to this circuit.

The teacher followed in the same manner to correct work with students from different groups giving answers on the board, which took twenty minutes. After this he handed out a new worksheet with problems for students to do. The Worksheet was photocopied from the Teacher's Guide for Unit 9.2 on Electricity.

44. **Teacher**: In tomorrow's lesson we will measure current and voltage.

The teacher was referring to a planned practical session in which students would develop skills in taking current and voltage measurements with ammeters and voltmeters from a simple series electric circuit.

Five minutes passed in which students tried to solve problems from the new Worksheet that was handed out to students earlier. The majority of the students worked on their own, answering questions in their note books. David moved around the classroom, checking students' work.

45. **Teacher**: Discuss with your friends. Share ideas.

Noise came from the field nearby where some boys were playing touch rugby. The majority of students in this class were working at a leisurely pace. However, they were quiet and busy with their work. After another fifteen minutes the bell rang signaling the end to this class.

46. **Teacher**: Complete that? … Yes or no?
47.   Write your name at the top and I'll collect them. Tomorrow I'll
48.   return them and we can connect these series circuits and do
              problems on them.
49.   If you haven't finished, just write your name and hand in.

Students were slowly getting up. The majority of students were still writing on the worksheets. The teacher urged the students to hurry because a class was coming in to use the laboratory.

4.2.4.2 Interpretations from Vignette 1

The lesson highlighted in Vignette 1 was a non-practical 40-minute lesson taught in the science laboratory in the usual way by David. In the lesson David started off by reviewing important concepts on static electricity taught the previous day (line 17). Then he led students orally through the solutions to homework problems on a worksheet that was taken from the teacher's guide. At certain points in the lesson David asked students from each group to come to the front and write the group's answer on the chalkboard (for example, line 38). In general the lesson combined brief teacher explanation of important points (for example, line 14), questioning (for example, line 23) to test students' understanding, and student working on set problems (for example, line 36). The components of teacher explanation and questioning occupied a major part of the lesson, making the lesson more teacher directed and less student centred in nature.

Students' activities involved copying down notes of solutions to problems from the chalkboard and responding to the teacher's questions and instructions when required to. On many occasions students engaged in withdrawal or non-participatory behaviour such as not responding to questions asked by the teacher unless specifically asked to by David, with their heads down and appearing to be busy copying notes (commentary after lines 23, 38). Some students were reluctant to participate fully in the classroom interactions with their teacher by asking questions and holding discussions in their groups (commentary after line 38).

In general, most students readily accepted what David taught without question and were reluctant to discuss subject content delivered through worksheet problems and experiments in student groups. Students showed limited evidence of taking responsibility for their learning, thus learning in this type of situation reflected a transmission perspective. The situation was reminiscent of assumptions made from transmission perspectives a few decades ago about

learners, including the "tabula-rasa" (Gilbert, Osborne, & Fensham, 1982) and "teacher dominance" (Osborne & Freyberg, 1985) assumptions. The former assumes learners have a blank mind which can only be filled by the teacher or textbook author. The latter assumes learners have prior ideas related to the topic under instruction but these ideas can easily be replaced with scientifically correct ideas at school. Thus, learning in this environment was seen as the transferring of knowledge from the teacher to the students, usually in the literal sense. The teacher dominated and directed teaching and learning while students became passive recipients of knowledge.

In the view of the researcher the pace of the lesson was observed to be slow during most parts of the lesson. Nevertheless, the overall impression gained by the researcher was that the teacher was well liked and respected by the students as both personable and knowledgeable.

4.2.4.3 Vignette 2

The second vignette also provides a summary, a transcript, and an analysis of one of David's practical lessons, based on transcriptions of video recordings, and the researcher's field notes. A full 80-minute double-period practical lesson selected at random, it serves to illuminate a practical session where students are required to be actively involved in student centred activities by the Electricity Unit 9.2 Teachers Guide. This lesson was conducted during periods 1 and 2 on a Tuesday morning, in Term 1, Week 9 (see schedule in Table 4.2). The transcript is annotated in italics to indicate what students and the teacher were doing at various points during the lesson.

David had organised a practical laboratory session for this double period of 80 minutes. He came in some minutes before the bell rang to make sure all apparatus required for the practical were placed on the front bench. The researcher took up his post at the back of

*the room at his usual spot after having switched on video camera 1 for a wide angle view
of the laboratory.*

*Students began to enter after the bell went. A student is assisting David to move
apparatus to the front bench from one of the senior science laboratories nearby.*

1. **Teacher**: Good morning class.

2. **Students**: Good morning Mr. Mark and Mr. Najike

3. **Teacher**: You may sit down. Now, for revision, "What was the last topic we learned on Friday?" Raise your hands …Martin?

4. **Martin**: Voltage

5. **Teacher**: Good, We learned about voltage. What did we say voltage was? …Ruth, what is voltage?

6. **Ruth**: Voltage is the measure of force that pushes the electrons or current around a circuit.

7. **Teacher**: Is she correct?

8. **Most students**: Yes

9. **Teacher**: Voltage is the measure of a force that pushes current around an electric circuit. What is the unit for voltage, Rachael?

10. **Rachael**: Volts

11. **Teacher**: Good, [voltage is] represented by capital letter 'V'. What is the instrument used for measuring voltage, Tess?

12. **Tess**: voltmeter

13. **Teacher**: Very good, [it is the] voltmeter.

   In these two periods we will be dealing with voltage drops in series and parallel electric circuits. And, [we] will come up with a conclusion on the nature of voltage drops in series and parallel circuits.

14.   For the next 30 minutes I'd like you to learn about the nature of voltage drops in these circuits when you do the practical activities planned for this session.

15.   This morning we'll be measuring voltage drops across circuit components in two types of circuits. This will be our topic.

David writes "Measuring voltage in series and parallel circuits" on the chalkboard. This is followed by diagrams of both a series and a parallel circuit where each circuit diagram consists of 3 light bulbs, 4 dry cells and a switch. He then writes procedures for conducting practical Activity 1 in which students were to consider voltage drops at various points of a series circuit were the three light bulbs are connected side by side.

A male student comes in late quietly and finds a place to sit…David is busy writing notes on the chalkboard and the students are copying these notes into their books.

Ten minutes goes by. A female student comes into the science laboratory. She is also late. By now the class was 20 minutes into its lessons. David tells her quietly to remove her footwear and go and find a place to sit with her group. It was a rule for students to remove footwear when entering the laboratory to keep the floor clean.

16. **Teacher**: Who's finished [copying down notes from the chalkboard]? Raise your hands 1, 2, 3…

17. …Good, we'll commence our experiment now.

But David spends a further 5 minutes writing more notes on the chalkboard. They were summary notes relating to the expected outcome of the planned practical activities.

18. **Teacher**: Don't get this down; this is for the results you will get from the practical.

David was writing concluding statements with blanks for students to fill in after the practical session. He planned for students to copy this segment of notes later after the class orally summarised their results at the close of the double period lesson.

19. **Teacher**: Okay, Group 1 come and get your equipment for your practical.

Ian comes from Group 1 to pick up a circuit board, dry cells, light bulbs and a voltmeter from the front bench.

20. **Teacher**: Do the connections. First we start off with activity 1. That activity involves a series circuit. P1 is the first spot to get your first [voltage drop] reading.

P1 was a point in the series circuit before the first light bulb. At this point, the voltage drop across the dry cells would be measured as V1.

The bell rings for the end of the first period as David points to the first circuit diagram as he explains.

21. **Teacher**: There are four dry cells. Take your reading across them and put it down as V1. Don't put your result there [in the blank]; we'll try to conclude as a class.

22. Do the first connection. We have already gone through some connections in our previous lesson. Connect at this point here,

get the reading and put here. This will take you five minutes to
do. …Good.

After a pause David proceeds to Activity 2.

23. **Teacher**: This circuit diagram goes with activity 2. This time you are to do
these connections. The connections must be in parallel. Get V1
(voltage drop across the dry cells) and V2 (voltage drop across the
first light bulb connected in parallel) and we'll see what our
conclusion is like for this [circuit]. Is that clear?

24. **Some students**: Yes

25. **Teacher**: Now go on with your experiment. Okay Group 2 and Group 3
reps., come and get your equipment.

Two male students come to the front to collect apparatus.

26. **Teacher**: Are you connecting the voltmeter in series or in parallel [in your
circuit]?

27. **Some students**: Series

*This meant inserting the voltmeter in the circuit, similar to the way ammeters are
connected to measure current.*

28. **Teacher**: No, connect in parallel. Not in series, you will blow the voltmeter
if you do that.

David goes to another group at the rear of the room.

29. **Teacher**: Some of you in this group join Group 2 because I don't have any
more voltmeters to go around.

Three groups were now working instead of five because of shortage of voltmeters in the laboratory.

The researcher switches from video camera 1 to video camera 2 to focus on activities of Group 1 members. Video camera 2 shows a close-up view of Group 1 members and the bench on which they conducted their group work. Group 1 members were the four focus students, Allison, Ian, George and Demi, and four others, two of which were reserve focus students who would fill in for any of the focus students if unable to continue their participation in the study. The researcher moves closer to Group 1 to observe students at work.

George replaces a weak dry cell with a new one in series with three others in the circuit. Allison and Mary are slowly taking readings on the voltmeter which was connected across dry cells connected in an electric circuit with three light bulbs and a switch. The rest of the group members appear to be noting down readings in their note books as they are read out by Allison and Mary who had the voltmeter directly in front of them.
The aim of Activity1 was to measure voltage drops across a) the dry cells (V1), b) first light bulb (V2), c) first and second light bulbs(V3), and the three light bulbs together(V4).

This goes on for another 10 minutes by which time the last of the readings were taken. About this time the noise level in the class had reached a high due to some students' frustrations over the difficulty with working with large student numbers as the other two groups had more than 15 students each, all crowding around their respective workstations.

George, Mary and Ian of Group 1 are arranging circuit components for Activity 2. George is taking the lead and seems to know what he is doing. Ian is a bit unsure of himself as he connects up the three light bulbs in parallel. Allison waits to read the voltmeter. Demi is quietly writing something into her book. She appeared to be waiting upon the Group to provide readings which she would jot down in her book. So far she has not said much during the group work.

After about 5 minutes the voltage drop across the dry cells, V1 for Activity 2 is measured by Group 1 members.

30. **Teacher:** By now most of you should be getting readings for voltage drops in the second circuit. If you are still doing Activity 1, I ask you to stop what you are doing and go straight to Activity 2 because we have 20 minutes before the end of this lesson.

There is a bit of commotion in the left hand corner of the laboratory where a group was working. Someone was pushed and a few students were talking loudly. David did not seem to notice what was going on there. After about 5 minutes the commotion subsided and the situation was back to normal and it was as if nothing had happened.

31. **Teacher:** May I have your attention please. Who has got all the voltage readings for the two circuits?

Some students raise their hands. A few were still taking readings. Some students were busy writing in their books. Most students in Group 1 were paying attention to David. They had finished taking the final voltage readings from Activity 2.

32. **Teacher:** Now we will together summarise the main ideas from this lesson. Look at this first circuit diagram. V1 is… Group1?

The researcher switches to video camera 2 for a wider view of the class. It seemed it was now time for the class to discuss their results.

33. **George:** …4.6 volts

34. **Teacher:** Group 2?

35. **Some students from Group 2:** 5.2 volts

The bell rings signaling the end of period 2.

36. **Teacher:** Those voltage readings are okay because we have 4 dry cells, and normally a new dry cell has a source voltage of 1.5 volts, and for 4 cells normally 6 volts would be measured.
A correct reading for V1 should not exceed 6 volts.

37. Group 3; give us your reading for V2.

38. **Joshua:** We got 1.9 volts.

39. **Teacher:** Good. V2 should be around 2 volts, depending on the resistance of the light bulbs. V3 should be around 4 volts and V4 should be around 6 volts if the light bulbs are identical which they are.

40. Time has caught up with us. So, for homework there are 2 things I want you to do:

41. First, make sure you enter all voltage readings taken during this lesson into the appropriate spaces in the table.

42. Second, turn to your notes and fill in the blanks for the conclusion of today's practical lesson.

The concluding statements with blanks written on the chalkboard were:

In a series circuit, voltage drops across loads vary depending on the load resistance. The source voltage is _____ to the sum of voltage drops in a series circuit.
In a parallel circuit, voltage drop across all loads connected in parallel are the _____ and they are _____ to the source voltage drop.

The students slowly begin to leave the class for their other lesson in period 3. A few students are busy writing in their books.

43. **Teacher**: You may now go for your next class.

The teacher releases the students 4 minutes after the bell rang

4.2.4.4 Interpretations from Vignette 2

The lesson observed in vignette 2 was a double period practical lesson of 80 minutes duration (Section 4.2.4.3). The objective of the lesson was to determine by experiment the characteristics of voltage drops across lamps connected in both series and parallel circuits, as stated in Table 4.2 for lessons taught in Term 1 Week 9. David commenced his lesson by reviewing the definition, nature of voltage and the concept of voltage as a power source as well as a potential difference across a lamp connected in simple circuits, taught in the previous lesson (line 3). Next, David introduced the practical lesson where students were to work in their groups to measure voltage differences across lamps which they connected in both series and parallel (line 15). After a brief introduction of the lesson David wrote on the chalk board the heading, circuit diagrams, and the procedures required for doing the experiment which students copied into their books. As previously, mentioned in Section 4.2.2, students had been organised into 5 groups for practicals. However, due to a shortage of voltmeters 3 groups were formed (line 29), resulting in further overcrowding around the work benches and the restriction of many students from directly participating in the practical activities. In general, the lesson comprised periods of instructions from David (line 21), and students practical work of connecting up simple circuits and taking down voltage readings that lasted an hour.

Students' activities during the lesson mostly involved setting up circuits and taking readings, and entering readings into their books. For each of the 3 groups, about 4 students were actively involved in setting up circuits and taking readings while the rest observed and noted the readings in their books. On the other hand, the teacher's involvement in the lesson was restricted to providing direct explanations, asking questions, and supervision of students' practical work. In many instances David provided direct explanations on how to connect the circuits and measure voltage correctly (line 21). David even went as far as to preempt the results students were expected to discover through practical activities by writing the expected outcome of the planned practical activities (commentary after line 17) before students started the lessons, which was contrary to the guided discovery method of teaching and learning approach for practical lessons encouraged at the local tertiary institution where David obtained his teaching qualification.

Overall, the instructional strategies and activities observed in the lesson hardly took into account students' prior knowledge and preconceptions about electricity. However, David showed that he had a solid grasp of the subject matter. David seemed to direct the lesson from start to finish, and his tendency to offer direct explanations on content as he went along did not leave much room for students to take responsibility over their learning. Students seemed to expect David to pass on all there was to know about electricity to them. As noted previously, in the interpretations of the lesson observed in Vignette 1 in Section 4.2.4.2, again students remained passive recipients of knowledge while David dominated and directed teaching and learning. Although the lesson was a practical one, fewer students were involved in the practical activities. In the researcher's view, the pace of the lesson was slow as usual, but students seem to enjoy this lesson.

4.2.5   Summary: The learning environment context of the study

This section introduced readers to the specific learning environment context in which the research was undertaken. Despite the fact that the contemporary teaching and learning situation in this high school in Papua New Guinea was based on an imported Western model, there were important differences from that model that were observed in its implementation. The number of students in the class was high, resulting in over-crowding in the science laboratory which was the classroom used for all science lessons by the class. Overcrowding affected the teacher's ability to attend to different group workstations offering guidance and responding to student queries during group practical sessions. Overcrowding also placed a strain on resources such as laboratory apparatus and materials for experiments. Teaching and learning in this particular classroom learning environment was conducted from an essentially transmission perspective that saw the teacher as dominant, and taking a directive role in the classroom. The emphasis in learning was for students to reproduce what they were taught. There was limited evidence to suggest the occurrence of meaningful learning in this classroom, even though at times David made attempts at encouraging students to interact in ways that may have developed it, for example, line 20.

David had a full teaching load and was usually busy during the day. If he was not teaching, he was usually occupied with preparing lesson plans and marking students' work. As noted earlier, David and a number of his colleagues (science teachers) believed that the time designated for teachers to teach Unit 9.2 by NDOE was inadequate. They were usually pressed for time and so practical sessions became relatively fewer in number and most teaching comprised reviewing main points covered in the last lesson, introducing a new topic, writing of notes on the board, explaining by the teacher, marking of problems. The practical sessions where students conducted experiments usually took a double 80-minute lesson. They usually began with a brief explanation about the

experiment to be conducted by students in groups. The teacher explained on the chalkboard and sometimes handed out to students an experiment sheet with tables and blank spaces to be filled in by students from their experiment results. These sheets were usually handed in for marking.

The next section discusses David's perception of teaching and teaching strategies employed in this classroom.

4.3   David's perceptions of teaching and the teaching strategies employed

4.3.1   Introduction

As mentioned earlier, this section highlights David's perceptions of teaching and the approaches to teaching strategies he applied in his classroom when teaching students electricity during the study. Interviews were also conducted with other teachers in the school who were teaching Grade 9 science at the same time as David or had taught Grade 9 science recently in the past two years. Their views are also discussed to compare their perceptions with the perceptions David held and the teaching approaches he employed.

4.3.2   David's teaching ideals

Having been a recent graduate in his first year of teaching, David had limited teaching experience in high schools as a science teacher. On the other hand he had many modern ideas about teaching and learning. For instance, he considered his teaching role as that of a facilitator of student learning whose task was to promote group work and greater student participation in class. He preferred to see students asking questions and actively participating in teaching and learning activities in the classroom.

> I think students should be participating and answering or asking questions if they
> are not sure of anything. (Teacher Interview; David 11.04.01, line 25)

The first two periods in the morning were science. The class was taught the nature of current behaviour in parallel circuits by involving students in a practical session where they connected three identical light bulbs in parallel in a circuit with dry cells and a switch and took current and voltage measurements. Prior to the practical lesson David used the analogy of water flow in pipes to illustrate the concepts of

- current and resistance (The flow of water symbolised electric current and the resistance to water flow caused by the diameter of the pipes represented resistance); and,

- summation of electric current at a junction in an electric circuit from each circuit path. (This being analogous to the water flow in separate pipes to a junction resulting in increase in strength of water current).

> The aim of the practical was to show students that the three identical light bulbs connected in parallel had the same brightness suggesting that the magnitude of current passing through each light bulb had the same value, and the voltage drop across each light bulb being of the same.(Field Notes: 20.03.01)

Lines 15, 18, 24 and 38 of the vignette in Section 4.2.3 for example, show David's attempts at fostering students' active participation by asking students to respond to questions from where they were sitting in groups or to come forward to the chalkboard at the front of the classroom to write solutions on the chalkboard.

David had his students organised and sitting in five groups to promote group work and greater student participation through practical sessions and discussions. He expected his students to actively engage in group activities, and in any discussions that followed practical sessions to draw conclusions to experiments conducted in class.

This view is contrary to the existing teaching and learning culture in classrooms in Papua New Guinea where students are accustomed to accepting what is taught without question and with limited discussion. Since the first day a child enters school at age seven in Papua New Guinea, he or she is expected to take on a subservient role of obedience to the cultural conventions in place, absorbing and accepting what the teacher teaches in the classroom without question.

For example, the following excerpt from an interview with a student in his class highlights this point.

> **Researcher**: Do you believe that there are electrons in the copper wire? You haven't seen them but the teacher tells you that there are electrons in the atoms of matter. Do you believe the teacher?
>
> **Mae**: Yes
>
> **Researcher**: Why?
>
> **Mae**: Because he is educated… and the teacher told us the electrons are in the atom. (Student Interview: Mae, 13.03.01, line 30)

This interview was conducted after the teacher taught a lesson on basic terms and concepts in electricity. According to the student interviewed (Mae), the teacher was educated and so what he said must be (always) correct. Consistent with this, according to the class teacher David, students in his class did not actively participate in class due to their Melanesian cultural values and learning patterns.

> **David**: Yes, that's one thing that I see. Students don't tend to be asking

questions. They think what the teacher says is all true and they don't need to question the teacher as the master of knowledge. I myself think that's not true. Sometimes I'm bound to make mistakes. What I put on the board and what I discuss is accepted as the knowledge which they come to learn and gain. So they accept everything that I say. On the other hand, experiments conducted seem to convince them to accept what I teach in class.

Researcher: Why do you think they have this attitude to accept what teachers tell them?

David: I believe it has to link back to their culture. From [our] Melanesian culture we believe that what an elderly person or somebody who is higher in status tells us anything we just accept it as it is true or correct. So culture has to contribute here. So it has determined how they think. Ways of doing things and accepting things has already been determined by the culture. So when they get into the classroom they think that I as a teacher I am somebody higher in status and what I say is true and they just accept it. In Western countries it's a bit different. Students don't see things like that, they ask more questions and express their curiosity to learn more than just letting teacher becoming dominant over everything inside the classroom. It is the culture that determines the way students learn. (Teacher Interview: David 11.04.01, line 190-212)

Many school students come from predominantly rural communities with indigenous cultures and practices, and at times the teaching and learning strategies adopted in science classrooms can be perceived as being in conflict with these culturally based learning strategies of the learner. Thus, teachers in classrooms can use practices that may inadvertently conflict with students'

previous learning patterns, home environments, morals and values (Thaman, 1993; Fisher & Waldrip, 1999).

David is also able to identify new ideas introduced by his colleagues in their practice. The majority of David's colleagues were young teachers like David who had recently completed university studies and were in their first few years of teaching in the field.

> One of the main methods that I've seen is the Guided Discovery Method in which my colleagues put things on the board but they don't really give everything away. They put questions in such as homework form or assignment form where students themselves discover things and find out for themselves. (Teacher Interview: David, 11.04.01, line 5)

The above excerpt from the third round of interviews conducted on 11.04.01 with David highlights David's acknowledgement of his colleague's lessons which he described as using the guided discovery method. David sees that controlled questions were used in homework and assignments to scaffold students' learning to arrive at certain canonical understandings of scientific ideas.

4.3.3. David's approach to teaching

David had students sitting in groups of eight and nine, making a total of five groups. Groups maintained their sitting positions throughout all the lessons taught on the electricity unit. Through directed questioning David made attempts to encourage students to participate actively in the classroom.

> **Teacher**: Take it (homework) out… We have connected the first stage, now we correct the rest of the problems. I want a volunteer from each group to come and draw the circuit on the board. …Rose, good you can come and do it…that's a rep. from Group 5.

Rose was the group leader of Group 5 and took it upon herself to volunteer. Three minutes goes by where Rose copied onto the chalkboard a series circuit diagram from her notebook. Some students were talking away in little groups. Many students were writing things in their books with heads down, probably checking their work against Rose's on the chalkboard. In general, it seemed students were reluctant to respond to their teacher's questions unless they were specifically called by name to respond. (Vignette: line 35-38)

Teacher: Discuss with your friends. Share ideas.

Noise is coming from the field nearby where some boys are playing touch rugby. The majority of students in this class are working at a leisurely pace. However, they are quiet and busy with their work. After another 15 minutes the bell rings for end of this class.
(Vignette: line 45)

However, despite his efforts to get students responsible for their learning, the teaching and learning approaches evident in the classroom were largely teacher driven and lapsed back to the traditional chalk-and-talk expository style. The following two excerpts, the first from the researcher's field notes and the other from an interview with another teacher serve to illustrate this point.

I observed period 1 and 2 science lessons on Electrostatics. I was unable to record this particular lesson on videotapes because there was a power blackout at 8:25 AM that lasted 25 minutes.
The lesson commenced with an introduction by David that summarised the main points of the last lesson and made links to the day's lesson in the first 10 minutes. Then David wrote notes on the chalkboard for students to copy into their books. These notes briefly described what electrostatics is. The next activity David did was to demonstrate the presence of electrostatic forces. He used a 30 cm plastic rule and a piece of cloth to show that "a force" is created on the side of the plastic rule when rubbed with a piece of cloth or fur. This "force" on the side of the rule was able to pick up bits of paper and make hair on the back

of students' hands stand up when placed within close proximity. After David conducted the demonstration at the front bench, students were asked to try out the experiment in pairs using their plastic rules and bits of paper. Students seemed to show interest and were involved in the activity for 20 minutes. During the experiment students were expected to answer questions on the experiment in the handout provided by the teacher.

David facilitated student discussion on the outcome of the activity but as usual he was doing most of the talking with minimum input from students in the form of short responses to David's questions. The lesson concluded with David reinforcing the main points about electrostatics. Overall, this lesson was teacher-directed with limited student participation. (Field Notes 13.3.01)

This view is supported by comments from another teacher based on his experiences.

Students are usually polite and well behaved. They are also quiet in class and sometimes it is hard to get them to talk and express their ideas. They usually wait on the teacher to do most things for them in the classroom. For example, during practical work they want the teacher to show them how to do the actual experiments instead of them finding out how to do them and learn by their mistakes. (Teacher Interview: Albert 11.04.01, line 66)

Practical sessions implemented by David became fewer in number as the unit progressed. For example, in the first 4 weeks there were 4 double period practical sessions, in the next 4 weeks there were 2 practical sessions, and 1 practical session in the last 3 weeks. His teaching methods were forced by the situation present to become part of the formal learning culture in the classroom environment that was established over the years. For instance, during his teaching, David felt he needed to "break concepts down and explain things in more detail for them to absorb" (Teacher Interview: David 11.04.01, line 3) and he believed

students in his class learned well by absorbing science concepts and ideas in small amounts, suggesting a transmission model of learning. Yet, David tried to overcome the existing culture of teaching and learning by emphasising student centred activities in his teaching. The existing culture in the classrooms promoted a teacher driven approach and limited student centred teaching and learning consistent with the purpose being for students to pass examinations in contrast to learning for deeper understanding of the subject content.

This situation is very similar to the case in Fiji (Muralidhar, 1989; Taylor, 1997) and the Solomon Islands (Rodie, 1997), which are neighbouring Pacific Island countries similar to Papua New Guinea in many ways. In an in-depth study conducted by Muralidhar (1989), in which he documented his observations of how the Fiji Basic Science course was taught by classroom teachers, he described how students were given little opportunity to conduct practical activities. Teacher-centred and directed teaching and learning were the predominant form of instruction during science lessons in Fijian classrooms. In the Solomon Islands, Rodie (1997) reported on his findings of a study he conducted on Form 4 students' attitudes and perceptions about science and science teaching. He found students preferred science teaching and learning where there were more practical sessions over note taking from the chalkboard and listening to what their teachers had to say. These Form 4 students in the Solomons saw the aim of studying science as being the sole purpose of getting good grades for further studies or securing better employment opportunities.

David maintained the view that his task as a teacher was to ensure that his students understood the science concepts he taught in class. As he stated below, he was concerned that students had difficulty with grasping abstract science concepts.

> It's not like other topics where things are concrete …like ecology
> where students study the environment and animals that exist in practice.
> Electricity is a very abstract topic to teach. Students tend to have

problems with abstract ideas. So at times I need to break concepts down and explain things in more detail for them to understand. (Teacher Interview: David 11.04.01, line 3)

David also admitted that timetabling and lack of science equipment affected his practical lessons.

> **Researcher**: The teachers' guide for Unit 9.2 (on Electricity) recommends six weeks of teaching but in reality it takes more time than that. Do you think that is because of the classroom size or are there other factors that make the teaching of the unit longer?
>
> **David**: I can say there are two factors. The first is with the general timetable of the school which allocates only one double period for a class in the beginning of the week for practicals. The next factor I see is the materials. We don't have enough equipment in the school to go around to all groups, like the apparatus for doing electric circuits such as voltmeters, and ammeters.
>
> **Researcher**: Is this a common problem with the other Grade 9 teachers teaching the unit?
>
> **David**: Yes, they are also facing the same problem. (Teacher Interview III: David, 11.04.01, line 4)

When asked why the unit on electricity took longer than the prescribed six weeks by NDOE to teach, David felt that the rate at which the unit was taught was slower than the prescribed schedule because in most cases students had difficulty with learning the concepts and principles.

According to David, the students' difficulty with understanding was the reason why it takes longer to teach Unit 9.2. Students had difficulty because of two reasons: timetabling did not allow for adequate double periods for experiments to be conducted (David believed students learn better through experiments) and laboratories lacked basic electrical equipment and materials for conducting experiments (Teacher Interview: David 11.04.01, line 4). The Unit 9.2 on Electricity (Table 4.1) had been designed by the Curriculum Branch of PNGNDOE to be taught in six weeks but for the majority of teachers it took additional time to teach. The researcher has noted previously that the program for the unit drawn up by the Head of Science (Table 4.2) allowed eleven weeks to teach the Unit 9.2.

The researcher's field notes also indicated that the pace at which the lessons were taught appeared slower than he would have contended as the normal pace, and seemed to drag on.

> On most occasions students were not pushed to think and work independently. When students were asked to solve problems they waited for the teacher to provide the answers and then they wrote them down in their notes.
> The pace at which the lesson was taught was slow, especially when some of the key terms covered were revision for students who had first learned about electricity at community school at Grade 6 and 7. (Field Notes: 6.03.01)

Students' interviews also revealed that time was unnecessarily spent on aspects of the unit previously covered by them in their earlier studies at community school.

> **Allison**: I was talking about resistance, the meaning of resistance.

> **Researcher**: Was that the first time for you to study resistance?

> **Allison**: No

Researcher: So you have been taught resistance before? Probably in Grade…

Allison: Grade 7. (Student Interview: Allison 01.04.01, line 11)

Other students also remarked on instances where they believed the rate at which new sections of Unit 9.2 on Electricity were taught were slow. This resulted in content becoming less challenging.

George: Most of the exercises Mr. Mark (David) gives to us are easy.

Researcher: Easy?

George: Yes

Researcher: Why do you say is easy?

George: Because……….its not hard to do.

Researcher: You went to North Side Primary for grades 7 and 8   or were you
                here?

George: Yes, here

Researcher: So you did grades 7 and 8 here?

George: Yes

Researcher: So what topics (in electricity) did you cover?

George: Electricity…circuits and all those things

Researcher: So what you are learning now is all revision?

George: Yes. (Student Interview: George 01.04.01, line 4)

Some of these students believed that they would be better off learning more advanced topics yet the teacher perceived they were struggling with concepts and diagnostic test instrument results (in Section 4.4.5) showed also considerable alternative conceptions. David aptly summarised the teaching and learning process in the classroom environment observed as, "…Teachers tend to take the whole time to teach them. Students only observe." (Teacher Interview: David 11.04.01, line 54)

The overall situation in which David's teaching and learning approach can be best illustrated is based on the structure of the Reformed Teaching Observation Protocol (Sawada, Piburn, Judson, Turley, Falconer, Benford & Bloom; 2002) developed to measure reform practices in science and mathematics classrooms. Sawada et al. (2002) include the teaching and learning movement away from the traditional didactic practice toward constructivism as their definition of reform. They describe the Reformed Teaching Observation Protocol as a 25-item classroom observation protocol which is standards based, inquiry oriented, and student centered. This protocol has high levels of interrater reliability as well as high internal consistency, as estimated by Cronbach's alpha.

Table 4.3 presents the approach to teaching and learning characteristics of David as evaluated by the researcher and derived from other evidence in data sources. It was based on information from interviews with David, the HOD of Lower Science at the school, and extensive observations of David's practice during the study by the researcher under the factor structure of the Reformed Teaching Observation Protocol (Sawada et al., 2002, p. 253). Observations of high frequency (example "often") in the items in this protocol are connected with a constructivist approach to teaching (Sawada et al., 2002).

Table 4.3

David's Observed Teaching Approach in the Classroom

PRACTICES OBSERVED IN DAVID'S CLASS	OFTEN	SELDOM	NEVER
I. Lesson Design and Implementation			
1. The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.			X
2. The lesson was structured to engage students as members of a learning community.		X	
3. In this lesson, student exploration preceded formal presentation.			X
4. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.			X
5. The focus and direction of the lesson was often determined by ideas originating with students.			X
II. Content			
Propositional knowledge			
6. The lesson involved fundamental concepts of the subject.	X		
7. The lesson promoted strongly coherent conceptual understanding.		X	
8. The teacher had a solid grasp of the subject matter content inherent in the lesson.	X		
9. Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.			X
10. Connections with other content disciplines and/or real world phenomena were explored and valued.			X
Procedural knowledge			
11. Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.			X
12. Students made predictions, estimations and/or			X

hypotheses and devised means for testing them.

Item			
13. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.			X
14. Students were reflective about their learning.			X
15. Intellectual rigour, constructive criticism, and challenging of ideas were valued.			X

III. Classroom Culture

Communicative Interactions

Item			
16. Students were involved in the communication of their ideas to others using a variety of means and media.			X
17. The teacher's questions triggered divergent modes of thinking.			X
18. There was a high proportion of student talk and a significant amount of it occurred between and among students.		X	
19. Student questions and comments often determined the focus and direction of classroom discourse.			X
20. There was a climate of respect for what others had to say.		X	

Student/Teacher Relationships

Item			
21. Active participation of students was encouraged and valued.	X		
22. Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.		X	
23. In general the teacher was patient with students.	X		
24. The teacher acted as a resource person, working to support and enhance student investigations.		X	
25. The metaphor "teacher as listener" was very characteristic of this classroom.		X	

A number of key observations characteristic of David's teaching highlighted in the observation protocol in Table 4.3 are discussed to illustrate David's approach to teaching. In relation to lesson design and implementation

from a constructivist perspective (Table 4.3), low frequency in the items were shown. David was not observed to relate to students' prior knowledge and preconceptions in his lessons due to time constraints he faced on most occasions in his teaching. For example, in the vignettes discussed earlier in Section 4.2.4 there was an absence in instances where David related to the prior knowledge of the fundamental electricity concepts taught earlier to students at Grade 7 in community schools. David was not observed to guide students along to explore or discover important concepts before formally presenting the concepts (Observation Protocol, Item 3). Again this may be attributed to time constraints and the limited science apparatus available at the school.

As far as the content of the subject taught went from a constructivist perspective, there were some levels of frequency shown (Table 4.3). David always displayed a solid grasp of the subject matter content for example (Observation Protocol, Item 8). When it came to observation of procedural knowledge the items showed low frequency.

The final portion of items on the protocol relating to classroom culture considered communicative interactions and student/teacher relationships. Items in communicative interactions showed slight increase in frequency but were still low. On the other hand, student/teacher relationships items registered a relatively high frequency, showing that this section of the protocol was the most consistent section with constructivist approach to teaching. For instance, in general David always encouraged and valued active participation of students in class, even though students' responses were limited. He was also patient with students and spent a lot of time in explanations on a one to one basis with students (Observation Protocol, Items 21 and 23).

In the next section, whole class data from the 43 students are presented to describe the students' views of science-technology-society, perceptions of their

classroom learning environment, interpersonal relationships in the classroom, and subject content knowledge of electricity prior to instruction.

4.4 Whole class data

4.4.1 Introduction

This section presents the results obtained for the whole class of 43 students from four sets of instruments employed as part of a multiple data gathering strategy adopted for the study. The instruments used were based on a) Views on Science-Technology-Society (VOSTS) questionnaire, b) My Classroom Inventory (MCI), c) Questionnaire on Teacher Interaction (QTI), and d) a Two-Tier Diagnostic Test on Electricity. These instruments were adapted for the Papua New Guinea context as discussed in detail in Section 3.7.4. Data from these instruments were useful largely for descriptive purposes for presenting the students' views about science-technology-society, students' perceptions of their classroom environment, interpersonal relationships with their teacher and prior knowledge of content related to elementary concepts of electricity.

4.4.2 Students' VOSTS results

The researcher administered the adapted VOSTS instrument to all students in the class. Results of students' views of science-technology-society are presented from two perspectives. First, responses to the VOSTS items are analysed to reveal both majority views and the range of responses received from rural, town and city students. Secondly, rural, town and city students' views of science are categorised as either one of naïve/crude, transitional or canonical as mentioned earlier in Section 3.7.4.1. This was done in order to provide an indication of the depth of students' experience in their science-technology-society views, within the context of the students' backgrounds of rural, town and city upbringing.

4.4.2.1 Students' responses to VOSTS items

Responses to VOSTS items by students are organised in two ways to highlight key points of the tendencies of student's views. Accordingly, the first analysis shows an overall classification of views of science held by the three grouping of origin of rural, town, and city students as well as general student views in this class of the 43 students. Of the 43 students in class, 28 % were of rural background, 46 % of town background and 26 % of city background. The overall view of science held by rural, town and city students in the class is presented in Table 4.4.

Table 4.4

Classification of Overall Views of Science-Technology-Society Held by Year 9 Students in the Class (N = 43)

Science views	Percent rural students (*n = 12*)	Percent town students (*n = 20*)	Percent city students (*n = 11*)	Total students (*n = 43*)
Crude/naïve	50 %	70 %	45.5 %	58 %
	(6)	(14)	(5)	(25)
Transitional	50 %	20 %	9 %	26 %
	(6)	(4)	(1)	(11)
Canonical	0 %	10 %	45.5 %	16 %
	(0)	(2)	(5)	(7)
Total	100 %	100 %	100 %	100 %
	(12)	(20)	(11)	(43)

The second column in Table 4.4 shows that out of 12 students with rural backgrounds in the class, 50 % of these students held crude/naïve views while the other 50 % held transitional views about science. None of the students with rural backgrounds expressed canonical views about science. On the other hand, out of 20 students with town background, 70 % of them held crude/naïve views while 30

% held transitional and canonical views (column 3, Table 4.4). The remaining 11 students were city students of which 45 % held crude/naïve views while more than 50 % held transitional and canonical views. In general, more city students held canonical views about science than rural or town students. Further, higher proportions of city, town, and rural students displayed crude/naïve views than canonical views which indicated that most students had a poor understanding of the nature of science in the class.

The next analysis of results in the form of a frequency response graph is concerned with the responses to each of the adapted VOSTS individual items by students under the three classifications of origin (i.e., rural, town and city backgrounds). The objective of this second analysis is to compare the nature and the trend in students' views about science for each individual adapted VOSTS item. Figure 4.1 shows Item 1 of the adapted VOSTS questionnaire which focuses on the definition of science.

_____

Item 1

Defining science is difficult because science is complex and does many things. But mainly science is:

(Your position)

a) a study of fields such as biology, chemistry and physics.

b) a body of knowledge, such as principles, laws and theories which explain the world around us (matter, energy and life).

c) exploring the unknown and discovering new things about the world and universe and how they work.

d) carrying out experiments to solve problems of interest about the world around us.

e) inventing or designing things (for example, artificial hearts, computers, space vehicles).

f) findings and using knowledge to make the world a better place to live in (for example, curing diseases, solving pollution problems and improving agriculture).

g) an organisation of people called scientists who have ideas and techniques for discovering new knowledge.

h) I do not understand.

i) I do not know enough about this subject to make a choice.

j) none of these choices fits my basic viewpoint.

Figure 4.1. Item 1 of the adapted VOSTS questionnaire

Item 1 of the adapted VOSTS questionnaire referred to students' perceptions of what science was. The responses to Item 1 by students in the class are reported in Figure 4.2. Based on the definitions for categories of science views of crude/naïve, transitional, and canonical earlier discussed in Section 3.7.3.1; choices f) and g) were considered to be canonical views, choices c), d) and e) were transitional views, choices a) and b) were crude/naïve, whilst h), i) and j) were regarded as other responses.
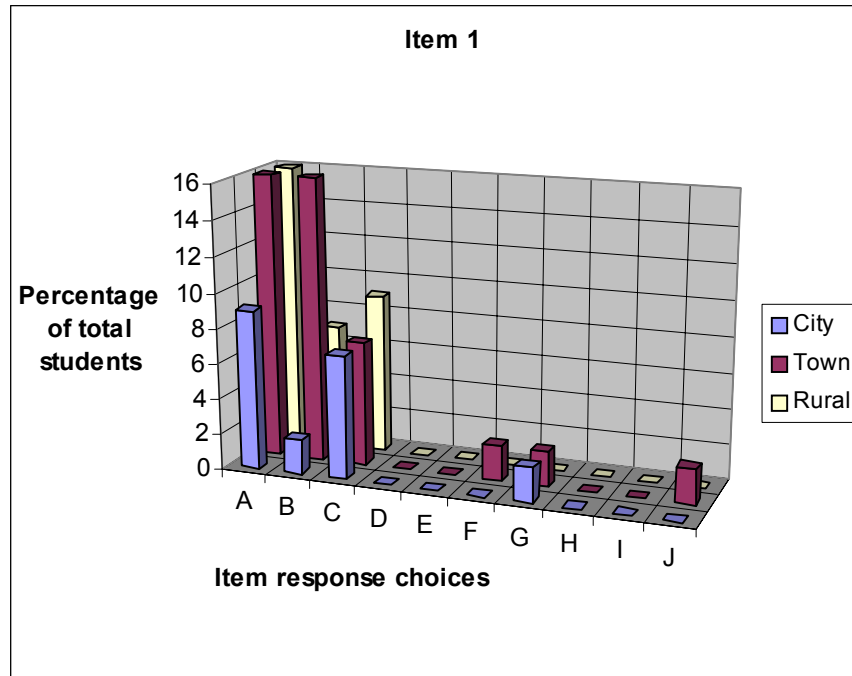
Figure 4.2. Item 1 and responses to Item 1 of city, town and rural students

As illustrated in Figure 4.2, the idea that science is a study of fields such as biology, chemistry and physics (Choice a) was the most popular with 50 % of rural students, 35 % of town students and more than 40 % of city students selecting that response choice which was identified as a crude/naïve view. Town students were largely split between the above view and Choice b, the idea that science is a body of knowledge, such as principles, laws and theories which explain the world around us (matter, energy, and life). The majority of city students thought science was a study of fields such as biology, chemistry and physics (Choice a) and science is exploring the unknown and discovering new things about the world and universe and how they work (Choice c).

Thus, for over 40 % of the students in the class, their description of science was linked with their perceptions of the science strands of biology, chemistry and physics taught at school, which was regarded as a crude/naïve view of science. Twenty five percent of students in the class described science as a body of knowledge such as principles, laws and theories which explains the world around them (crude/naïve view), and 23 % of students subscribed to the view that science is exploring the unknown and discovering new things about the world and universe and how they work (a canonical view).

Item 2

When scientists investigate, it is said that they follow the scientific method. The scientific method is:

(Your position)
a) the laboratory procedures or techniques ; often written in a book or journal, and usually by a scientist.
b) recording your results carefully.
c) controlling experimental variables carefully, leaving no room for misinterpretation.

d) getting facts, theories or hypotheses efficiently.

e) testing and retesting – proving something true or false in a valid way.

f) forming a theory then creating an experiment to prove it.

g) questioning, hypothesizing, collecting data and concluding.

h) a logical and widely accepted approach to problem solving.

i) an attitude that guides scientists in their work.

j) Considering what scientists actually do, there really is no such thing as the scientific method.

k) I do not understand.

l) I do not know enough about this subject to make a choice.

m) None of the above choices fits my basic viewpoint.

_____

Figure 4.3. Item 2 of adapted VOSTS questionnaire

This item refers to the students' perceptions of the scientific method of investigation. Choices a), b), and c) are views considered to be crude/naïve; choices d), e), and f) are transitional views; while choices g), h) and i) are canonical. Choices j), k), l) and m) are other responses (see Section 3.7.3.1).
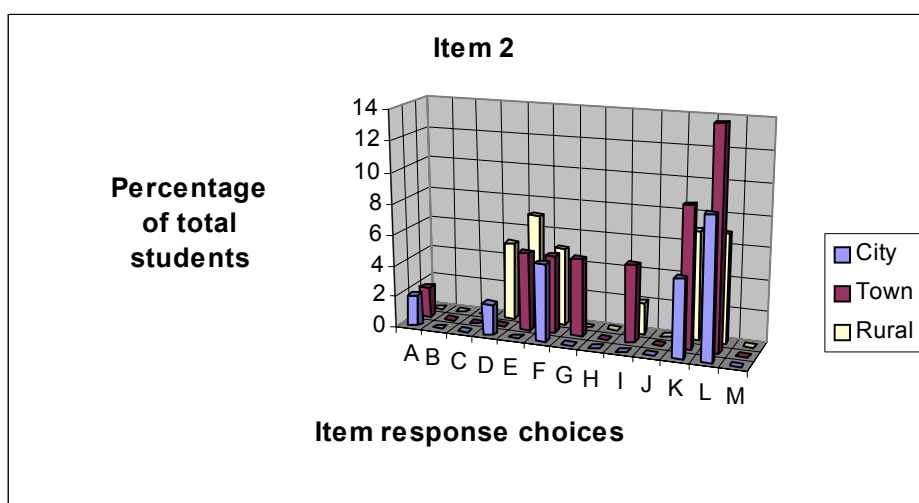
Figure 4.4. Item 2 and responses to Item 2 of city, town and rural students

For Item 2 as illustrated by Figure 4.2, all categories of students showed a spread of views with many saying they did not understand the definition or description of the scientific method of investigation (Choice k) or that they did not know enough about the subject to make a choice (Choice l). No student saw the scientific method as recording results carefully (Choice b), or controlling experimental variables carefully, leaving no room for misinterpretation (Choice c) or a logical and widely accepted approach to problem solving (Choice h).

However, all categories of students in the class agreed that a scientific method of investigation existed because none of them selected the view that denied the existence of a scientific method of investigation (Choice j). Overall, the students had difficulty in articulating a popular canonical view that defined the scientific method of investigation which referred to Choices g), h), and i) of Item 2. It seemed many students were not sure of what a scientific method of investigation was.

_____

Item 3

The more Papua New Guinea's science and technology develop, the wealthier Papua New Guinea will become.

(Your position)
Science and technology will increase Papua New Guinea's wealth;
a) because science and technology bring greater efficiency, productivity and progress.
b) because more science and technology would make Papua New Guinea less dependent on other countries. We could produce things for ourselves.
c) because Papua New Guinea could sell new ideas and technology to other countries for profit.
d) It depends on which science and technologies we invest in. Some outcomes

are risky. There may be other ways besides science and technology that create

   wealth for Papua New Guinea.

e) Science and technology decrease Papua New Guinea's wealth because it costs

   a great deal of money to develop science and technology.

f) I do not understand.

g) I do not know enough about this subject to make a choice.

h) None of these choices fits my basic viewpoint.

_____

Figure 4.5. Item 3 of adapted VOSTS questionnaire

Item 3 tests students' understanding of the relationship between the development of science and technology, and wealth creation for Papua New Guinea. Choices a), b) and e) appear crude/naïve; and choice c) is transitional whilst choice d) is canonical as discussed in Section 3.7.3.1. Item 3 responses by students are reported in Figure 4.6.
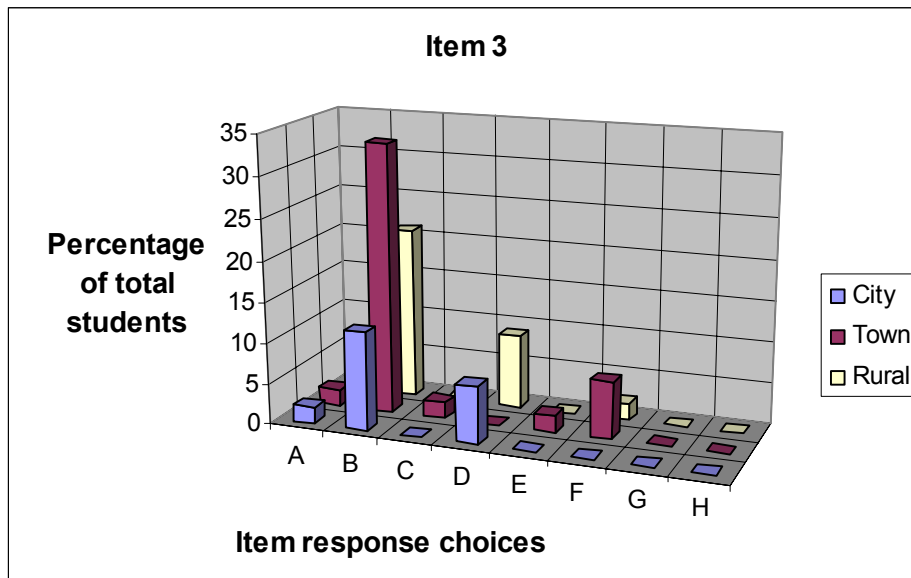
Figure 4.6. Item 3 and responses to Item 3 of city, town and rural students

One rural and three town students indicated that they did not understand the issue raised by Item 3 (Figure 4.6) as evident from responses to response choice f). On the other hand, more than 65 % of the students in the class subscribed to the crude/naïve view that science and technology will increase the wealth of Papua New Guinea because more science and technology would make Papua New Guinea less dependent on other countries. That is, Papua New Guinea could produce things for itself (choice b). Fifty five percent of city students, 70 % of town students, and 64 % of rural students held this view.

_____

Item 4

In your everyday life, knowledge of science and technology helps you personally solve practical problems (for example, getting a car out that is stuck in the mud, cooking, or personal care and hygiene when you have skin problems or sores on your body).

(Your position)

The systematic reasoning taught in science lessons (for example, hypothesizing, gathering data, being logical):

a) Helps me solve some problems in my daily life. Everyday problems are more
    easily and logically solved if treated like science problems.

b) Gives me greater knowledge and understanding of everyday problems.
    However, the problem solving techniques we learn are not directly useful in
     my daily life.

c) Ideas and facts I learn from science classes sometimes help me solve problems
    or make decisions about such things as cooking, keeping healthy, or
    explaining a wide variety of physical events.

d) The systematic reasoning and the ideas and facts I learn from science classes
     help me a lot. They help me solve certain problems and understand a wide
     variety of physical events (for example, thunder or rainbows).

e) What I learn from science class generally does not help me solve practical
     problems; but it does help me notice, relate to, and understand the world
     around me.

What I learn from science class does not relate to my everyday life:

f) Biology, chemistry and physics are not practical for me. They emphasis theoretical and technical details that have little to do with my day-to-day world.

g) My problems are solved by past experience or by knowledge unrelated to science and technology.

h) I do not understand.

i) I do not know enough about this subject to make a choice.

j) None of these choices fits my basic viewpoint.

_____

Figure 4.7. Item 4 of adapted VOSTS questionnaire

Item 4 refers to the relevance of science and technology to solving practical problems in everyday life; for example, getting a car out that is stuck in the mud, cooking, or personal care and hygiene when skin problems or sores develop on a person's body. Choices a), b), f), and g) are considered to be crude/naïve views, and choices c) and d) are transitional. Choice e) is canonical.
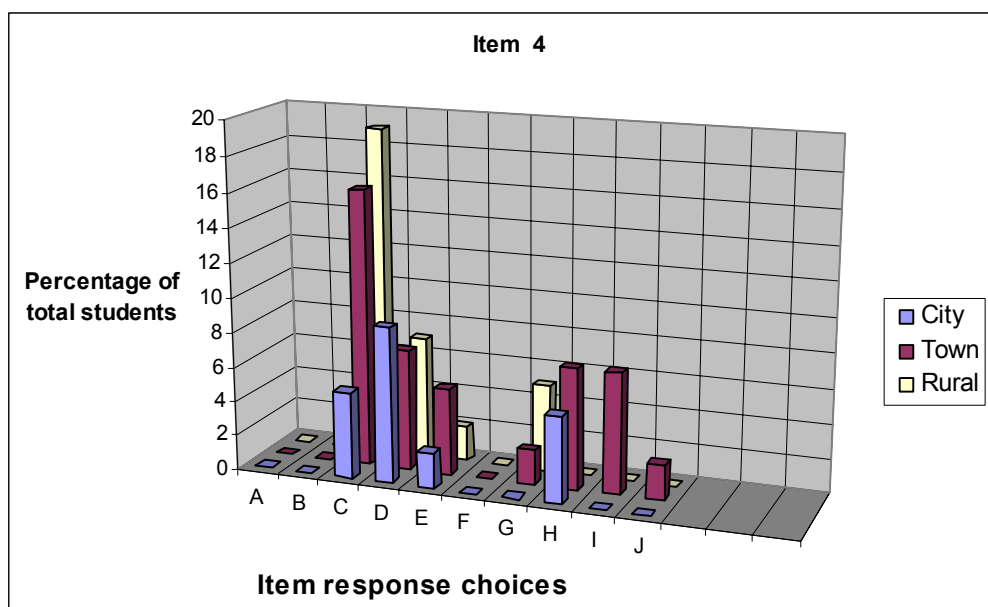
Figure 4.8. Item 4 and responses to Item 4 of city, town and rural students

For Item 4 (Figure 4.8) most town and rural students and 40 % of students in the class responded with the view that ideas and facts they learn from science classes sometimes helps them solve problems or make decisions about such things as cooking, keeping healthy, or explaining a wide variety of physical events (Choice c). This view was considered to be a transitional one. More city students than rural or town students agreed with Choice d (transitional view), that the systematic reasoning and the ideas and facts they learn from science classes helps them solve certain problems and understand a wide variety of physical events such as having a better understanding of thunder or rainbows.

It was interesting to note that 7 % of students in the class (one town and two rural) believed that what they learned from science classes did not relate to their everyday life. They had the notion that their problems were solved by past experience or by knowledge not related in any way to science and technology (choice g).

Item 5

Science and technology can help people make some moral decisions (that is, one group of people deciding how to act towards another group)

(Your position)
Science and technology can help you make some moral decisions:
a) by making you more informed about people and the world around you. This background information can help you cope with the moral aspects of life.
b) By providing background information, but moral decisions must be made by individuals.
c) Because science includes areas like psychology which study the human mind and emotions.

Science and technology cannot help you make a moral decision:

d) Because science and technology have nothing to do with moral decisions. Science and technology only discover, explain and invent things. What people do with the results is not the scientist's concern.

e) Because moral decisions are made solely on the basis of an individual's values and beliefs.

f) Because if moral decisions are based on scientific information, the decisions often lead to racism, by assuming that one group of people is better than another group.

g) I do not understand.

h) I do not know enough about this subject to make a choice.

i) None of these choices fits my basic viewpoint.

_____

Figure 4.9. Item 5 of adapted VOSTS questionnaire

Students' views on whether science and technology can help people make moral decisions or not is tested in Item 5. Choices a), b), and f) are crude/naïve and choices c) and d) are transitional. Choice e) is canonical. The Item 5 responses by students are reported in Figure 4.10.
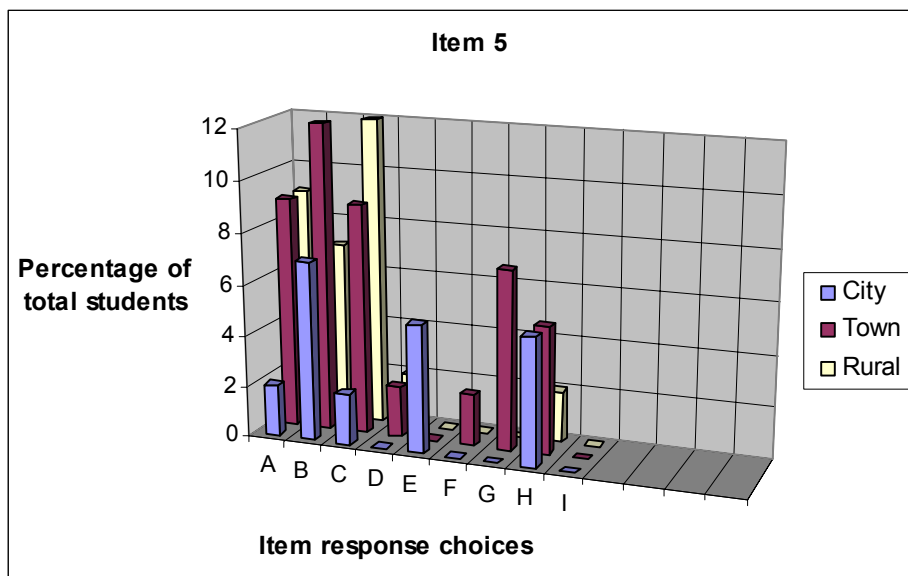
Figure 4.10. Item 5 and responses to Item 5 of city, town and rural students

Interestingly, for Item 5 the majority of the students (70 %) believed science and technology could help people make some moral decisions, as shown by the selection of Choices a), b), and c) in Figure 4.10. A small 11% of the students refused to accept that science and technology could help people make moral decisions (Choices d, e, f). Nineteen percent of the students admitted lack of understanding, or did not know enough about the subject to make an informed choice, and so selected choices g, and h respectively.

Item 6

Science and technology offer a great deal of help in resolving such social problems as poverty, crime and unemployment.

(Your position)
   a) Science and technology can certainly help resolve these problems. The problems could use new ideas from science and new inventions from technology.
   b) Science and technology can resolve some social problems but not others.
   c) Science and technology solve many social problems, but science and technology also cause many of these problems.
   d) It's not a question of science and technology helping, but rather it's a question of people using science and technology wisely.
   e) It's hard to see how science and technology could help very much in resolving these social problems. Social problems concern human nature; these problems have little to do with science and technology.
   f) Science and technology only make social problems worse. It's the price we pay for advances in science and technology.
   g) I do not understand.
   h) I do not know enough about this subject to make a choice.
   i) None of these choices fits my basic viewpoint.

Figure 4.11. Item 6 of adapted VOSTS questionnaire

Item 6 tested students' perceptions of whether science and technology can help to resolve social problems such as poverty, crime and unemployment. Choice f) is considered to be canonical. Choices c), d) and e) are transitional while choices a) and b) are crude/naïve as discussed in Section 3.7.3.1.
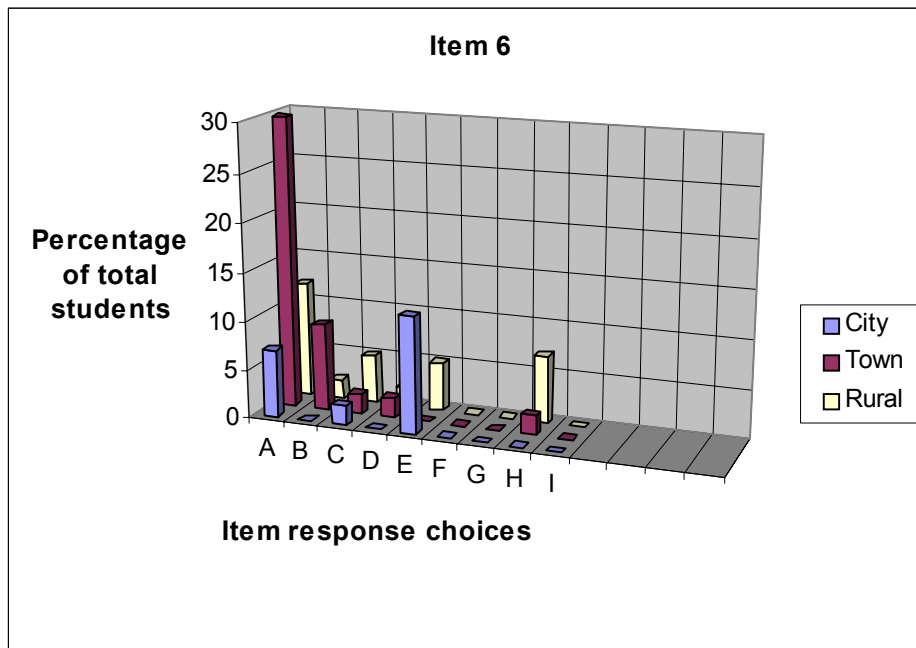
Figure 4.12. Item 6 and responses to Item 6 of city, town and rural students

The results in Figure 4.6 suggest that City students' views were split over two opposing views of choices a) and e). The city students believed science and technology could certainly help resolve social problems. The problems could use new ideas from science and new inventions from technology (Choice a). The opposing view also held by city students was that they disagreed that science and technology could help very much in resolving these social problems. Social problems concern human nature and these problems have little to do with science and technology (Choice e). The majority of the town students selected choice a) which was also the popular view expressed by 49 % of the students in the class.

Item 7

Some cultures have a particular viewpoint on nature and man. Scientists and scientific research are affected by the religious or ethical views of the culture where the work is done.

(Your Position)

Religious or ethical views DO influence scientific research:

a) because some cultures want specific research done for the benefit of that culture.

b) because scientists may unconsciously choose research that would support their culture's views.

c) because most scientists will not do research which goes against upbringing or their beliefs.

d) because everyone is different in the way they react to their culture. It is this individual differences in scientists that influence the type of research done.

e) because powerful groups representing certain religious, political or cultural beliefs will support certain research projects, or will give money to prevent certain research from occurring.

Religious or ethical views do NOT influence scientific research:

f) because research continues in spite of clashes between scientists and certain religious or cultural groups (for example, clashes over evolution and creation).

g) Because scientists will research topic which are of importance to science and scientists, regardless of cultural or ethical views.

h) I do not understand.

i) I do not know enough about this subject to make a choice.

j) None of these choices fits my basic viewpoint.

Figure 4.13. Item 7 of adapted VOSTS questionnaire

Item 7 considered the religious or ethical views of the culture in which scientific research was conducted. The question asked in Item 7 was whether religious or ethical views do influence scientific research. Choice e) was considered to be a canonical view. Choices c), d), and g) were transitional while choices a), b), and f) were crude/naïve as earlier discussed in Section 3.7.3.1.
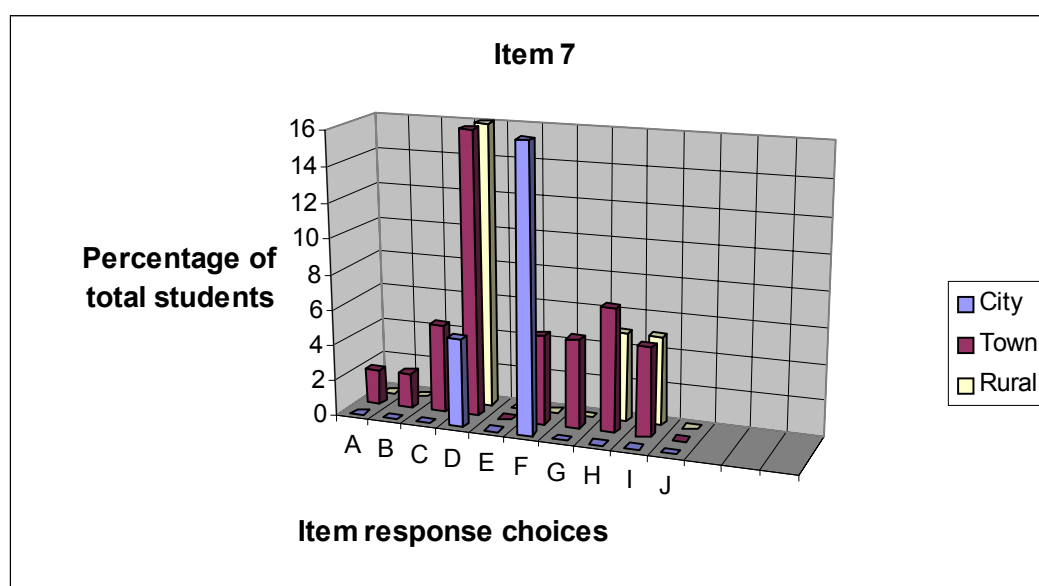
Figure 4.14. Item 7 and responses to Item 7 of city, town and rural students

Under 40 % of rural students selected Choices h) and i), suggesting that they had not understood the issue well enough to select a choice. The rest of the rural students subscribed to the view that religious or ethical views do influence scientific research because everyone was different in the way they react to their culture. And, it is these individual differences in scientists that influence the type of research done (Choice d). The majority of town students concurred with the view expressed by rural students who selected Choice d. However, contrary to this, more than 77 % of city students disagreed and believed religious or ethical views do not influence scientific research because research continues in spite of clashes between scientists and certain religious or cultural groups; for example, clashes over evolution and creation theories (Choice f).

_____

Item 8

Science rests on the assumption that the natural world can not be altered by a supernatural being (for example, a God).

(Your position)

Scientists assume that a supernatural being will NOT alter the natural world:

   a) because the supernatural is beyond scientific proof. Other views, outside the realms of science, may assume that a supernatural being can alter the natural world.

   b) Because if a supernatural being did exist, scientific facts could change in the wink of an eye. But scientists repeatedly get consistent results.

   c) It depends. What scientists assume about a supernatural being is up to the individual scientist.

   d) Anything is possible. Science does not know everything about nature. Therefore, science must be open-minded to the possibility that a supernatural being could alter the natural world.

   e) Science can investigate the supernatural and can possibly explain it. Therefore, science can assume the existence of supernatural beings.

   f) I do not understand.

   g) I do not know enough about the topic to make a choice.

   h) None of these choices fits my basic viewpoint.

_____

Figure 4.15. Item 8 of adapted VOSTS questionnaire

Item 8, the last item on the adapted VOSTS questionnaire used in the study referred to the fundamental scientific assumption that a supernatural being will NOT alter the natural world. Choice e) was considered to be a canonical view

while choices c) and d) were transitional, and choices a) and b) were crude/naïve as explained in Section 3.7.3.1.
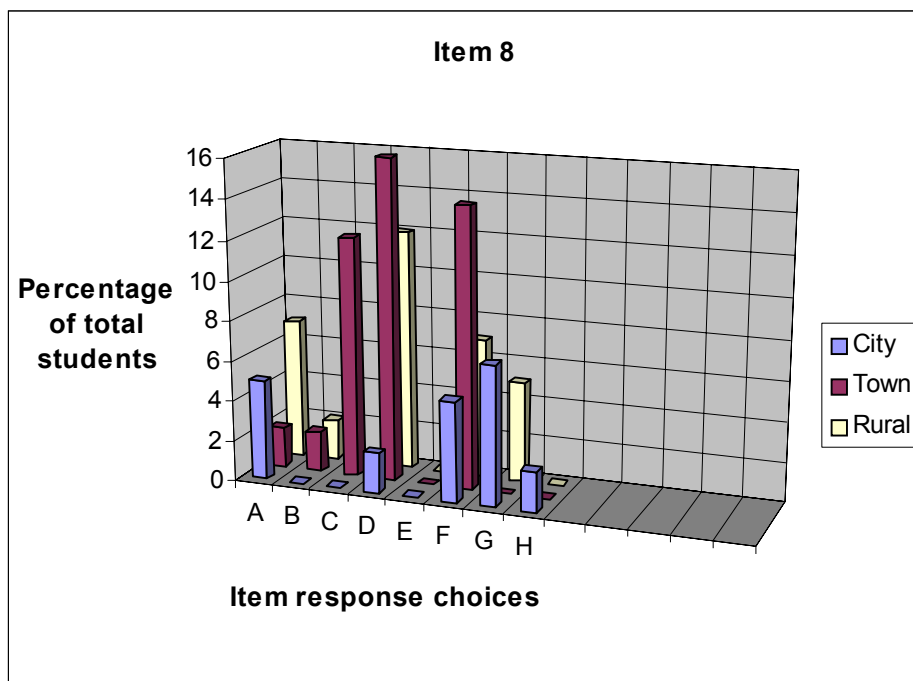
Figure 4.16. Item 8 and responses to Item 8 of city, town and rural students

Students responded to Item 8 with a greater spread of views than was displayed in the responses from the rest of the items of the adapted VOSTS questionnaire. Forty percent of the total students in class abstained from expressing a view by giving other responses (choices g, h and i). The popular view expressed by the class was choice d), a transitional view: Anything is possible. Science does not know everything about nature. Therefore, science must be open-minded to the possibility that a supernatural being could alter the natural world. None of the students selected the canonical view (choice e).

Students' responses to the eight adapted VOSTS items provided a valuable insight into students' conceptions about science and its impact on technology and society. Overall, the views expressed by students in the class were predominantly

crude/naïve as reported in Table 4.4. For instance, students' views on their understanding of science were predominantly linked to their perception of the science strands of biology, chemistry and physics taught at school. Students did not have a clear understanding of the scientific method of investigation as shown by their responses to Item 2. Many students believed science and technology would increase wealth because increase in science and technology would enable Papua New Guinea to be less dependent on other countries (Item 3). In relation to the relevance of science and technology to solve practical everyday problems, there were mixed responses (Item 4). When it came to whether science and technology would help people make moral decisions over 70 % agreed. Rural students were restricted to crude/naïve and transitional views. Town and city students expressed all views with city students expressing the most canonical views about science.

4.4.2.2 Views on science-technology-society expressed by students

Table 4.4 in Section 4.4.2.1 presents data that displayed students' expressed views of science-technology-society as predominantly canonical, transitional or crude/naive. Depending on where students spent the most part of their early childhood and primary school years, they were classified as having either a rural, town or city background as discussed earlier in Section 3.7.3.1. Not surprisingly, Table 4.4 shows that the predominant views of science expressed by students with town and city backgrounds differed from their counterparts with rural backgrounds.

Over half of the total students in the class expressed views of science considered to be crude/naïve in the test while about one quarter of the students in the class expressed transitional views and a smaller number indicated canonical views. No student from a rural background was categorised as expressing a predominantly canonical view of science. For students with city backgrounds the views they expressed were one of either canonical or crude/naïve, with only one

student having expressed transitional views. Students with a town background predominantly held crude/naïve views, with only 30 % having transitional or canonical views. For rural and town students the number of students displaying the three types of views form a pattern which appeared consistent with the researcher's experience in teaching in Papua New Guinea. Based on the researcher's observation over time, students have difficulty generally with understanding and expressing canonical views of science taught in schools. Students from rural backgrounds were usually less able in this respect than town and city students.

In brief, the trend in the data was for a decreasing number of rural and town students expressing crude/naïve to transitional to canonical views. For this class, city students had results polarised between crude/naïve and canonical views of science. On the other hand, transitional views decreased in students' from rural to town to city, whilst the reverse occurred for canonical views. Further, canonical views of science increased for rural to town to city students.

4.4.3 Students' actual and preferred classroom environment

Due to the focus of the study, the understanding of the learning environment in which students' teaching and learning of abstract science concepts and principles occurred, comprised a significant component of this research. In order to provide information about subtle but important aspects of classroom life as well as obtaining feedback from students about psychosocial aspects and teacher interaction occurring in the learning environment of the classroom, the adapted versions of My Classroom Inventory (MCI) and the Questionnaire on Teacher Interaction (QTI) were administered as discussed in Section 3.7.4.2 and Section 3.7.4.3 respectively. The MCI results are discussed and students' perceptions of their actual classroom environment are compared against the students' perceptions of preferred classroom environment. Results from the QTI will be outlined in Section 4.4.4.

Table 4.5 shows the number of items in each scale, class means, standard deviations and alpha reliability coefficients for each scale of the actual and preferred classroom learning environment forms that were employed in this study. As mentioned earlier in Section 3.7.4.2, the MCI questionnaire used in the study was based on the shorter version (Fraser, 1993) measuring five different dimensions of classroom environment with 25 individual items in total. As a result each dimension had 5 items arranged in a cyclic order and in blocks of five to enable ready hand scoring. However, even though the instrument was pilot tested to eliminate misunderstandings by students of items, certain items for both actual and preferred scales did not perform as well as expected, resulting in low values of alpha reliability for the affected scales. Consequently, poorly performing items in some scales were omitted resulting in improved alpha reliability for these scales. On scale of satisfaction, for example one item was omitted, while the scales of competitiveness, and difficulty omitted two each as shown in Table 4.5. The same items in both the preferred and the actual scale were omitted. The final alpha reliability values recorded for each scale were reasonable, ranging from .50 to .79; although results from the scales with lower reliabilities should be interpreted with caution. The scales of actual satisfaction, actual difficulty and actual cohesiveness recorded low alpha reliability values of .53, .50 and .53 respectively, and a plausible suggestion for this is attributed to some students' perceptions of a formal learning environment being at odds with their traditional informal learning environment based on their indigenous culture leading to differing interpretations of items. In the students' traditional informal learning environment in Pacific cultures, the individualised nature of much classroom interactions often contrasts with group values such as humility, cohesiveness, and the collective interest of the group (McLaughlin, 1995; Taylor, 1997). The MCI actual and preferred questionnaires are reproduced in Appendix B and should be consulted in conjunction with Table 4.5. The MCI was administered to all students in the class starting with the actual form. The preferred form was administered to the students a day later.

Table 4.5

Class Performance on the MCI

Scale	Number of items	Actual			Preferred			
		Mean	SD	Alpha reliability	Number of items	Mean	SD	Alpha reliability
Satisfaction	4	2.29	1.35	.53	4	2.40	1.36	.61
Friction	5	1.72	1.63	.65	5	1.42	1.06	.79
Competitiveness	3	2.90	0.82	.72	3	2.44	1.63	.68
Difficulty	3	1.70	1.02	.50	3	1.47	1.15	.66
Cohesiveness	4	1.91	1.85	.53	4	2.71	1.91	.64

Note: Item response scale from 1 to 3 (1- never, 3- always)

The class mean score for Satisfaction is relatively high for the preferred classroom environment of students, suggesting students' preference for enjoyment in their schoolwork, happiness, having fun and liking their class. Similarly, the class mean score for the preferred Cohesiveness scale is also high suggesting students' desire for a high level of friendliness among students in the class.

Overall, the actual classroom environment scales respective mean scores, show that students in the class perceived somewhat average Satisfaction, low Friction, high Competitiveness, low Difficulty and low Cohesiveness in the existing classroom environment. On the other hand, the students' preferred classroom environment respective scale mean scores indicate students' desire for slightly higher levels of Satisfaction and substantially higher levels of Cohesiveness. Less desirable were Friction, Competitiveness, and Difficulty dimensions in the classroom, each of which were lower on preferred scales.

Students' results from the MCI instrument were interesting in terms of the students' understanding and conceptualisation of scales used. It seemed the students' cultural and worldviews may have influenced their interpretations of some of the dimensions integral to the MCI instrument. Some students'

interpretations of scales may have differed to the interpretation of a student from a developed Western nation. For instance, cohesiveness would be highly desirable and have a different meaning to the students than say the competitiveness scale because in the students' traditional culture the collective community interests take priority over individual interests (Pauka et al., 2000). This will be further discussed in Chapter 5.

4.4.4 Interpersonal relationship in the classroom environment

The teacher's interpersonal relationship with students in the classroom environment was measured using a version of the QTI (Wubbels, 1993; Wubbels et al., 1993) adapted for the Papua New Guinea context, as discussed earlier in Section 3.7.4.3. The QTI can be used to map students' and teachers' perceptions using a model for interpersonal teacher behaviour. In this model, the teacher behaviour has a Proximity Dimension (Cooperation, C to Opposition, O) and an Influence Dimension (Dominance, D to Submission, S). These dimensions can be represented on a coordinate system divided into eight equal sections, as presented in Figure 4.9. According to Wubbels et al. (1993) every instance of interpersonal teacher behaviour can be placed within this system of axes. The eight sectors corresponding to the eight scales of the QTI are labeled DC, CD, CS, SC, SO, OS, OD, and DO; according to their position in the coordinate system. For instance, the two sectors DC and CD are both characterised by Dominance and Cooperation. In the DC sector, the Dominance aspect prevails over the Cooperation aspect, whereas the adjacent sector CD includes behaviours of a more cooperative and less dominant character. Similarly, the Proximity Dimension (Cooperation to Opposition) and Influence Dimension (Dominance to Submission) can be represented on the coordinate system with different biases to cater for a wide range of interpersonal teacher behaviour (Figure 4.9).

The adapted QTI was administered by David to the whole class of 43 students, as well as completing one himself to portray his perceptions of himself as the class teacher. Table 4.6 displays mean scores for the eight QTI scales of students' perceptions and David's self perceptions of interpersonal behaviour in

the classroom for comparative analysis. The fourth column presents David's self rated mean scores for each of the eight QTI scales, while the rest of the data in Table 4.6 refer to the class performance on the adapted QTI questionnaire used.

Table 4.6

Class Performance and David's Self Perception on QTI

		Students		Teacher	
Scale	Number of items	Class mean	Alpha reliability	David's self rated mean	Std. dev.
DC Leadership	7	3.42	.75	3.56	2.45
CD Helpful / friendly	8	3.31	.75	3.44	2.99
CS Understanding	8	3.29	.64	3.38	2.61
SC Student Responsibility	8	1.85	.67	2.47	1.44
SO Uncertain	7	0.71	.54	0.62	0.28
OS Dissatisfied	9	0.89	.72	0.46	0.44
OD Admonishing	8	0.97	.56	0.41	0.74
DO Strict	9	2.11	.54	2.56	1.21

Note: Item response scale from 0 to 4.

As mentioned earlier in Section 3.7.4.3, the proximity and influence dimensions of the teacher's behaviour are able to describe the teacher's interactions in class. A high mean score for a scale suggests students perceive increased behaviour of a particular nature by the teacher as covered by the scale. And a low mean score suggests less behaviour of a particular nature by the teacher.

There were many similarities noted when comparing the alpha reliability values in this study with those from studies conducted in three other countries; USA, Australia and the Netherlands (Wubbels, 1993, p. 71) presented in Table 4.7.

Table 4.7

Alpha Reliability for QTI Scales for Students in Three Countries and Papua New Guinea

QTI Scale	Alpha Reliability			
	USA	Australia	The Netherlands	PNG
DC Leadership	.80	.83	.83	.75
CD Helpful/friendly	.88	.85	.90	.75
CS Understanding	.88	.82	.90	.64
SC Student responsibility/freedom	.76	.68	.74	.67
SO Uncertain	.79	.78	.79	.54
OS Dissatisfied	.83	.78	.86	.72
OD Admonishing	.84	.80	.81	.56
DO Strict	.80	.72	.78	.54
Number of Students	1 606	792	1 105	43

The lowest alpha reliability values in the current study were scored for SO (Uncertain) and DO (Strict). In the studies conducted in the three countries presented in Table 4.7 these scales also registered among the lowest reliabilities. On the other hand, the highest alpha reliability values were recorded for the scales of DC (Leadership), CD (Helpful/friendly) and CS (Understanding) in the results of the studies in all four countries, including the results of this study in Table 4.6. On average, students in this class considered their teacher to be relatively high on Leadership, Helpful/Friendly and Understanding behaviour. Correspondingly, there were relatively low scale means on Uncertain, Dissatisfied and Admonishing behaviours. Consistencies with this overall class profile of David's classroom behaviour were observed by the researcher and supported by student comment.

> David was moving from group to group attending to students' queries
> which were mostly about how to connect circuits correctly. David

seemed to display enthusiasm and genuine interest in his students'
work. (Field Notes: 9.03.01)

Dobson: I like the teaching by Mr. Mark

Researcher: Why is that?

Dobson: Because he is helpful and understands us. He is able to
explain things clearly to us when we do not understand.
(Student Interview: Dobson 13.03.01)

The mean student profile of David's interactions on the QTI shown in
Figure 4.17 is indicative of a cooperative classroom in which favourable student
attitudes and achievement are likely to be promoted, notwithstanding the
differences in student perception on several scales (Wubbels et al., 1993).
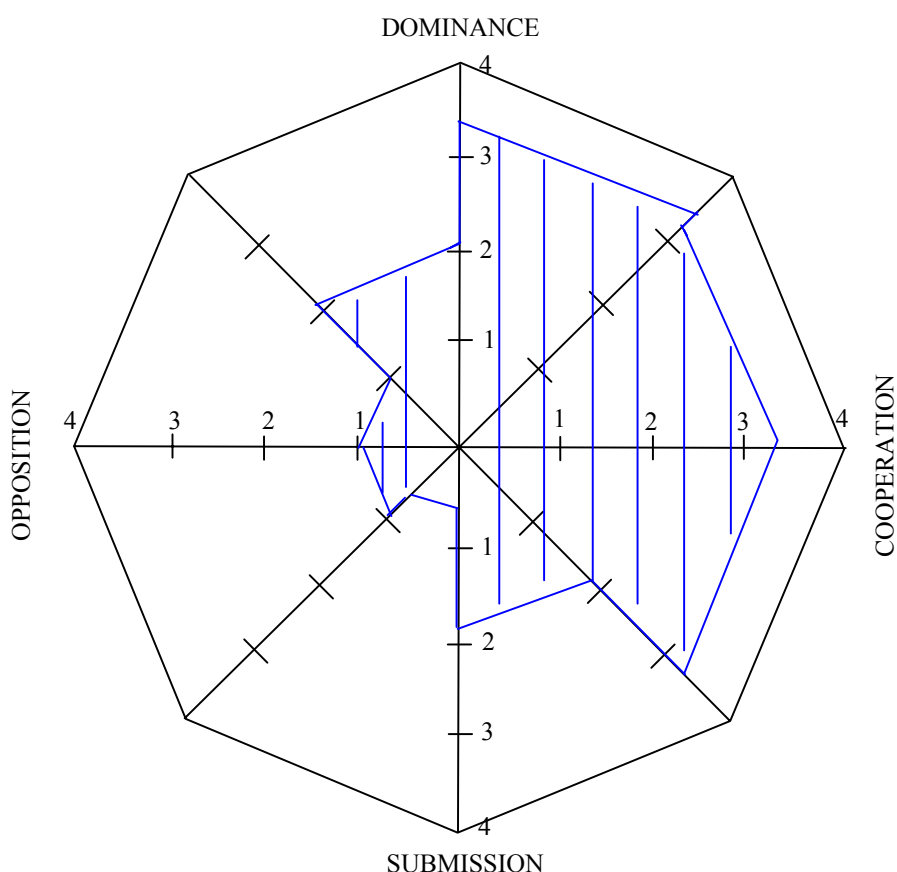
Figure 4.17. Mean students' perceptions of David's interpersonal interactions

David's self-perceptions of his interaction behaviours are similar to students' perceptions as shown in Table 4.6. Both profiles (Figures 4.17 and 4.18) display the highest scale scores on DC (leadership), CD (helpful/friendly), and CS (understanding); and lower on SO (uncertain), OS (dissatisfied), and OD (admonishing). Interestingly, David saw himself as stricter (DO), less dissatisfied (OS), admonishing (OD) and giving more student responsibility than did the students. Student and teacher profiles in Figures 4.17 and 4.18 are indicative of a predominantly cooperative classroom environment in which favourable student attitudes and achievement are likely to be promoted (Wubbels et al., 1993).
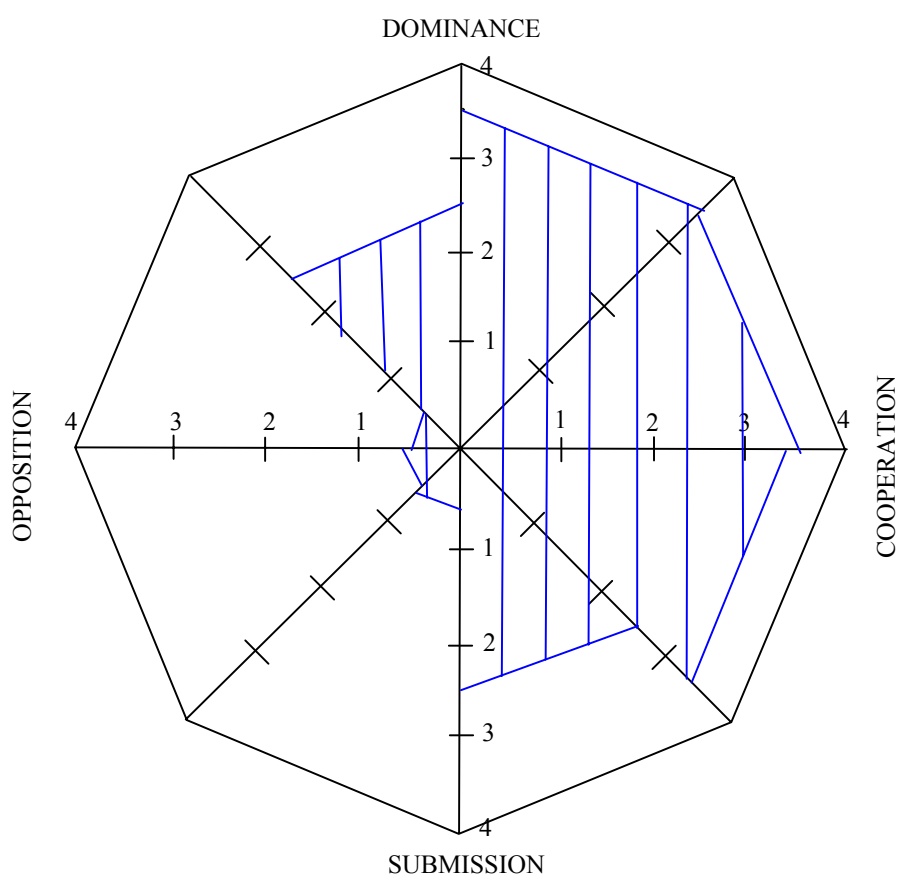
Figure 4.18. David's perceptions of himself as the class teacher

4.4.5   Students' preconceptions of electricity

Students' understandings of elementary concepts of direct current electricity prior to instruction were tested using a Two Tier Diagnostic Test Questionnaire on Electricity discussed earlier in Section 3.7.4.4. David, the class teacher, administered the questionnaire a week before teaching the electricity unit. The unit on electricity was a part of the normal teaching requirement for Grade 9 Science specified in the Papua New Guinea School Syllabus. The results from the Two Tier Diagnostic Instrument are presented in Table 4.8. A total of ten two tier items covered a range of concepts involving fundamental direct current circuit behaviour and other elementary electricity concepts. The first column in the table displays important current concepts associated with direct current electricity that appeared as test items in the Two Tier Diagnostic Instrument. The second column indicates the frequency (with percentage in brackets) of students who provided the correct response to the first tier of the item tested. The third column gives the percent frequency of students (with percentage in brackets) who gave the full correct answers to both first and second tiers. Finally, the last column records the alternative views expressed by students, with the frequency of views in brackets.

Table 4.8 (a)

Class Data for Two Tier Diagnostic Test on Direct Current Electricity: Current Behaviour in Circuits

Concept tested	Frequency of correct choice (%)	Frequency of correct choice and reason (%)	Alternative view expressed by members of the class (Frequency)
Item 1: A closed circuit is necessary for current to flow	42 (98)	12 (29)	1. Current flows as long as a piece of wire is attached to battery terminals (30).
Items 2, 3, 4: Current is never used up in a circuit	2 (4)	0 (0)	1. Current decreases in magnitude because some of it gets used up in the circuit (28). 2. Current flowing to the light bulb is used up completely (25).

3. Current before a light bulb is greater than current after the light bulb (26).

4. In Item 2(b), current will flow in a direction toward the light bulb in both wires (19).

5. In Item 3, the magnitude of current is unpredictable at any point in the circuit (7).

6. In item 4, current is greater at A_3, less at A_2 and least at A_1 because a) the batteries are near these points where the current flow is at full force (2) b) the current will be used up by A_3 (sic) (1) c) the current will be used up by A_1 and A_2 (7).

7. In Item 4, current reading is the same at A_1 and A_3 but less at A_2 because a) the current is used up by A_1 and A_3 through the two lamps (15), b) A_3 and A_1 are closer to the batteries (1).

8. Current will flow in a direction toward the light bulb in both wires (see Item 2b) because current flowing to the light bulb is almost used up and the small amount remaining returns to the battery.

9. For circuit in Item 4, the current readings at A_1, A_2 and A_3 will be the same because a) the carbonic acid was getting weak (sic) (1), b) the dry cell used up (1).

10. No reasonable answer given except indications of guessing by students (16).

Item 5: The strength of current in a circuit is dependent on the loading when source voltage is constant.	(60) 26	(9) 4	1. The more the load (light bulbs) is in the circuit, the greater is the current used up. 2. Two light bulbs will use more current than one light bulb (39). 3. Total resistance of circuit 1 is more than that of circuit 2. (1) 4. No proper answers but indications of guessing by students (3).
Item 6: The strength of current	(87) 38	(87) 38	1. In Item 6, the current in circuit 1 is greater than current in circuit 2 because circuit 1 has

in a circuit is dependent on source voltage when loading is constant.		only one battery compared to circuit 2 (1). 2. In Item 6, the current in circuit 1 is unpredictable in relation to current in circuit 2 (1). 3. No proper answers but indications of guessing by students (5).

Table 4.8 (b)

Class Data for Two Tier Diagnostic Test on Direct Current Electricity: Application of Concepts

Concept tested	Frequency of correct choice (%)	Frequency of correct choice and reason (%)	Alternative view expressed by members of the class (Frequency in brackets)
Item 7, 8: Understanding of Ohm's law	4 (8)	1 (2)	1. For Item 7, there were no proper responses except indications of guessing by students (43). 2. In Item 8, the current is greater for series circuit 8a) compared to parallel circuits (20).
Item 9: In circuits where light bulbs are connected in parallel, current in each path is determined by load resistance while voltage across each load in parallel remains equal to source voltage	40 (91)	29 (67)	1. In Item 9, current passing through the battery does not have the same value as those passing through each light bulb because a) sometimes the current will not have resistance values (1) b) light bulbs have different resistances (9) c) the bulbs use up battery power. They do not have own current (1). 2. No proper responses except for indications of guessing by students (3).
Item 10: Electrical energy is transferred from voltage source to load.	40 (93)	35 (80)	For Item 10, there were no proper responses except for indications of guessing by students (5).

The notion that current is never used up or consumed in an electric circuit (Items 2, 3 & 4) and understanding of Ohm's law (Items 7 & 8) proved to be the areas with which students had the most difficulty. On the other hand almost all students understood that a closed circuit was necessary for current to flow (Item 1).

Results from Table 4.8(a) showed that students understood clearly that current driven by a voltage source passed through wires and did light up light bulbs. However, only about a third of students in the class were able to understand that current would only flow if there were a closed loop in an electric circuit (Item 1). The rest of the students in the class believed that a light bulb would light up indicating current flow as long as a piece of wire connected to a battery terminal made contact with the light bulb. They showed no understanding of the characteristic movement of current in a closed pathway. From interviews with students in the class it was revealed that many students had used portable dry cell operated electric torches where normally the light bulb sits directly above the dry cells and a switch which slides a metal strip up or down to switch on or off the torch. Therefore, data collected from the students in the class suggests that students were not able to see a complete closed loop circuit as a condition for current flow in these torches. Helen's response in an interview is an exemplar of this misunderstanding.

An electric current flows as long as a piece of wire is attached to the battery terminals. (Helen)

A high percentage of students in the class believed that current was used up completely or partially in an electric circuit (Item 2).

Current flowing to the light bulb is used up completely. (Dolly)

Current flowing to the light bulb is almost used up and the small amount remaining returns to the battery. (Ernie)

Therefore, it made sense to those students that due to the decrease or absence of current the battery goes weak. Only 2 students out of the class of 43 displayed the canonical view that current was never used up in an electric circuit.

When it came to the understanding of the Principle of Ohm's Law (Items 7 & 8), none of the whole class of forty-three students displayed evidence of a clear understanding or an alternative conception that was plausible enough to explain Ohm's Law. Cedric, a 15-year-old student with city background stated "…I'm just guessing" in his response to Items 7 and 8.

For the last two concepts on Table 4.8 (b), testing students' understanding of current and voltage characteristics in parallel circuits and energy transfer (Items 9 & 10), over 90 % of students in the class answered the first tier of the items correctly. However, the second tier of the items where students were required to offer an explanation for their response in the first tier, more than 67 % of students in the class were not able to do so. For Item 10 many explanations offered by students in the class showed evidence of guesswork, unrelated answers or were incomplete, evident in the following responses.

Energy must have transferred in order for the light to.... (Mae)

The battery itself has the carbohydrate. (Mary)

The current flow through wires before it reaches the light bulb. (Philip)

The result of this part of the study suggests that despite previous instruction on electricity in Grade 6 and 7 in community schools some basic but important alternative conceptions continue to exist in students' cognitive

structures. For example, the alternative conception identified by Item 2, 3 and 4 in relation to the strength of current in a series circuit being consumed is a commonly held student view. Shipstone (1984) refers to it as the "attenuation current" model. More current leaves one terminal of the battery than current returning to the other terminal of the same battery after passing through loads where some current is believed to be consumed.

David did not have access to the results of this part of the research during his teaching of the unit on electricity because the researcher did not want to in any way influence David's teaching strategies in accordance with the aims and focus of this interpretive research study.

4.4.6 Summary and conclusion: Whole class data

The learning environment investigated was consistent with the Western model but there were important differences noted. These differences were mainly due to resource constraints faced by the school. The most notable being the lack of adequate apparatus and equipment for conducting experiments, and the large student numbers for the class participating in this study. Teaching and learning was very much directed and controlled by the class teacher, David. Students' input into learning activities in this environment was restricted to a minimum level involving basic short responses to David's directed questions and instructions at individual students, and participation in group practical sessions and some chalkboard work. The limited student involvement in teaching and learning was attributed to students' behaviour and interactions in class which had cultural overtones, and not due to David's teaching approaches. David provided opportunities for students' involvement but these were not grasped effectively by the students. David was aware of his role as a contemporary trained modern teacher to facilitate learning by encouraging greater student involvement in class but the results of his efforts were not significant. Students remained passive and maintained subservient roles in class.

Students' collective views on science-technology-society were predominantly crude/naïve. This is shown by fifty-eight percent of students in the class holding crude/naïve views, twenty-six percent holding transitional views, and sixteen percent holding canonical views.

Students in the class viewed their present classroom learning environment as having medium satisfaction, low friction, high competitiveness, low difficulty and low cohesiveness. Students demonstrated clearly on the MCI that they preferred a learning environment where there was higher satisfaction, higher cohesiveness but lower friction, lower competitiveness, and lower difficulty.

As far as the students' perception of David's interpersonal interaction in the learning environment was concerned, students' perceptions of David's interactions were consistent with an approach that normally translates into high student cognitive outcomes (Wubbels, 1993). The high class mean scores on the QTI scales of leadership, helpful/friendly and understanding and to some extent strictness when coupled with low uncertain, dissatisfied, and admonishing behaviours were positive for student achievement. The final whole class data was on students' conceptions of electricity prior to instruction in this study. The results of the Two Tier Diagnostic Questionnaire showed many students had alternative conceptions which were robust and convincing to them, similar to students elsewhere.

The analysis and reporting of the students' whole class data provide insights into the context of the research and the nature and dynamics of the classroom learning environment landscape. They have also advanced progress toward the answering of the research questions 1, 3 and 4 in particular. Section 4.4.2 has shed some light on students' views of science raised in research question 1. Sections 4.4.3 and 4.4.4 have provided some insights into students' classroom

environment alluded to by research question 3. Section 4.4.5 provides insights into students' prior knowledge of electricity addressed by research question 4.

These insights are useful in that they provide an initial glimmer of evidence to suggest that there is much happening in the teaching and learning in this particular high school classroom in Papua New Guinea. The next segment elaborates these data with data from observations of the four selected focus students; Allison, Ian, George and Demi (pseudonyms) whose backgrounds span the important categories of student participants (rural, town, city) as described earlier in Chapter 3.

4.5   Selected focus students' perceptions and learning

4.5.1   Introduction

The previous section provided insights into the nature and dynamics of the classroom-learning environment as a whole through discussions of the class teacher's perceptions and his approaches to teaching and learning in this particular school as well as the presentation of whole class students' perceptory data. This section serves to expand as well as elaborate on the investigations and interpretations of teaching and learning in the classroom environment of the particular school. Accordingly, the data for the four selected students are now presented in detail.

As an introduction to the focus students, Table 4.9 provides general background information, their categorisation from responses on the adapted VOSTS questionnaire, and the Two Tier Diagnostic Test score on students' understanding of electricity prior to instruction. Important information on students' backgrounds, and the use and analysis of the questionnaires presented in Table 4.9 were discussed earlier in Chapter 3.

Table 4.9

Selected Focus Students' VOSTS Results

Student	Age	Background	Predominant view of science expressed on Adapted VOSTS test	Pre-diagnostic test score (mean = 55%, SD = 8)
Allison	15	City	Canonical	70 %
Ian	18	Rural	Transitional	45 %
George	16	Town	Transitional	65 %
Demi	15	Rural	Crude/naïve	45 %

Each student's view of science was classified as canonical, transitional or crude/naïve depending on the nature of their responses on eight adapted VOSTS items as discussed earlier in Section 4.4.2.

Prior knowledge of the content area was considered an important aspect that may influence learning. Thus, the diagnostic test results in the last column of Table 4.9 presented an indication of the students' level of alternative conceptions of basic electricity concepts on the Diagnostic Test Questionnaire (Section 4.4.3). A high score on the diagnostic test, for example, reflected a better understanding of electricity concepts with fewer alternative conceptions about concepts in electricity. Conversely, a low score on the diagnostic test points to a poorer understanding of electricity concepts implying a large number of alternate conceptions about electricity concepts prior to instruction.

The age range in this class was wide, the lowest being 14 years and the highest 18 years. Students' background information in the third column of Table 4.5 categorises students as either rural, town, or city. This is significant in providing information on the level of students' exposure to modern technology.

In order to provide a richer description of the teaching and learning occurring and the classroom environment being studied, further specific data on each of the four selected focus students is now presented.

4.5.2   Perspective 1: Allison

4.5.2.1 Description and background of Allison

Allison was a 15 year old who attended community school in the city of Port Moresby before transferring to her home province with her family recently. She enrolled at a top-up community school near her village just outside the town boundaries in order to complete Grades 6, 7 and 8 before proceeding on to high school studies. She was the eldest in a family of two sisters and a brother. Her father was a retrenched soldier from the Papua New Guinea Defence Force whose highest educational qualification attained was Grade 10. Her mother was a housewife who had basic education up to Grade 6. They lived in a village five kilometres out of town in a semi-permanent house with running water from a tank and electricity. Allison had lived most of her life in the city of Port Moresby with her family. Both her parents had basic formal education and so she was categorised as a city student in the study.

Allison did not think about science as a subject relevant to her needs, especially in relation to her future career interests in becoming an accountant. Later, she realised that science was involved with most things.

Researcher: Do you find the electricity topic interesting in class?

Allison: No, but sometimes I think that later it will not be ….I don't get interested in science because I don't think it will benefit me later. So I don't …

Researcher: You're looking at becoming an accountant so you don't think it will benefit you.

Allison: I usually like math and like English but I don't do well in math.

> **Researcher**: You do like English then. Now you say (science) will not help you but accountants use computers, calculators and they depend on electricity. So if you had a little knowledge about electricity, would you think that would help you understand the computer a bit more, or the calculator?

> **Allison**: Now I realise that science is involved with most things. (Student Interview: Allison 13.03.01, line 77)

Allison's view on science-technology-society is discussed next.

4.5.2.2 Allison's VOSTS results

Her views were obtained through an adapted version of the VOSTS questionnaire (Aikenhead et al., 1989) for students from Papua New Guinea. As discussed earlier in Section 3.7.4.1, there were eight items on the adapted VOSTS questionnaire used to gather students' views in the class. All eight views expressed by Allison are presented in Table 4.10. In each case the statement is in italics while the response is written in normal font.

Table 4.10

Views Expressed by Allison on adapted VOSTS Questionnaire Items

Item	Stimulus question	Chosen response	View
1	*Defining science is difficult because science is complex and does many things. But mainly science is:*	A body of knowledge, such as principles, laws and theories which explain the world around us (matter, energy and life).	transitional
2	*When scientists investigate, it is said that they follow the scientific method. The scientific method is:*	I do not know enough about the subject to make a choice.	other
3	*The more Papua New Guinea's science and technology develop,*	because more science and technology would make Papua	Canonical

	the wealthier Papua New Guinea will become. Science and technology will increase Papua New Guinea's wealth:	New Guinea less dependent on other countries. We could produce things for ourselves.
4	*In everyday life, knowledge of science and technology helps you personally solve practical problems (for example, getting a car out that is stuck in the mud, cooking, or personal care and hygiene when you have skin problems or sores on your body)*:	What I learn from science class generally does not help me solve practical problems; but it does help me notice, relate to, and understand the world around me.	Canonical
5	*Science and technology can help people make some moral decisions (that is, one group of people deciding how to act towards another group). Science and technology can help you make some moral decisions*:	By providing background information; moral decisions must be made by individuals.	Canonical
6	*Science and technology offer a great deal of help in resolving such social problems as poverty, crime and unemployment*:	It's hard to see how science and technology could help very much in resolving these social problems. Social problems concern human nature; these problems have little to do with science and technology.	Canonical
7	*Some cultures have a particular viewpoint on nature and man. Scientists and scientific research are affected by the religious or ethical views of the culture where the work is done. Religious or ethical views do NOT influence scientific research*:	because research continues in spite of clashes between scientists and certain religious or cultural groups (for example, clashes over evolution and creation).	Canonical
8	*Science rests on the assumption*	Anything is possible. Science	Canonical

that the natural world cannot be	does not know everything
altered by a supernatural being	about nature. Therefore,
(for example, a God). Scientists	science must be open-minded
assume that a supernatural being	to the possibility that a
will NOT alter the natural world:	supernatural being could alter
	the natural world.

Allison's response to the adapted VOSTS questionnaire had five canonical, one transitional and one "other" response (Table 4.10). Thus, Allison's performance on the adapted VOSTS questionnaire reflected a predominantly canonical view of science-technology-society as noted in Table 4.9 which was consistent with responses by city students.

4.5.2.3 Allison's actual and preferred learning environments

Allison expressed her views on the actual learning environment in the classroom in which she studied as well as her preferred learning environment through the MCI questionnaire (Fraser, 1993) administered to the whole class. A description of the MCI is given in preceding Sections 3.7.4.2 and 4.4.3. Allison's actual and preferred learning environments data are presented in Table 4.11. The first column shows the scales of the MCI comprising satisfaction, friction, competitiveness, difficulty, and cohesiveness.

Table 4.11

Comparison of Allison's Actual and Preferred MCI Scores against Class Mean Scores

		Actual			Preferred		
Scale	Number of Items	Student mean	Class mean	Class SD	Student mean	Class mean	Class SD

Satisfaction	4	2.2	2.29	1.35	2.6	2.40	1.36
Friction	5	1.4	1.72	1.63	1.0	1.42	1.06
Competitiveness	3	2.6	2.90	0.82	2.2	2.44	1.63
Difficulty	3	2.6	1.70	1.02	1.4	1.47	1.15
Cohesiveness	4	1.4	1.91	1.85	2.2	2.71	1.91

Note 1. Item response scale from 1 to 3 (1- never, 3- always)

Allison's scores are shown enabling comparison with the whole class means (standard deviation) for actual and preferred classroom environments. Allison perceived her actual classroom environment to be highly competitive and difficult but also relatively satisfying. Cohesiveness and friction were perceived as relatively low. She preferred a classroom environment that had even higher satisfaction, more cohesiveness but much less friction and difficulty.

4.5.2.4 Allison's perception of the teacher's interpersonal interactions

Allison's individual scores on the QTI (Wubbels, 1993) for scales of Leadership (DC), Helpful (CD), Understanding (CS), Student responsibility (SC), Uncertain (SO), Dissatisfied (OS), and Strict (DO) are presented in Table 4.11 along with the class group mean and standard deviation. As described previously in Sections 3.7.4.3 and 4.4.4, the letters in brackets after the QTI scales refer to a Proximity Dimension (Cooperation, C to Opposition, O) and an Influence Dimension (Dominance, D to Submission, S) which are represented in a coordinate system as exemplified in Chapter 3 (Figure 3.2).

Table 4.12

Comparison of Allison's QTI Score with the Class Performance and the Teacher's Self Rated Score

Scale	Number of Item	Student mean	Class mean	Class SD	Teacher's mean

DC Leadership	7	4.00	3.42	2.45	3.56
CD Helpful / friendly	8	3.75	3.31	2.99	3.44
CS Understanding	8	3.75	3.29	2.61	3.38
SC Student Responsibility	8	1.00	1.85	1.44	2.47
SO Uncertain	7	0.00	0.71	0.28	0.62
OS Dissatisfied	9	0 .78	0.89	0.44	0.46
OD Admonishing	8	0 .50	0.97	0.74	0.41
DO Strict	9	1.78	2.11	1.21	2.56

Note: Item response scale from 0 to 4

According to Allison, David showed very high leadership characteristics that enabled him to be very dominant in his interpersonal behaviour with students compared to his cooperative behaviour. He was aware of what was happening in the classroom, was able to lead, organise, give orders, set tasks, determine procedures, structure the classroom situation, explain, and hold students' attention.

Allison's perception of David's interpersonal behaviour in the classroom environment had some similarities to the whole class students' perceptions discussed in Section 4.4.4. The DC (leadership), CD (helping/friendly), and CS (understanding) scales were the highest in each profile, in each case being high for Allison's perceptions than the class. Similarly, the teacher's self ratings were higher mean scale scores were for same dimensions, again lower than for Allison's perceptions. The teacher's perceptions were 1 SD (related to class mean) above Allison's.

Analysis of the class mean scores shows the model for interpersonal teacher behaviour depicting David's interpersonal interactions with the students in this particular classroom portrays David's behaviour as follows:
Leadership behaviour is excellent. David is helpful / friendly, and understanding

but weak in the area of student responsibility and freedom. He is very certain of his position, role and what is expected of him. He is also very satisfied, supportive but not very strict in his behaviour in the classroom.

4.5.2.5 Allison's prior knowledge of electricity concepts

Allison scored 70 % on the Two-tier Diagnostic Test for Understanding of Electricity prior to instruction (Section 4.4.5.2, Table 4.5). Compared to the class mean of 55 % her understanding of electricity was satisfactory. However, she displayed the following alternative conceptions in her understanding of electricity when responding to Items 3, 4, 5, and 7. (She correctly responded to Items 1, 2, and 6; hence, her views in relation to these items were the scientifically acceptable ones).

Items 3 and 4 tested the concept that current was never used up in a circuit but maintained a constant value. Allison got both items wrong, including both tiers of the questions. For Item 3 she believed that the value of current after it passed through two lamps in series would be less compared to the value of current before the lamps. The reason for her answer given in the second tier of the item erroneously suggested, "Current decreases in magnitude because some of it gets used up in the circuit." In Item 4 she reasoned that "Because the batteries are near at these points where the currents flow at full force."

For Item 5 testing the concept of magnitude of current dependent on load, Allison answered the first part correctly but provided a wrong reason for her answer. She reasoned, "Two light bulbs will use more current than one light bulb."

Item 7 tested for the understanding of Ohm's law. Allison correctly answered the first part of the item but gave an incorrect explanation for her answer. She correctly stated that if a current of 1 amp flowed in a series circuit

where the battery voltage was 1.5 volts, then the resistance of the light bulb must be 1.5 ohm. Her reasoning was incorrect. She stated, "Because if all the current is applied to the bulb it might blow up so some current is resisted."

Some perceptions on learning in this particular classroom environment from Allison's perspective are discussed in the following.

4.5.2.6 Allison's perceptions about teaching and learning

Allison showed reluctance to both discuss problems with her peers and ask David questions in class. She kept to herself on most occasions. As stated by Allison, she believed she was an independent worker, always trying to find out answers herself and not learning from others.

> I just like to do research on my own and …I don't like to learn things from others. I want to learn on my own. (Student's Interview: Allison 01.04.01, line 31).

Allison did not believe in designed group work in class during practical and problem solving sessions to enhance learning. The reason given for her behaviour was that she did not trust her peers because they were not experienced. She preferred to discuss schoolwork with experienced people such as her teacher, who she highly respected.

> **Researcher**: Now when you are in class I notice that you normally sit on your own. You don't discuss things with your friends…now why is that?.. Are you shy with your friends or you find the lessons clear and easy to understand.

> **Allison**: Like… as for myself when I see things that are easy I don't try to discuss.

Researcher: Now when you find things hard what do you do?

Allison: I just like to do research on my own and ...I don't like to learn things
from others. I want to learn on my own.

Researcher: How about discussing problems with others?

Allison: Like experienced people is ok but …

Researcher: Not other students who are not…

Allison: I don't trust them and I don't like to talk to them. (Student Interview:
Allison 01.04, line 15)

As far as teaching and learning went in her classroom learning environment, she seemed satisfied with David's teaching approach (Table 4.10). However, an aspect of the lessons that concerned Allison was the apparent lack of communication between the primary and secondary levels to coordinate subject content taught by teachers. In this case David repeated some topics that she had already done in electricity taught at Grades 6 and 7 at primary school level in this class. As indicated in the excerpt below from interviews with Allison, this affected students' learning, causing boredom for Allison and other students who have also had previous instruction on electricity in earlier grades.

Researcher: You are free to comment on the science lessons and whatever that
goes on in the class.

Allison: I like the teaching by Mr. Mark. He is patient and helpful to students.

Researcher: Who were your previous science teachers?

Allison: We have a lot of changes in teachers at our primary school.

Researcher: Primary school! Ok. You went to Komiufa Primary School. Did you
study electricity at Grade 7 there?

Allison: Yes

Researcher: What areas did you study?

Allison: About static electricity. Like the things we learn now… we already
learned them there at Grade 7.

Researcher: Oh… so you should be very good at it (electricity). So it is not
entirely new.

Allison: That's why I don't like it.

Researcher: So it's a bit boring (in class). Shouldn't you be challenged more in
class?

Allison: Yes, We have already learned it so I don't think it is new. So … it
is…like boring to me. (Student Interview: 13.03.01, line 87)

4.5.2.7. Summary: Perspective 1 – Allison

Allison, a 15-year-old classified as a city student showed predominantly
canonical views of science-technology-society, being one of the sixteen percent of
students in the class who held such views. Her understanding of the effect of
science and technology, application of science in everyday life, moral aspects of
science, effect of science and technology on social problems faced by people,
influence of culture on science, and the relationship between science and a
supernatural being were all canonical as discussed earlier in Section 4.4.5.2.2. Her
assessment of the present learning environment was that it was satisfying, difficult

and highly competitive. Cohesiveness and friction were on average perceived between sometimes and never on the response scale. However, similar to the whole class data on the learning environment, she preferred higher satisfaction, higher cohesiveness but lower competitiveness, friction and difficulty. Her perception of David's interpersonal interactions with students as gauged by the QTI instrument were that he displayed high leadership, high helpful/friendly and high understanding behaviours conducive to high student achievement.

Allison scored relatively high on the Two Tier Diagnostic Test compared to the class mean. Thus, her prior knowledge of electricity had relatively fewer alternate conceptions compared to her peers. It is possible that her city upbringing might have been an important influence contributing to her canonical views of science-technology-society, and fewer alternate conceptions about electricity compared to other students in the class.

4.5.3 Perspective 2: Ian

4.5.3.1 Description and background of Ian

Ian was an 18 years old student who came from a rural village higher up in the mountains to the west of the town. Therefore, he is classified as a rural student. He attended a community school near his village completing Grades 1 to 6. Due to the local school not being a top-up school offering Grades 7 and 8 he had to transfer to a top-up community school in town to complete his primary education. He lived with relatives while attending school in town. His parents lived in a traditional village and were subsistence farmers with no formal education. Their life style was very much unchanged by the influence of modern technology. They lived most of their daily lives as their ancestors did for many years. Thus, Ian was categorised as predominantly a rural student. His views on science-technology-society differed from those of Allison who was categorised as

a city student. The next section describes Ian's responses to the VOSTS instrument item by item.

4.5.3.2. Ian's VOSTS results

The VOSTS instrument (Aikenhead et al., 1989) was employed to seek Ian's views on science-technology-society. As shown earlier in Table 4.5 and discussed in Section 4.4.2, Ian displayed a predominantly transitional view about science-technology-society on the adapted VOSTS test. This was indicative of his views of science-technology-society undergoing transformation from a crude/naïve understanding to one that was approaching a canonical understanding. The eight responses corresponding to the eight items on the VOSTS instrument expressed by Ian are now presented in Table 4.13.

Table 4.13

Views Expressed by Ian on Adapted VOSTS Questionnaire Items

Item	Stimulus question	Chosen response	View
1	*Defining science is difficult because science is complex and does many things. But mainly science is:*	a study of fields such as biology, chemistry and physics.	Crude/naive
2	*When scientists investigate, it is said that they follow the scientific method. The scientific method is:*	getting facts, theories or hypotheses efficiently.	Transitional
3	*The more Papua New Guinea's science and technology develop, the wealthier Papua New Guinea will become. Science and technology will increase Papua New Guinea's wealth*:	It depends on which science and technologies we invest in. Some outcomes are risky. There may be other ways besides science and technology that create wealth for Papua New Guinea.	Transitional
4	*In everyday life, knowledge of*	Ideas and facts I learn from	Transitional

	science and technology helps you personally solve practical problems (for example, getting a car out that is stuck in the mud, cooking, or personal care and hygiene when you have skin problems or sores on your body):	science classes sometimes help me solve problems or make decisions about such things as cooking, keeping healthy, or explaining a wide variety of physical events.	
5	*Science and technology can help people make some moral decisions (that is, one group of people deciding how to act towards another group). Science and technology can help you make some moral decisions*:	Because science includes areas like psychology which study the human mind and emotions.	Crude/naive
6	*Science and technology offer a great deal of help in resolving such social problems as poverty, crime and unemployment*:	I do not know enough about this subject to make a choice.	Other
7	*Some cultures have a particular viewpoint on nature and man. Scientists and scientific research are affected by the religious or ethical views of the culture where the work is done. Religious or ethical views do NOT influence scientific research*:	I do not understand.	Other
8	*Science rests on the assumption that the natural world cannot be altered by a supernatural being (for example, a God). Scientists assume that a supernatural being will NOT alter the natural world*:	Anything is possible. Science does not know everything about nature. Therefore, science must be open-minded to the possibility that a supernatural being could alter the natural world.	Canonical

Ian's response to the items showed one canonical, three transitional, two crude/naïve and two "other" (Items 6 and 7) responses. Accordingly, Ian's performance on the adapted VOSTS instrument was categorised as reflecting overall a predominantly transitional view of science-technology-society as shown in Table 4.5. He was unable to express a view on two items (Items 6 and 7) out of a total of eight because he felt he did not know enough or did not have adequate knowledge about the issue raised by the item in the adapted VOSTS instrument.

4.5.3.3. Ian's actual and preferred learning environments

Ian's view on the nature of the classroom environment was also investigated. Ian recorded his perceptions on the actual as well as the preferred learning environment under which he learned science through the MCI questionnaire on classroom environment (Fraser, 1993). A description of the MCI is given in Sections 3.7.4.2 and 4.4.3.

Ian's scores are shown along with the whole class mean scores and standard deviation for actual and preferred classroom environment results in Table 4.13. The first column shows the scales of the MCI comprising satisfaction, friction, competitiveness, difficulty, and cohesiveness.

Table 4.14

Comparison of Ian's Actual and Preferred MCI Scores with the Class Mean Scores

Scale	Number of Items	Actual			Preferred		
		Student mean	Class mean	Class SD	Student mean	Class mean	Class SD
Satisfaction	4	3.0	2.29	2.35	2.6	2.40	2.36
Friction	5	1.4	1.72	1.63	1.0	1.42	2.06
Competitiveness	3	2.2	2.90	0.82	1.8	2.44	1.63

Difficulty	3	1.4	1.70	2.02	1.4	1.47	1.65
Cohesiveness	4	1.0	1.91	2.85	2.6	2.71	1.91

Note 1. Item response scale from 1 to 3 (1- never, 3- always)

Ian perceived a higher level of satisfaction than the class did but lower levels of friction, competitiveness, difficulty which are consistent with the higher level of satisfaction. Interestingly, Ian perceived a lower level of cohesiveness but indicated a preference for much higher levels of that dimension. Except for cohesiveness, Ian's preferred classroom environment mean scores were lower (or equal) on the other dimensions.

4.5.3.4. Ian's perceptions of the teacher's interpersonal interactions

In order to determine Ian's perception of the teacher's interpersonal interactions in the classroom his QTI questionnaire scores for eight scales were analysed. His individual scores on the QTI for scales of Leadership (DC), Helpful (CD), Understanding (CS), Student responsibility/freedom (SC), Uncertain (SO), Dissatisfied (OS), and Strict (DO) are presented in Table 4.9 against the whole class mean and standard deviation.

Table 4.15

Comparison of Ian's QTI Scores with Class Performance and the Teacher's Self Rated Score

Scale	Number of Item	Student mean	Class mean	Class SD	Teacher's mean
DC Leadership	7	3.86	3.42	4.45	3.56
CD Helpful / friendly	8	3.38	3.31	4.99	3.44
CS Understanding	8	3.00	3.29	4.61	3.38
SC Student Responsibility	8	1.00	1.85	3.94	2.47
SO Uncertain	7	0.57	0.71	4.28	0.62

OS Dissatisfied	9	0.78	0.89	4.44	0.46
OD Admonishing	8	0.75	0.97	4.74	0.41
DO Strict	9	2.22	2.11	5.21	2.56

Note: Item response scale from 0 - 4

The QTI results are presented in Table 4.15 along with Ian's score against the class mean and standard deviation. According to Ian, David showed very high leadership behaviour and at the same time was helpful/friendly and understanding. The other scales of the QTI suggest that he perceived David certain of himself, satisfied, allowed low student responsibility/freedom, agreeable, and strict to a certain extent.

4.5.3.5 Ian's prior knowledge of electricity concepts

Ian scored 45 percent on the Two-Tier Diagnostic Test for understanding of electricity prior to instruction, discussed in Section 3.7.4.4. His score was below the class mean score of 51 percent. The test items are reproduced in full with circuit diagrams at Appendix D and should be consulted in conjunction with these discussions on Ian's performance on the diagnostic test. His response to Items 1, 2, 3, 4, 5, 7, 8, and 9 were incorrect in part or whole. Items 6 and 10 were answered correctly.

Item 1. The first tier of the item was correctly answered. However, he incorrectly responded to the second tier. He erroneously thought as long as any piece of wire was attached to a battery terminal an electric current would flow through the wire. He needed to fully understand the principle of current flow in a circuit being conditional to a closed loop arrangement.

Item 2. Ian's responses to both tiers of Item 2 were incorrect. He incorrectly believed current flowed through wires out of both ends of the same battery when connected in an electric circuit. He also held the view that current

flowing to a light bulb was almost used up and the small remaining amount returns to the battery.

Item 3. Ian's answers to item 3 were both incorrect. He firmly held the view that current is consumed in an electric circuit.

Item 4 also tested the concept that current is never used up in a circuit. Ian's response was interesting this time. He deviated from his current consummation view that he applied in Item 3 and this time agreed correctly that current passing through loads connected in series would maintain a constant magnitude.

Item 5 first tier was answered correctly. The second tier response suggested that two loads in series would draw more current than a single load if all loads had identical resistances.

Item7. Ian correctly answered the first tier of the item. For the second tier he wrote:

> I'm just guessing the answers so later I will learn.

Item 8. For this item he answered the full question incorrectly. He was guessing because he wrote:

> I just guessed the answer. The current A will be greater than current D.

Item 9. First tier was correctly answered. Ian's answer to the second tier did not make any sense at all. It read:

> Because sometimes the current will not have resistance values.

As noted earlier on Table 4.5, Ian's prior knowledge of electricity concepts was low (45 %) despite having received instruction on electricity earlier

at Grade 6 and 7 at community school. (This is consistent with the general trend of class results being lowest for rural students). When asked whether he first learned about electricity at his Grade 7/8 studies at community school, he replied, "Yes, we learned electricity there but we did not do experiments like what we are doing here" (Student Interview: Ian 10.04.01, line 47).

Ian attributed his poor understanding of electricity prior to instruction to the way he was taught earlier. Ian felt that when he was taught electricity in earlier grades, there were no practical sessions to apply the theory he learned. He was glad that now in his science course he was doing practical work to enhance his understanding of electricity.

The next section discusses some perceptions about the learning environment and   learning from Ian's perspective.

4.5.3.6   Ian's perceptions about teaching and learning

To Ian, David was pleasant and attempted at all times to assist students to better understand what he was teaching them.

Researcher: How do you find the teacher's lessons?

Ian: It is all right. Mr. Mark (referring to David) is a good teacher.

Researcher: Why?

Ian: Because…. He explains things clearly and is helpful.

Researcher: How is he helpful?

Ian: …He explains very clearly… He is helpful.

Towards the end of this interview presented in the above excerpts, specific questions were asked about the last science lesson in relation to Ian's learning and whether he understood the definition of current for example. Ian responded by saying he did not understand the definition of current. When pressed further he simply said it was not clear (Student Interview: Ian 01.04.01, line 5).

Overall, Ian perceived David as a helpful and understanding teacher who explained electricity concepts clearly, but Ian, himself, did not have a proper understanding of electricity concepts, as evident in his low performance on the Two-tier Diagnostic Test for Understanding Electricity.

4.5.3.7   Summary: Perspective 2 - Ian

Ian represented a category of student classified as rural. Being a student with rural background, Ian at 18 was older than most of his peers. His parents had no formal education and little exposure to the outside world having being subsistence farmers and spending most of their lives in an isolated rural community.

His views on science-technology-society were predominantly transitional in nature. This reflected views which were changing from basic crude/naïve to the canonical. His definition/description of science was canonical but his understanding of the scientific method of investigation, effect of science and wealth creation, application of science in everyday life were overall clarified as transitional. He admitted lack of sufficient knowledge to comment on the effect of science and technology on social problems and the influence of culture on science. As far as the dynamics of the classroom learning environment went, Ian believed the present classroom environment was highly satisfactory and competitive but less cohesive. He thought friction and difficulty experienced by students were less. He preferred a learning

environment that displayed higher cohesiveness, lower satisfaction, lower competition, and friction, and low but similar to what's being experienced difficulty. For interactions in the classroom learning environment, Ian's perception of David's interpersonal interactions showed high leadership, high helpful/friendly behaviour and high understanding. David was very certain, satisfied, supportive and not very strict in his view. Student responsibility/freedom was low. Again, Ian' perception of David was similar to the whole class perception reported in Section 4.4.4. In regards to prior knowledge of electricity, Ian did not possess a reasonable level of basic canonical knowledge of electricity inspite of having instructions on electricity earlier at Grades 6 and 7 at community school. His score was below the class mean on the Two Tier Diagnostic Test on Electricity indicating a high level of misconceptions in electricity. In general, it seemed one of the conditions attributed to Ian's high degree of misconceptions encountered in his understanding of electricity concepts prior to instruction may have been his rural upbringing. His views of science-technology-society were slowly undergoing transition from crude/naïve to the canonical. Being a mature student compared to his peers it seemed he was able to make this transition in his understandings easily.

4.5.4   Perspective 3: George

4.5.4.1 Description and background of George

George was 16 years old and came from a family who enjoyed a higher socioeconomic status relative to the local economic conditions. His father was an academic at a local University. Having completed studies from Grades 1 to 6 at a community school nearby, George went to secondary school to do Grades 7 to 12. George spent most of his life in town, occasionally visiting his home village during holidays and some weekends. He had a

brother attending national high school and two others in community school. He had career ambitions to become an airline pilot.

> **Researcher**: Where did you attend primary school?

> **George**: At North Community School

> **Researcher**: Grades 1 to 6?

> **George**: 1 to 6 and grades 7 and 8 here.

> **Researcher**: Right, your favourite subjects…………last time you told me were…

> **George**: Math and science

> **Researcher**: Yes, and your career interests…. you want to fly. So you want to become a pilot.

> **George**: Yes

> **Researcher**: How do you feel about the science lessons you are learning in class? Do you find the topics easy to understand, or difficult, or very easy?

> **George**: Some are easy and some a little bit confusing. (Student Interview: George 27.03.01, line 21)

George's favourite subjects were mathematics and science. He found science interesting and admits that some science concepts are easy to understand while others are confusing to him. His view on science-technology-society is discussed in the next section.

4.5.4.2 George's VOSTS results

George's views on science-technology-society were obtained through an adapted version of the VOSTS questionnaire (Aikenhead et al., 1989) for students from Papua New Guinea. Once the views were collated they were categorised as predominantly crude/naïve, transitional or canonical. The results presented are designed to highlight the nature of the views as well as identifying whether George's understanding of issues in science-technology-society were crude/naïve, transitional or canonical. It was also important to identify possible relationship between these views and his classification as a town student.

As discussed earlier in section 3.7.4.1, there were eight items that were selected and included on the adapted VOSTS questionnaire because they were deemed relevant to the focus of the study as guided by the research questions. The items and George's response to each item are presented in Table 4.16.

Table 4.16

Views Expressed by George on Adapted VOSTS Questionnaire Items

Item	Stimulus question	Chosen response	View
1	*Defining science is difficult because science is complex and does many things. But mainly science is:*	findings and using knowledge to make the world a better place to live in (for example, curing diseases, solving pollution problems and improving agriculture).	Canonical
2	*When scientists investigate, it is said that they follow the scientific method. The scientific method is:*	an attitude that guides scientists in their work.	Canonical
3	*The more Papua New Guinea's*	because more science and	Crude/naive

	science and technology develop, the wealthier Papua New Guinea will become. Science and technology will increase Papua New Guinea's wealth:	technology would make Papua New Guinea less dependent on other countries. We could produce things for ourselves.	
4	*In everyday life, knowledge of science and technology helps you personally solve practical problems (for example, getting a car out that is stuck in the mud, cooking, or personal care and hygiene when you have skin problems or sores on your body)*:	Ideas and facts I learn from science classes sometimes help me solve problems or make decisions about such things as cooking, keeping healthy, or explaining a wide variety of physical events.	Transitional
5	*Science and technology can help people make some moral decisions (that is, one group of people deciding how to act towards another group). Science and technology can help you make some moral decisions*:	Because science includes areas like psychology which study the human mind and emotions.	Crude/naive
6	*Science and technology offer a great deal of help in resolving such social problems as poverty, crime and unemployment*:	The problems could use new ideas from science and new inventions from technology.	Crude/naive
7	*Some cultures have a particular viewpoint on nature and man. Scientists and scientific research are affected by the religious or ethical views of the culture where the work is done. Religious or ethical views do NOT influence scientific research*:	I do not understand.	Other
8	*Science rests on the assumption that the natural world cannot be altered by a supernatural being*	It depends. What scientists assume about a supernatural being is up to the individual	Transitional

(for example, a God). Scientists   scientist.
assume that a supernatural being
will NOT alter the natural world:

George had two canonical, two transitional, three crude/naïve and one "other" response. As a result, George, a town student was categorised as having predominantly transitional views of science-technology-society as shown in Table 4.5. He was not able to express a view on one item (Item 7) out of the eight due to lack of understanding.

George was also able to express his perceptions on the nature of the classroom learning environment in which he studied science.

4.5.4.3 George's actual and preferred learning environments

George expressed his views on the actual and a preferred learning environment under which he studied science through the MCI questionnaire (Fraser, 1993). David administered the MCI to the whole class of 43. A description of the MCI is presented in sections 3.7.4.2 and 4.4.3. George's actual and preferred learning environments data are displayed in Table 4.10. The first column shows the five scales of the MCI comprising satisfaction, friction, competitiveness, difficulty, and cohesiveness; other columns show scale statistics for actual and preferred learning environments.

Table 4.17

Comparison of George's Actual and Preferred MCI Scores with the Class Mean Scores

		Actual			Preferred		
Scale	No. of items	Student mean	Class mean	Class SD	Student mean	Class mean	Class SD

Satisfaction	4	2.2	2.29	2.35	3.0	2.40	2.36
Friction	5	1.8	1.72	1.63	1.4	1.42	2.06
Competitiveness	3	3.0	2.90	0.82	2.2	2.44	1.63
Difficulty	3	1.4	1.70	2.02	2.2	1.47	1.65
Cohesiveness	4	2.2	1.91	2.85	2.6	2.71	1.91

Note: Item response scale from 1 to 3 (1- never, 3- always)

Overall, George's scores of the actual classroom environment did not differ markedly from those of the class mean scores. Both of these scores followed similar patterns. The data suggest that in George's view the present learning environment was very high in Satisfaction, high in Cohesiveness, and very high in Competitiveness while the degree of Friction experienced by George in the class was about average. Difficulty experienced was low. On the other hand, there were differences in the class and George's scores for the preferred learning environment. George displayed preferences for higher satisfaction, and cohesiveness which in turn is consistent with his preference for low friction, competitiveness and difficulty.

The interpersonal interaction of the teacher in the class was also measured and George's perceptions of his teacher are discussed next.

4.5.4.4 George's perception of the teacher's interpersonal interactions

This section presents data in Table 4.18 which highlight George's perceptions of interpersonal interactions of David the class teacher, David's self rated mean scores and the whole class mean for each of the scales.

Table 4.18

Comparison of George's QTI Score with the Class Performance and the Teacher's Self Rated Score

Scale	Number of Items	Student mean	Class mean	Class SD	Teacher's mean

DC Leadership	7	3.43	3.42	4.45	3.56
CD Helpful / friendly	8	3.63	3.31	4.99	3.44
CS Understanding	8	3.50	3.29	4.61	3.38
SC Student Responsibility	8	2.13	1.85	3.94	2.47
SO Uncertain	7	0.71	0.71	4.28	0.62
OS Dissatisfied	9	0.89	0.89	4.44	0.46
OD Admonishing	8	1.13	0.97	4.74	0.41
DO Strict	9	2.44	2.11	5.21	2.56

Note 1. * George's mean scores.

2. Mean scores from 0 to 4.

According to George, David showed high Leadership (DC), Helpful/friendly (CD), Understanding (CS) but low on Uncertain (SO), Dissatisfied (OS) and Admonishing (OD). Scores for Student responsibility (SC), and Strict (DO) were not too low. For the two scales of Uncertain (SO) and Dissatisfied (OS), George's mean scores was equal to the class mean scores.

It appears reasonable to conclude that George saw David as very certain, very satisfied, supportive but not very strict in his behaviour in the classroom. According to George's perception, David fitted the profile of a teacher with high cognitive outcomes (Wubbels, 1993).

4.5.4.5 George's prior knowledge of electricity concepts

George scored 65 % on the Two-tier Diagnostic Test for Understanding of Electricity prior to instruction. Compared to the class mean of 55 % he did reasonably well. However, he displayed the following alternative conceptions in his understanding of electricity when responding to Items 2, 3, 4, 5, 7 and 9. (He correctly responded to Items 1, 6, 8 and 10; hence his views in relation to these items were the scientifically accepted ones).

Item 2. The response by George to the second tier of Item 2 was incorrect. He erroneously believed current flowing to a light bulb would be used up completely.

Item 3. The answer for the first tier was incorrect. However, the correct reasoning was chosen in the second tier for his incorrect answer. More than anything else, it appeared George was a bit confused with working out his response to Item 3.

In item 4 he got both tiers wrong. It was clearly shown by George that current passing through a series circuit will be used up by the series connected loads.

Item 5 tested the concept of the strength of current being dependent on load given a constant voltage from the source. George answered the first part correctly but provided a wrong reason for his answer. He reasoned, "Two light bulbs will use more current than one light bulb."

Item 7 tested for the understanding of Ohm's law. George correctly answered the first tier by guesswork because in the space for the answer in second tier he wrote, "It's a guess."

For item 9, his response again showed that George was guessing. He correctly said it was not true for a current passing through the battery has the same value as those passing through each of the three light bulbs connected in parallel across a battery as shown in the circuit diagram of Item 9 of the Two Tier Diagnostic Test Questionnaire.

4.5.4.6   George's perceptions about teaching and learning

George portrayed an image of a serious student who wanted to make the most of the opportunities presented before him to learn. He readily participated in the experiments conducted during the practical sessions by assisting in connecting circuits for experiments and taking down reading of currents and voltages in circuits. On a number of occasions in class he appeared bored and not challenged enough. He felt most of the exercises on what were taught given to students by David were easy to do.

George: Most of the exercises Mr. Mark gives to us are easy.

Researcher: Easy?

George: Yes

Researcher: Why do you say it is easy?

George: Because……….its not hard to do.

Researcher: You went to North Side Primary for grades 7 and 8, didn't you? Or, were you at this school?

George: Yes, here

Researcher: So you did grades 7 and 8 here?

George: Yes

Researcher: So what topics [in electricity] did you cover?

George: Electricity…circuits and all those things

Researcher: So what you are learning now is all revision?

George: Yes. (Student Interview: George 11.04.01, line 5)

This situation is reflected in his MCI scoring on the Difficulty scale (Table 4.10), where he assessed the actual classroom environment as low in Difficulty and preferred higher Difficulty levels.

Similar to sentiments expressed by Allison earlier, George believed that topics were taught without any coordination amongst teachers in schools,

thus resulting in repeat teaching of some subtopics. He also thought examples, worksheet problems, and exercises were not hard to do.

4.5.4.7 Summary: Perspective 3 - George

George represented a category of students who were town students. Most students in this category were born and raised in towns. As a result these students had reasonable exposure to modern technological devices such as telephones, television and personal computers compared to their rural counterparts. George's view on science-technology-society was predominantly transitional in nature reflecting the change in his understanding from basic crude/naïve to canonical. His assessment of the present classroom learning environment was high on satisfaction, high on cohesiveness, and high on competitiveness while friction and difficulty were low according to Table 4.10. He preferred a learning environment that was high on satisfaction, high on difficulty and high on cohesiveness. He preferred low friction and low competitiveness. As noted earlier from field notes, interviews and MCI data in Section 4.5.4.6, he did prefer the level of difficulty in the lessons taught to be high because he thought David was repeating topics in electricity earlier covered at Grade 6 and 7 at Community Schools. George believed most parts of the lesson taught were easy and he needed to be challenged. As far as learning in classroom was concerned, George thought in general the lessons were less challenging and boring at times. He would like to see more difficult examples and exercises to be given to students. As far as David's interpersonal interactions in class were concerned, George perceived David's behaviour as having high leadership, high helpful/friendly behaviour, high understanding, but low in student responsibility and freedom. Satisfaction was high.

4.5.5   Perspective 4: Demi

4.5.5.1   Description and background of Demi

Demi was a 15-year-old female student living 18 kilometres out of town in a bush material house without power and running water. Her village was situated a few minutes drive from a major regional highway connecting all towns in the Highlands of Papua New Guinea. As a result, her community was not totally isolated from the outside world. She completed Grades 1 to 6 in a nearby Government run community school before attending schools in town. Her parents were subsistence farmers but had completed Secondary School Education up to Grade 12 and Grade 10 levels respectively.

Researcher: Where do you live at the moment?

Demi: Komiufa [village] (a pseudonym)

Researcher: Do you have power in the village?

Demi: No

Researcher: So you use lamps [at night to study]?

Demi: Yes

Researcher: What are your favourite subjects at school?

Demi: Maths, science, English, social science.

Researcher: Why do you like these subjects?

Demi: Because they explain things I didn't know… new things.

Researcher: What do you want to become when you finish school?

Demi: Airhostess [Airline stewardess].

Researcher: Why do you want to become an airhostess?

Demi: I want to see many [new] places. (Student Interview: Demi 28.02.01, line 27)

Demi's favourite subjects in school were mathematics, science, English and social science. She aspired to be an Air Stewardess after leaving school. Her views on science-technology-society are presented in the next section.

4.5.5.2 Demi's VOSTS results

From an adapted VOSTS questionnaire (Aikenhead et al., 1989) for the Papua New Guinea context that all students in the class completed it was possible to gauge her views on science-technology-society. All eight views expressed by Demi are presented.

Table 4.19

Views Expressed by Demi on Adapted VOSTS Questionnaire Items

Item	Stimulus question	Chosen response	View
1	*Defining science is difficult because science is complex and does many things. But mainly science is:*	exploring the unknown and discovering new things about the world and universe and how they work.	Transitional
2	*When scientists investigate, it is said that they follow the scientific method. The scientific method is:*	I do not know enough about the subject to make a choice.	Other
3	*The more Papua New Guinea's*	because more science and	Canonical

science and technology develop, the wealthier Papua New Guinea will become. Science and technology will increase Papua New Guinea's wealth:

technology would make Papua New Guinea less dependent on other countries. We could produce things for ourselves.

4	*In everyday life, knowledge of science and technology helps you personally solve practical problems (for example, getting a car out that is stuck in the mud, cooking, or personal care and hygiene when you have skin problems or sores on your body)*:	Ideas and facts I learn from science classes sometimes help me solve problems or make decisions about such things as cooking, keeping healthy, or explaining a wide variety of physical events.	Transitional
5	*Science and technology can help people make some moral decisions (that is, one group of people deciding how to act towards another group). Science and technology can help you make some moral decisions*:	by making you more informed about people and the world around you. This background information can help you cope with the moral aspects of life.	Crude/naive
6	*Science and technology offer a great deal of help in resolving such social problems as poverty, crime and unemployment*:	Science and technology can certainly help resolve these problems. The problems could use new ideas from science and new inventions from technology.	Crude/naive
7	*Some cultures have a particular viewpoint on nature and man. Scientists and scientific research are affected by the religious or ethical views of the culture where the work is done. Religious or ethical views do*	I do not know enough about this subject to make a choice.	Other

	NOT influence scientific *research*:		
8	*Science rests on the assumption* *that the natural world cannot be* *altered by a supernatural being* *(for example, a God). Scientists* *assume that a supernatural being* *will NOT alter the natural world*:	I do not understand enough about the topic to make a choice.	Other

Demi was unable to decide on an appropriate response for three items (Items 2, 7 and 8) out of a total of eight. This is consistent with the trend of response from rural students who showed a higher frequency of other answers instead of crude/naïve or transitional or canonical answers in their responses. In total, Demi had one canonical, two transitional, two crude/naïve, and three other responses resulting in a predominantly crude/naïve position on issues on science-technology-society raised in the adapted VOSTS questionnaire as displayed in Table 4.5.

4.5.5.3 Demi's actual and preferred learning environments

Demi expressed her views on the actual learning environment under which she studied as well as her preferred learning environment through the MCI questionnaire (Fraser, 1993) administered to the whole class. Data on Demi's actual and preferred learning environment mean scale scores are presented in Table 4.20. Demi's mean scores are shown along with the class mean, and standard deviation for actual and preferred classroom environments.

Table 4.20

Comparison of Demi's Actual and Preferred MCI Scores with the Class Mean Scores

Scale	Number of Items	Actual			Preferred		
		Student mean	Class mean	Class SD	Student mean	Class mean	Class SD
Satisfaction	4	2.2	2.29	2.35	1.8	2.40	2.36
Friction	5	1.4	1.72	1.63	1.4	1.42	2.06
Competitiveness	3	2.2	2.90	0.82	2.2	2.44	1.63
Difficulty	3	1.0	1.70	2.02	1.4	1.47	1.65
Cohesiveness	4	2.2	1.91	2.85	2.6	2.71	1.91

Note: Item response scale from 1 to 3 (1- never, 3- always)

Demi perceived her actual classroom environment to be higher in satisfaction, competitiveness and cohesiveness. However, she preferred lower satisfaction and high cohesiveness. Her perceptions of friction and difficulty were low in the actual as well as in the preferred classroom environments. It is highly likely that her preference for low satisfaction may well have been an error due to fatigue and difficulty in understanding of the MCI items relating to the satisfaction scale. Demi is a weak student academically, as shown by her expressed view of science which was predominantly crude/naïve, and low score of 45 % on the Two Tier Diagnostic Test (Table 4.5).

4.5.5.4 Demi's perception of the teacher's interpersonal interactions

The next set of results relate to David's interpersonal interactions in the classroom learning environment. Demi's individual scores on the QTI for scales of Leadership, Helpful, Understanding, Student responsibility, Uncertain,

Dissatisfied, and Strict are presented in Table 4.13 against the class group mean and standard deviation.

Table 4.21

Comparison of Demi's QTI Score with the Class Performance and the Teacher's Self Rated Score

Scale	Number of Items	Student mean	Class mean	Class SD	Teacher's mean
DC Leadership	7	3.00	3.42	4.45	3.56
CD Helpful / friendly	8	2.88	3.31	4.99	3.44
CS Understanding	8	2.88	3.29	4.61	3.38
SC Student Responsibility	8	1.63	1.85	3.94	2.47
SO Uncertain	7	0.71	0.71	4.28	0.62
OS Dissatisfied	9	0.89	0.89	4.44	0.46
OD Admonishing	8	0.38	0.97	4.74	0.41
DO Strict	9	1.67	2.11	5.21	2.56

Note: Item response scale from 0 to 4

The QTI results presented in Table 4.13 show Demi's score along with the class mean score and standard deviation of each scale. According to Demi, David showed high Leadership behaviour, high helpful/friendly behaviour and high understanding. David's perceived student responsibility/freedom, and strict behaviours were low while certainty, satisfaction and agreeable dispositions were high. According to the admonishing scale mean score Demi thought David was highly agreeable to students.

4.5.5.5   Demi's prior knowledge of electricity concepts

Demi's prior knowledge of electricity was also tested. The results are discussed. Demi scored 45 % on the two-tier diagnostic test for understanding of electricity prior to instruction. Her score was below the class mean of 55 %. The test items are reproduced in full with circuit diagrams at Appendix D and should

be consulted in conjunction with these discussions on Demi's performance on the diagnostic test. Her response to items 1, 2, 3, 4, 5, 7, and 8 are incorrect in part or whole. Items 6, 9 and 10 were answered correctly.

Item 1. The first tier of the item was correctly answered. However, she incorrectly responded to the second tier. She thought as long as any piece of wire was attached to a battery terminal   an electric current would flow through the wire. She needed to fully understand the principle of current flow in a circuit being conditional to a closed loop arrangement.

Item 2. Demi's response to both tiers of Item 2 was incorrect. She incorrectly believed the current returning to the battery was less than the amount initially flowing out of the battery and passing through the loads. She also held the incorrect view that current flowing to a light bulb is used up completely.

Item 3. Again Demi's misconception about current being used up in the circuit is further verified here, "The current decreases in magnitude because some of it gets used up in the circuit". She got both answers wrong.

Item 4 also tested the concept that current is never used up in a circuit. Demi's response was very similar to those of items 2, and 3.

Item 5 first tier was answered correctly. The second tier response suggested that two loads in series would draw more current than a single load if all loads had identical resistances.

Item 7. Demi correctly answered the first tier of the item. For the second tier she wrote something about guessing the answer, "I don't understand but I'll just   choose one answer (sic)."

Item 8. For this item she answered the full question incorrectly. For the second tier she wrote, "The current will be greater than d (sic)" which really did not mean much to the question being asked.

On the basis of her performance on the Two Tier Diagnostic Test she had the lowest score suggesting limited knowledge of electricity compared to Allison, and George. This was not surprising because she had not been introduced to electricity earlier at Grades 7 and 8 because the school she attended missed teaching this unit.

> **Researcher**: How do you feel about your science lesson today on electrostatics? Was it easy to follow or was it hard?
>
> **Demi**: Some of them easy and some of them hard.
>
> **Researcher**: Which parts were hard?
>
> **Demi**: … (No response)
>
> **Researcher**: You went to Komiufa Primary. Was it top-up school?
>
> **Demi**: No
>
> **Researcher**: Did you study electricity there?
>
> **Demi**: No
>
> **Researcher**: So this is your first time to learn electricity?
>
> **Demi**: Yes. (Student Interview: Demi 13.03.01, line 5)

The next section discusses some of Demi's perceptions about the learning environment and learning.

4.5.5.6 Demi's perceptions about teaching and learning

Demi appeared to be a quiet person in class who only responded when she was required to do so. Her participation in class activities was minimal. She had somehow missed units in electricity taught in community school.

> **Researcher**: How do you feel about your science lesson today on electrostatics? Was it easy to follow or was it hard?
>
> **Demi**: Some of them easy and some of them hard.
>
> **Researcher**: Which parts were hard?
>
> **Demi**: … (No response)…
>
> **Researcher**: You went to Komiufa Primary (a pseudonym). Was it top-up school?
>
> **Demi**: No
>
> **Researcher**: Did you do electricity there?
>
> **Demi**: No
>
> **Researcher**: So this is your first time to learn electricity?
>
> **Demi**: Yes. (Student Interview: Demi 13.03.01, line 5)

Demi was also a shy student and was not confident enough to interact in class with other students or with David.

> **Researcher:** That's good. Why do you like discussing things in class with your friends?
>
> **Demi**: Why I like it is because some of the answers I find it hard to. …hard to work out so I like to discuss with my friends because they will doubt some of my methods to work out the answers.

Researcher: Now if your friends were not able to get the correct answers would you feel free to ask Mr. Mark?

Demi: …I will be shy.

Researcher: If your science teacher were a female, would you feel free to ask questions?

Demi: Yes

Demi would feel freer interacting with a female teacher than with David, a male teacher

Researcher: The lesson taught yesterday was on resistance. Is it your first time to study resistance?

Demi: Yes

Researcher: How do you find it?

Demi: I find it hard. (Student Interview: Demi 01.04.01, line 16)

4.5.5.7   Summary: Perspective 4 - Demi

Demi was categorised as a rural student having completed her primary education in a government school near her village. She held predominantly crude/naïve views of science-technology-society as revealed earlier in Section 4.5.5.2. She admitted that she did not know enough to present a position on the definition/description of the scientific method of investigation, the influence of culture on science, and the possibility of influence of a supernatural being on the natural world. Her assessment of the present classroom learning environment through the MCI in Section 4.5.5.3 revealed high satisfaction, high competitiveness, high cohesiveness and low in friction and difficulty. On the other hand she preferred a learning environment that was high in cohesiveness, slightly less but still high in satisfaction, and low in difficulty. Competitiveness and

friction levels were to remain the same as assessed for the present learning environment.

Demi's score in relation to David's interpersonal interactions as presented in Table 4.21 pointed to a teacher profile with high cognitive outcomes. Demi's Two Tier Diagnostic Test score was very low suggesting a poor prior knowledge of electricity. This was not surprising, due to her limited exposure to the modern technological devices that are not easily accessed in her rural environment. In class Demi was usually quiet and reserved in manner. She felt shy and less confident to interact with others and David in classroom activities.

4.6　　Summary and conclusion: Chapter 4

This chapter presented the results of this research conducted to investigate and interpret the learning environment, and teaching and learning that occurred in a Grade 9 classroom environment in Papua New Guinea within a constructivist framework. The most body of data gathered was derived from the whole class of students and the class teacher, which was further amplified with crucial in depth data from the embedded case study involving four focus students.

The whole class data of students showed that almost 60 % of students in the class held crude/naïve views related to science-technology-society, while 16 % of students held canonical views as shown in Table 4.22.

Table 4.22

Summary of Students' Results for Adapted VOSTS and Two-Tier Diagnostic Test of Understanding Questionnaires

Students in class	Crude/naïve views	Transitional views	Canonical views	Test of understanding mean (Class mean = 55 %)
Rural	50 %	50 %	0%	50 %

Town	70 %	20 %	10 %	55 %
City	45 %	9 %	16 %	65 %

Those who held canonical views were town or city students. Furthermore, the test means for town and city students were higher than for the rural students.

Students in the class preferred a learning environment that was high in satisfaction, high in cohesiveness, but low in friction, low in competitiveness, and low in difficulty. Students' perceptions of David's interpersonal relationships displayed a profile of a teacher with high cognitive outcomes. As far as students' alternative conception of electricity were concerned, students displayed robust and convincing alternative views about electricity concepts similar to those reported in both developing and Western developed countries.

The results of the study reported in this chapter are discussed with implications made to practice and research in chapter 5.

Chapter 5

Discussion and Implications

5.1   Introduction

The aim of this research was to investigate and interpret teaching and learning as they unfolded in a classroom learning environment in which a Grade 9 class was taught a unit on electricity in Papua New Guinea, by the regular class teacher. Data were gathered through multiple data gathering techniques and sources. As earlier mentioned in Section 2.7, to provide a focus for the study, four research questions were formulated:

1. How did the students in this classroom view the nature of science in the context of teaching and learning?

2. How did the students perceive their learning environment and the teacher's interpersonal interaction?

3. What were the students' prior knowledge and experiences about electricity before instruction?

4. What were the cultural referents displayed by the teacher and the students that impacted on teaching and learning?

In this chapter the major findings of the study are discussed in relation to these four questions in turn and the research literature previously reviewed in Chapter 2. The first four sections of this chapter are structured around answers to each of the questions in turn. The proposed answers serve as headings for these sections. The sixth section reviews the methodology employed in this study and identifies its limitations and delimitations. Implications for science education and science education research, particularly for the Papua New Guinea situation, will be proposed in the seventh section. The eighth and final section provides a summary of the chapter.

5.2 How did the students in this classroom view the nature of science in the context of teaching and learning? - Research question 1.

5.2.1 The students' views about the nature of science in the context of classroom teaching and learning: Overview

Section 4.4.2 discussed the results on students' views about science obtained through the use of an adapted VOSTS questionnaire in this study. The students' views data sourced from interviews and the researcher's field notes resulted in the development of a body of findings arising about students' views on the nature of science. Students' understanding of the nature of science and the understanding of the science-society interrelations are both essential factors in the teaching and learning of science (Driver et al., 1996). Students' predominant views about science-technology-society could be grouped into these categories, as one of either crude/naïve, transitional or canonical. Furthermore, students were divided into three groups based on their origin as one of either rural, town or city students.

All rural students subscribed to views of science that were predominantly crude/naïve or transitional. Town students expressed views that were similar to that of rural students but included some canonical views. For city students, more than 50% held predominantly transitional or canonical views.

There was also a degree of similarity in views expressed between the three student groupings of origin in that 58 % of the total number of students in the class expressed crude/naïve views about science or at least 45 % of students from anyone of the groupings of origin displayed crude/naïve views about science (Table 4.4). Moreover, it appears that the variations of the categories of students' science views (crude/naïve, transitional, canonical) were related to the students' three groupings of origin (rural, town, city) which were linked to their background

and upbringing. For instance, many rural students displayed predominantly crude/naïve views about science-technology-society.

5.2.2 Similarities and differences between groupings of students to their science views

The evidence presented in this study through the adapted VOSTS questionnaire showed the three different categories of students' views about the nature of science (crude/naïve, transitional and canonical) expressed by the students. This aspect of the study reflected students' understanding of the nature of science, that are referred to as the metacognitive dimension (Seroglou & Koumaras, 2001) in teaching and learning science. The metacognitive dimension represents the use of generative self-regulatory strategies which enable students to reflect on, construct meaning from and control their own activities, enhance the acquisition of knowledge by overseeing its use and by facilitating the transfer of knowledge to new situations. Students are more likely to develop wide-ranging thinking skills if they are encouraged to think about their own thinking, to become aware of the strategies of their own thinking and actions (Adey & Shayer, 1993; Perkins & Salomon, 1989). The metacognitive dimension of students' learning includes the understanding of the nature of science and the understanding of the science-society interrelations which are both essential factors in the teaching and learning of science (Driver et al., 1996; McComas et al., 1998). The understanding of the nature of science involves the understanding of the content of science as well as the understanding of the nature of scientific methodology. According to Seroglou and Koumaras (2001), the understanding of the nature of the content of science is reflected in the understanding of the philosophical dimension of explanation, of experiment, and on the recognition that science is a functional model of interpreting, describing and predicting phenomena.

As alluded to earlier in Section 2.5.3.2, inadequacies in students' understandings of the nature of science are related to their understanding of the strengths and limitations of science, interest in science and social decision making (McComas et al., 1998). Findings in this study were similar to those of an earlier study conducted in Papua New Guinea (Section 2.6.3) by Mackay (1970) who investigated three key areas of trainee teachers' understanding of the nature of science. They were understandings about the science enterprise, understandings about scientists, and understandings about the methods and aims of science. The findings from Mackay's study showed that first year high school trainee teacher's understandings of the nature of science were consistently less than desired. In this study a high percentage of students in each grouping of origin (rural, town, city) subscribed to crude/naïve views, resulting in almost 60 % of students in the class having this view. That is, 50 % of rural students, 70 % of town students, and 45 % of city students held crude/naïve views of science. On the other hand, 26 % of students in the class expressed transitional views, which comprised 50 % of rural students, 20 % of town students, and 9 % of city students. Only 16 % of students in the class expressed canonical views of science which included 10 % of town students and 45 % of city students. None of the rural students expressed canonical views of science.

While commonalities in views of science-technology-society between groupings of origin were evident, so too were variations. The variability of students' views to VOSTS items based on student's origin was one noteworthy aspect of the research findings which has not been evident in other studies. For example, this variation is evident when comparing the views of Allison and Demi. Allison, a city student displayed predominantly canonical views of science compared to Demi (a rural student) who held predominantly crude/naïve views.

In summary, more than half of the students in the class and relatively higher percentages of rural, and town students held crude/naïve views about science. Transitional views were mostly expressed by rural and town students,

whilst canonical views of science were expressed by a higher percentage of city students. Thus, transcending groupings of origin of rural, town and city, many students expressed similar views of science which were crude/naive. On the other hand, differences were noted in the canonical views expressed. Appreciably more city students were able to express canonical views of science than their rural and town counterparts.

5.2.3   Explaining the variations of the groupings of origin to science views

As pointed out in the above section, a large number of students (58 %) across the three groupings of students' origin held predominantly crude/naïve views about science. Only town and city students in the sample were found to hold canonical views. Allison and Demi were of the same age, gender and lived in villages about 10 kilometers apart. However, Allison lived most of her life in Port Moresby, the capital city of Papua New Guinea before returning to her village two years ago. Allison's home had electricity and running water because her village was a modern one on the outskirts of town and had access to electricity and telephone services.

On the other hand, Demi had lived most of her life in her village with limited modern conveniences in her home and at the local primary school she attended. Accordingly, her exposure to the modern, high technology world was less than her urban counterparts. Thus, her limited exposure to the modern world and its technology was reflected in her views of science-technology-society. As earlier alluded to in Section 2.6.3, the only recorded study on students' views of the nature of science undertaken in Papua New Guinea at the time of conducting this study was by Mackay (1970). One of his major findings was that students' understanding of the nature of science at the completion of high school studies was considerably less than expected for the students in Papua New Guinea. This suggested that in general, students' understanding of the nature of science was inadequate and consequently would impede their understanding of science taught

in schools. There was no formal course on the nature of science in the NDOE curriculum. Thus, it was not surprising that more than half of the students in the class observed subscribed to crude/naïve views about science-technology-society.

Apart from the non-inclusion of nature of science units in the curriculum, the other likely explanation for the poor understanding of the nature of science was because of the overall students' relatively limited exposure to the trappings of the western cultures. For example, students who lived and attended school in a rural community in Papua New Guinea had less experience with computers compared to their counterparts in town or city schools who had easy access to computers and were computer literate to a certain level. In the view of the researcher this was crucial to students' learning of science because modern technology and science are closely related in many regards. Accordingly, city and town students who are more exposed to modern technology might be suspected to have a better grasp and appreciation of modern technological equipment and instruments in their learning environment. Conversely, their rural counterparts are prone to becoming easily overwhelmed when confronted by aspects of modern science and technology, thus unnecessarily slowing their rate of learning in a science class. Aikenhead (1996) emphasises that science and technology are western subcultures and in order for the students to learn canonical science, it may assist if they are familiar with the everyday aspects of the developed western world such as modern conveniences, technologies and electronic media which are important in the modern world.

5.3 How did the students perceive their learning environment and the teacher's interpersonal interaction? – Research question 2.

5.3.1 Introduction: The contemporary learning environment

As discussed earlier in Section 2.5.4, over the past three decades many researchers internationally have shown interest in the conceptualisation,

measurement, and investigation of perceptions of psychosocial characteristics of the learning environment of schools; culminating in the development of several instruments to assess classroom environment (Fraser, 1998; Kim et al., 1999; Taylor et al., 1997).

The learning environment concerned in this study was investigated in part, using the adapted MCI and QTI questionnaires. Table 4.2 presented the whole class performance on the MCI for actual and preferred classroom environments. As briefly mentioned earlier in Section 4.3.3, the alpha reliability for the students' results from the MCI instrument were interesting in terms of the students' understanding and conceptualisation of the scales used. It seemed the students' worldviews based on their culture may have influenced their interpretations of some of the dimensions integral to the MCI instrument. Accordingly, some students' interpretations of scales may have differed to the interpretation made by their counterparts from developed Western nations where the questionnaire was developed. Cohesiveness, for example, meant a whole lot more for the group's survival in the context of their informal traditional learning environment because the collective interest of the group is fostered if the group is cohesive. Accordingly, it would be desirable for students from Papua New Guinea to promote a highly cohesive environment because in the Papua New Guinean students' traditional culture, the collective community interests take priority over individual interests (Pauka et al., 2000; Waldrip & Taylor, 1999). By the same token, the difficulty scale would be viewed by students as being in direct opposition to the groups' interest, and so will be less important for the students' consideration. Overall, out of the five scales of satisfaction, friction, competitiveness, difficulty, and cohesiveness; satisfaction and cohesiveness would be highly valued by the students who would have strong traditional backgrounds. The students' perception of their actual learning environment was different from their traditional environment, which is elaborated in the next section.

5.3.2 Students perceived the actual learning environment as high in competitiveness, low in friction, difficulty and not too low in satisfaction, and cohesiveness

The perception of the actual learning environment by the students differed from their traditional learning environment where satisfaction and cohesiveness is highly valued. For example, students perceived the actual learning environment in the classroom was highly competitive for them (and they preferred lower levels of competition), in contrast to their traditional learning environment in which competition by individual members of the group was less important than group competition. In the traditional cultures of Melanesia where the students came from, the collective interests of groups take precedence over individual interests and concerns, as highlighted in the previous section (Pauka et al., 2000; Taylor, 1997; Waldrip & Taylor, 1999). Further, students perceive the difficulty level of the classroom was low and this may be due to the fact that electricity was taught earlier at Community Schools. David the class teacher also took almost double the time to teach the unit on electricity as instructed by Head of Lower Science in the teaching schedule she prepared for teachers (Table 4.2). Friction was perceived to be low and it is culturally acceptable to have less friction in the group than friction between different groups.

In summary, it is clear that there was some mismatch between the actual learning environment in class and the students' traditional learning environment based on their indigenous cultures as perceived by students. The MCI questionnaire was developed by researchers within a developed Western world context and thus reflected western values and norms that were very much different to the local context in Papua New Guinea.

5.3.3 Students preferred a learning environment that was high in satisfaction, cohesiveness, and competitiveness, but low in friction, and difficulty

Students' desire for a learning environment higher in satisfaction and cohesiveness reflects the nature of their traditional learning environment as discussed in Section 5.2.3 above. The high mean scores for the scales of preferred satisfaction and preferred cohesiveness meant students preferred a learning environment that was more satisfying, and cohesive. This could be described as an environment where the students enjoyed doing their schoolwork, were happy, and felt it was fun to be in class. They also had friends and worked well with others in class. Students' expressed preference for relatively high competitiveness may be seen as due to the pressure to score better grades to obtain a place at tertiary institution for further studies or formal employment in urban areas. Thus, competition has been fostered by modern life styles that were due to modernisation in Papua New Guinea. At the same time, students preferred even less friction, and less difficulty. Students liked to see behaviour which had fewer conflicts amongst themselves, and school work that was less difficult to do.

5.3.4 Students' perception of David's interpersonal interactions highlighted leadership, helpful/friendly, and understanding.

Students in this particular classroom in Papua New Guinea perceived their teacher, David to have demonstrated high leadership qualities, and that he was helpful/friendly and very understanding towards students. The students also believed David was very confident and certain in his interactions in class. Satisfying and supportive behaviours were highly evident in David's interactions in the classroom. These perceptions by students and David seemed to parallel general perceptions of teachers in the traditional informal learning environment where the teacher was usually a respected village elder with leadership qualities teaching students in a friendly / helpful and understanding manner to gain the skills of gardening or understanding traditional knowledge for example (Pauka & Treagust, 1999).

According to Wubbels (1993) such a profile of the class teacher is positive for an effective, productive learning environment, and extensive studies in several countries including Australia have indicated that the Strict (DO), Leadership (DC), and Helpful/friendly (CD) scales correlate positively with student achievement. Consequently, as earlier shown in Figure 4.9, David's interpersonal interactions in class depict behaviours which foster high cognitive outcomes. Interestingly, David's self perception (Figure 4.10) has similar scores to the students' perceptions (Figure 4.9) which reflects the commonality in the general expectations of the teacher during teaching and learning by students and the teacher.

5.4   What were the students' prior knowledge and experiences about electricity before instruction? – Research question 3

5.4.1   Introduction: The prior knowledge concerning electricity

The understanding of electricity concepts has been difficult for most students in Papua New Guinea because of the abstract nature of the content (Najike, 1993). It was even more difficult for most students in Papua New Guinea because of their rural backgrounds and upbringing, which limited their exposure to modern technology and way of life. Because 85 % of the population of Papua New Guinea lived in rural areas with subsistence farming lifestyles, electricity concepts and other electrical modern conveniences common in most homes, especially western homes, are foreign to these students.

For instance, students who lived and attended school in a rural community in Papua New Guinea had limited knowledge of computers compared to their counterparts in town or city schools who had easy access to computers and were computer literate to a certain level. In the view of the researcher this was crucial to students' learning of science because modern technology and science are closely related in many regards. Accordingly, city and town students who are

more exposed to modern technology might have a better grasp and appreciation of modern technological equipment and instruments in their learning environment. Conversely, their rural counterparts are prone to becoming easily overwhelmed when confronted by aspects of modern science and technology, thus unnecessarily slowing their rate of learning in a science class.

5.4.2 The commonality of conceptions

Students' preconceptions in the domain of electricity showed a number of alternate conceptions prevalent at this level of students in schools (Najike, 1993; Osborne, 1983; Shipstone, 1984), and related to the behaviour of current as it passed through light bulbs within an electric circuit and how current was affected by the dry cells. The two most common alternate conceptions experienced by the students were: Current flowing in an electric circuit does get used up, being consistent with Shipstone's (1984) attenuation model; and, an electric current flows through wires that are fixed to terminals of dry cells even if the wires do not form a complete closed loop for current to circulate in.

Tests on more advanced concepts involving application of Ohm's law, current and voltage relationships in parallel circuits, and energy transfer from voltage source to load also received incorrect responses. This was an expected outcome for these students because at their level of study the students' personal experiences provided limited opportunities for them to be exposed to the particular advanced concepts before them provided by the diagnostic test questionnaire on electricity.

5.4.3 Absence of traditional cultural ideas in prior knowledge about electricity

Students showed reluctance to express alternative ideas about the origin and nature of electricity that were linked in any way to their cultural worldviews, especially to explain why light bulbs light up in terms of the spirit world, for

example. Even if they had these views, they did not share them during interviews with the researcher. They may have thought their traditional culturally oriented worldviews were inferior and did not make any sense compared to the canonical science views. Part of this behaviour may be attributed to the influence of early missionaries in Papua New Guinea who held a dim view of the indigenous cultures and worldviews, considering them to be paganistic and anti Christian. It is also possible that this may be one area in the physical sciences where students' alternative conceptions are not likely to have cultural roots (Taylor, 1997).

As far as alternative conceptions that do not have cultural worldviews or roots are concerned, the students in the class displayed alternative conceptions that related to and evolved from their earlier basic study on electricity at community school where they were introduced to the basic concepts of voltage, current, and circuits. The students' alternative conceptions included the behaviour of current flow in simple direct current electric circuits. For instance, an electric current passing through a series circuit gets used up, and so the current in this circuit is greater in magnitude before a light bulb than after it (Table 4.8). The students' in this class in Papua New Guinea held alternative conceptions that were robust and convincing to them, similar to students in high schools elsewhere. It would appear that as Taylor (1997) suggested, in some aspects of physical science there may be little need for further research into alternative conceptions held by students in developing countries as these are not likely to have cultural roots and should vary little from those presented in the alternative conceptions literature.

5.5 What were the cultural referents displayed by the teacher and the students that impacted on teaching and learning? – Research question 4

5.5.1 Introduction: The cultural referents displayed by the teacher and Students in the classroom learning environment

As discussed in earlier sections in the literature in Chapter 2, students from developing countries such as Papua New Guinea attend school with very traditional Melanesian worldviews which may conflict with the Western worldviews. In general, Papua New Guinean students' traditional Melanesian worldviews remain robust, much the same, as they were generations ago because of the strong ties to land and the environment for survival. Most land in Papua New Guinea is owned by clans, and over 85 % of the population in Papua New Guinea live in rural communities and make a living through subsistence farming, whilst less than 15 % of the population live in towns and cities. Thus, many students would hold onto traditional beliefs and worldviews with vigour. Only a small minority of students who are raised in towns and cities would be likely to have modern beliefs and worldviews as a consequence of their upbringing in a modern environment.

In the study, the cultural referents displayed by David and the students were clear during teaching and learning, and interactions in the learning environment between students and David. These cultural referents displayed were inherent in (1) the nature of the learning environment, (2) students reaction and response to teaching and learning; and (3), teaching and learning approach adopted by David.

The students' preferred learning environment reflected students' anticipated learning environment that was consistent with their traditional learning environment which were usually highly cohesive and satisfactory, as earlier discussed in Section 5.2.3. In the students' traditional learning environment the groups' interest and survival through the acquisition of traditional knowledge was of greater importance. Traditional knowledge in these environments was transferred from teacher to student in a direct transmissionist model of teaching style that was dominated by teacher centered activities with limited student participation. In the learning environment investigated in this study, David was the knowledge source and students were the passive recipients

of knowledge. In the culture of the students and David, this was the acceptable approach of teaching where knowledge was transmitted from a source, usually a respected elder in the community to students. For students to ask specific questions about the content of traditional knowledge was seen as disrespectful to the teacher and was not encouraged (Waldrip & Taylor, 1999). Overall, there was limited student participation in class.

With less student participation, students' reaction and response to teaching and learning were equally subdued and appeared superficial. Most students responded only with short answers when questions were directed at them by David. It was rare for students to ask questions to find out more about the subject knowledge. David's approach to teaching and learning was again influenced by his cultural orientations. He saw himself as the dispenser of knowledge to students, and to a certain extent spoon fed students with content knowledge and information. On many occasions there were less challenging activities for students, and David rarely used students' prior knowledge in his teaching approach.

5.5.2   Influence of cultural referents on teaching and learning

The impact of traditional cultural ideas and worldviews of students and David influencing teaching and learning is discussed in the context of the observed learning environment and the strategies for teaching and learning utilised in studying electricity to provide an insight to the reader.

The influence of the observed behaviour associated with students' and David's culture impacted on learning in three important ways; (1) discouraged meaningful learning, and students becoming responsible for their own learning, (2) took more time to teach ; and (3), engaged lower cognitive skills of students. These attributes of traditional culture influencing teacher and learning are highlighted in the next few sections.

5.5.2.1 Discouraged meaningful learning and students' responsibility for learning

Learning of electricity by students was not deep enough to be meaningful and long lasting for students. Students were not actively engaged in their learning in the classroom. Despite efforts from David to encourage active student participation by emphasising student centred activities, students were not responding, and seemed to accept everything taught by David without question. Therefore, in general, David was trying modern classroom learning strategies but class response led to adoption of teaching strategies closer to traditional learning. This situation resulted in students becoming predominantly passive learners dependent on David's teaching strategies, notes on the chalkboard and handouts for information on electricity. The existing school culture did not improve matters because the entrenched school culture in public schools in Papua New Guinea and neighbouring Melanesian Island countries of Fiji and the Solomon Islands promoted a teacher driven approach and limited student-centred teaching and learning consistent with the purpose being for students to pass examinations in direct contrast to learning for deeper understanding of the subject content (Muralidhar, 1989; Rodie, 1997; Taylor, 1997).

5.5.2.2 Took more time to teach

Teaching and learning in the classroom learning environment became a slow process because David frequently attempted to help each individual student master key points of his lessons before progressing further. In this regard, David seemed to be applying a mastery learning approach which is a common trait in the traditional teaching and learning model based on the indigenous culture of students and David. On many occasions some students thought David was repeating topics taught earlier in lower grades at primary school which showed lack of linkages with science content taught previously. Yet, David could see students were not

forthcoming about their prior understandings so as to demonstrate they understood the concepts.

It is also noteworthy to understand that in the traditional teaching and learning situation there was no pressure on students to meet deadlines in their learning or for the elder teaching these students to finish a topic within a given time frame. The traditional teaching and learning environment was informal and there was no time limit on teaching a certain unit of work. For example, it really did not matter whether students learned to build a canoe in a month or six months; or whether all the stories about the spirits in the forests are told to students by elders with in a limited time period or not. Also pressure on students to succeed in their studies in the traditional teaching and learning environment is less intense than in the modern formal teaching and learning situation in which parents and guardians impress on students the need to perform well at school in order to secure paid employment in towns and cities, and to cope with the pressures of modern life styles.

5.5.2.3 Engaged lower cognitive skills in students such as rote learning

Students' cognitive skills were not challenged enough. The teaching strategies and activities adopted by David rarely made connections to students' prior knowledge and preconceptions inherent therein. David's lessons on electricity involved fundamental concepts. He displayed a solid grasp of the subject matter content inherent in the lessons but students did not engage in thought provoking activities to show that what they learned was deep and meaningful. Students' showed learning occurred at a reproduction level when they reproduced what David presented in class, as either notes on the chalkboard, handouts, or orally. Application type problems were rarely set by David to challenge students' thinking and understanding of propositional and procedural knowledge.

5.5.3 Conclusion

Findings showed that the students displayed behaviour that was usually present in the informal traditional teaching and learning environment common throughout Papua New Guinea. These behaviours included students' reluctance to ask questions freely and waiting on the teacher to provide most answers to questions on worksheets and exercises. In practical sessions the teacher was expected to show students how to connect electrical circuits and take voltage and current measurements. In the informal traditional teaching and learning situations of story telling and apprenticeship type models students listen and learn by imitating what they see. In the classroom environment studied there seemed to be a mismatch of what the learning environment ought to be in David's class. Students attended the class with perceptions of a learning environment consistent with elements of the traditional informal learning environment whilst on the other hand David's perception of a learning environment was one in which meaningful learning was the most desired outcome. In order to improve students' learning and understanding of science in the particular classroom, the science curriculum should be revisited with a view to shifting the emphasis from a behavioural framework to one that promotes meaningful learning and makes students responsible for their learning. New components of cultural sensitivity should be included as well, aimed at building bridges or "border crossing" (Aikenhead, 1996) from the students' (and teachers') culturally oriented views to the canonical views in science and science pedagogy.

It is beyond the scope of this study to identify possible cultural referents that are inherent in this particular Papua New Guinean classroom environment that may be useful for fostering improvements in teaching and learning. However, these may become research questions for future research in the field of cultural aspects of learning science and related areas of research.

5.6 Methodological issues

This study has been conducted within the framework of constructivism to investigate and interpret teaching and learning, and the classroom learning environment; taking into consideration the influence of culture on practice in a high school classroom in Papua New Guinea. Section 2.6 reviewed the present state of research and the shortcomings of the research conducted in teaching and learning science, and classroom learning environment in Papua New Guinea. On the basis of this review and the need to investigate and interpret teaching and learning in a particular classroom environment, the researcher engaged in this research as a non-participant observer. This section reviews the limitations and delimitations of the research conducted and points the way to implications arising from the research that are outlined in the following section.

5.6.1   Limitations of the study

An important methodological issue in this research into the efficacy of an observation centred on teaching and learning electricity, and classroom environment conditions involves the time allowed for the observation phase, immediately following the classroom environment quantitative data gathering phase. All phases of the study constituted 12 weeks. This study, while investigating and interpreting the nature of teaching and learning, and the classroom learning environment that existed in the secondary school in Papua New Guinea may have benefited from further time to investigate the existing situation. It could be argued that observation of teaching and learning electricity after a prior phase of gathering quantitative data using questionnaires on classroom learning environment may have had an effect on some students. One can only speculate on the possible effects of having a more prolonged and varied engagement on teaching and learning and its entailments. A longer time frame for the research would also have enabled observation of a second topic to add to the body of data.

In relation to quantitative methods used in data gathering, the interpretations made from raw data resulting from the use of the four test instruments engaged in the

study should be interpreted with caution because those instruments were developed and validated in a different context and setting to the one in which the study was situated. The researcher was mindful of this particular situation and took particular care during piloting of the test instruments to ensure interpretability of instruments in the Papua New Guinea context.

A further limitation of this study relates to its design. The design of the study was centred on the embedded case study reported in Chapter 4. The researcher made a conscious decision to adopt such a design in order to provide an insight into a specific issue, teaching and learning of science, and the context in which teaching and learning occurred at a particular secondary school in Papua New Guinea. As Stake (1994, p. 245) noted, "The purpose of the case study is not to represent the world, but to represent the case." The case study has provided in-depth data related to the context of the focus students whose perspectives constituted the case. However, one consequence of this decision regarding the design is that it is incumbent on the reader to transfer the findings of the research with respect to that issue to other contexts. Importantly, also, the outcomes of this study need to take the context of the study into consideration when being interpreted. It may not be wise to generalise, especially regarding the perceptions of science and the learning environment by students across diverse contexts or with participants of different ages or backgrounds.

5.6.2 Delimitations

Section 2.6 reviewed the status and development of science education research in Papua New Guinea from the late 1960s, during Australian colonial rule, to the present time. This comprehensive review concluded that there was limited research, of which none at all was conducted into classroom environment, and teaching and learning using interpretive methodologies as applied in this study. As such, this research, for the first time provides an illuminating window through which the reader achieves some fuller understanding of the intricacies and salient points inherent in teaching and learning science in a high school learning environment in

Papua New Guinea. Undertaking research as an insider researcher involved as a non-participant observer also enabled the researcher to get close to the student participants and understand their individual and collective, views and contexts. The students' perspectives reported in this study suggest that students were willing to share their thoughts in a forthright and open manner. The researcher was privy to aspects of their world not often afforded outsiders. Unsolicited one-on-one interviews apart from the regular organised ones, notes during class, and reminiscences regarding past teachers and teaching approaches are examples of the avenues of communication that were afforded the researcher by virtue of his relationship and his insider status within the context. The same could be said of David, the class teacher participant.

5.7   Implications and future research directions

In this section the implications of the research and the future research directions are considered. A fundamental issue in relation to teaching and learning in Papua New Guinea is considered first. Research questions related to this issue follow this consideration. This is followed by issues and related questions that apply specifically to this current study. A brief explanation of the educational importance of each question and how each question might be investigated follows each question.

5.7.1   Teaching and learning as a duality

Overall, teaching and learning science at present in the classroom observed was directed by the predominant teaching style of more teacher directed activities and less student-centred activities. To a large extent, teaching and learning activities involved chalk and talk, some teacher demonstration of concepts and principles using science apparatus, and individual student group experiment work. The order of these activities reflected the emphasis placed on each activity where the first activity of chalk and talk occupies the most time with group experiments taking the least time. This approach to teaching and learning appeared to constitute elements of both

formal school teaching and the traditional teaching and learning strategies inherent in the students' and David's indigenous cultures. For instance, in the traditional teaching and learning situation the teacher (elder in the community) spends the most time of the lesson talking to his or her students. Furthermore, in class students tried to identify with aspects of their traditional learning environment by preferring cohesiveness and satisfaction for the collective interests of the group in contrast to individual competition and interests.

Ogunniyi (1988), and Mitchie and Linkson (1999) state that it is possible to hold simultaneously an indigenous view and a scientific view of the world. They believe it is feasible for students from developing countries, and indigenous and minority groups from developed countries to be given access to the full range of Western science and to understand its underlying philosophy, as well as retaining their cultural worldviews; thus, having a dual view of the world. It is evident from this study that students would also prefer to simultaneously engage in teaching and learning activities from both their indigenous traditional approach and the formal school approach in the classroom learning environment. The following principles related to teaching and learning in the classroom learning environment observed would seem credible on the basis of this study.

1. Teaching and learning involved activities based on the indigenous traditional approach, and the existing formal approach.

Further research would be required to define in practice how a dual approach to teaching and learning would work. However, as a first step it may make sense for teachers to be culturally sensitive in their practice. As Aikenhead (1996) states emphatically, new components of cultural sensitivity should be included as well aimed at building bridges or "border crossing" (Aikenhead, 1996) from the students (and teachers) culturally oriented views to the canonical views in science and science pedagogy.

2. Students seek a learning environment that related to their indigenous traditional learning environment.

Students are comfortable with what they are familiar with in their worldviews and perception of the learning environment and so teachers and curriculum writers need to be aware of this reality. Yet, the researcher does not see a situation where the traditional approach to teaching and learning and learning environment dominate over the formal approaches.

Future research into teaching and learning in a similar non-Western context based on such principles might investigate the following questions.

1. What are the characteristics of the student's classroom learning environment where elements of the dual approaches to teaching and learning are present?

It would seem appropriate to investigate students' perception of their learning environment and identify attributes that promote or constrain students' learning, in order to minimise the mismatch between the indigenous approach and the existing formal approach of teaching and learning. This question requires both large-scale, predominantly quantitative studies using available and yet to be developed classroom environment instruments that are coupled with intensive case studies which serve to amplify a body of data of the type reported in this study.

2. Are there differences between the indigenous and existing formal approaches with respect to the value and practices in relation to teaching and learning and, if so, what attributes mediate teaching and learning within those approaches?

The importance of cultural aspects in teaching and learning has been highlighted in this study. This question would benefit from large-scale survey

methodology with intensive case studies of the type reported in this study being used to further understand trends that emerge from the survey data.

5.8 Summary of the chapter

In this chapter the major findings of the study have been discussed in relation to the four research questions and the literature previously outlined in Chapter 2. Answers to the research questions have been proposed and discussed on the basis of the results. Several claims can be confidently made about teaching and learning, and the context in which teaching and learning transpired. There were differences in views about the nature of science in the context of teaching and learning amongst different categories of students. Regarding the context, students' perceived their learning environment in a positive light, though, predominantly higher cohesiveness and satisfaction were preferred, resonating with their traditional learning environment based on their indigenous cultures. The cultural referents displayed by David and the students impacted on teaching and learning in a number of ways. Students, as well, perceived David's interpersonal interactions as displaying leadership, helpful, friendly, and understanding qualities. The students' preconceptions on content area of Electricity has been highlighted and discussed. The limitations and delimitations of the methodology employed in this study have been identified and discussed. Implications for science education and science education research have also been proposed and discussed. This study makes a significant contribution to theoretical issues related to teaching and learning science in a context with many variations to that of the Western developed nations. The implications of the findings for future research were outlined by way of a series of research questions that have the potential to further advance knowledge and understanding in this area and in doing so possibly advance classroom teaching and learning. In the final, forthcoming chapter of this thesis concluding remarks are made regarding this study.

Chapter 6

Summary and Conclusions

The thesis began by highlighting what the study was about, why the study was conducted, the aim of the study, the context specific to Papua New Guinea, and the significance of the research. As stated previously in Chapter 1, the study was about investigating teaching and learning that occurred in a high school classroom learning environment because of learning difficulties of science concepts and principles experienced by students in Papua New Guinea. The aim of the study was to investigate and interpret learning approaches and outcomes, as they unfolded in a naturalistic setting in which a Grade 9 class was taught a unit on Electricity by the regular class science teacher. The study was intended to present a model that interpreted the teaching and learning approaches employed in the learning environment by students and their teacher; as well as, interpret learning outcomes in the particular school. No intervention was introduced. In accordance with the aim of the study the following research questions were formulated:

1. How did the students in this classroom view science in the context of teaching and learning?

2. How did the students perceive their learning environment and the teacher's interpersonal interactions?

3. What were the students' prior knowledge and experiences about electricity before instruction?

4. What were the cultural referents displayed by the teacher and the students that impacted on teaching and learning?

It was envisaged that as a result of this study, science education in Papua New Guinea stood to gain in the following ways; by enabling the researcher to establish a foundation for productive science education research at the main teacher training tertiary institution where he is employed as a full time academic staff member; and, contributing to the development of teaching and learning science in high schools to foster improvement in students' learning.

A review of the literature provided the theoretical background to the study, drawing the reader's attention to the problems inherent in students' teaching and learning in relation to their poor grasps of abstract science concepts, in a Secondary School learning environment in Papua New Guinea. Students' poor understanding of abstract science concepts, and teaching and learning in general in formal classroom learning environments have been shown to be influenced by the students' and the teacher's cultures and worldviews. The individuals' worldviews and the cultural context in which learning occurred was highlighted, together with the complexity and importance of the shifts in learning paradigms in science education research, the nature of the learning environments, and the changing fashions in science education research. The review of the literature ended by drawing the reader's attention to the contextual issues related to the existing teaching and learning practices which generally employed low-level cognitive skills of students, and the incongruity of educational objectives with actual outcomes of science education in Papua New Guinea. Furthermore, science education research in Papua New Guinea was shown in the literature review to be limited in scope and volume, and therefore there was a need for research to be increased in almost all areas of science education. At the time of writing this thesis, there were no interpretive research in science education of the type applied in this study conducted into teaching and learning, and the learning environment in schools in Papua New Guinea.

For this study, an interpretive research methodology involved the researcher taking on the role of a non- participant observer in a Grade 9 classroom in a Secondary School in Papua New Guinea. In this way the researcher sought to

make the research ecologically valid. Multiple research methods were used to allow the researcher to maintain foci on students' learning environment, students' and the teacher's perceptions about teaching and learning, and teaching and learning in the classroom; while also giving attention to investigating the contexts of the research. The focus on contexts was in keeping with the constructive nature of the research. A Grade 9 Unit on Electricity was taught in the usual way by David, who was the regular science class teacher.

The findings from the research portray a model that interprets the teaching and learning approaches inherent in the classroom, as well as, students' perceptions of the learning environment present in this Secondary School in Papua New Guinea. Evidence was presented that student views about the nature of science in the context of teaching and learning varied from those which were crude/naive to those that were canonical. All rural students expressed views that were predominantly crude/naïve and transitional. On the other hand, city students held views of science that were predominantly transitional and canonical. These variations in views about science in the context of teaching and learning were dependent on students' backgrounds. Rural students had limited exposure to modern technology in contrast to town and city students. Also, evidence presented that students perceived their preferred classroom learning environment in a positive light with greater satisfaction, cohesiveness and competitiveness as expressed through MCI Questionnaires (Fraser, 1993). These preferences were congruent with traditional learning environments found in the students' indigenous cultures where the groups' satisfaction and cohesiveness were paramount. There was evidence to suggest that the students' perceptions of David's interpersonal behaviour in the classroom (Wubbels, 1993) highlighted leadership, helpful/friendly and understanding qualities characteristic of teachers in the students' traditional learning environments (Waldrip & Taylor, 1999; Pauka et al., 2000). Teachers in the traditional learning environments were usually village elders with leadership qualities who were highly respected by their students. There was evidence to suggest that the influence of the observed behaviour associated with students and David's culture impacted on learning in

three important ways; by limiting meaningful learning, was time consuming, and engaged lower cognitive skills of students.

The findings from the research support the claim that some of the students' preconceptions in the domain of electricity were common to high school students of similar age groups the world over (Najike, 1993; Osborne, 1983; Shipstone, 1984). Common misconceptions related to the behaviour of current as it flowed in electric circuits. On the other hand, it seemed David did not use students' prior knowledge of electricity in his teaching strategy. This may be due to what he believes is the limited time he has to teach the unit.

The scene is set for further research into teaching and learning, the learning environment, and the influence of the indigenous culture of the students in teaching and learning science in Papua New Guinea. Such research should look at, for example, the characteristics and types of classroom learning environment where there is dual approaches to teaching and learning within the dichotomy of the existing formal based on canonical science and the informal, influenced by the indigenous culture of the students, ways to adapt aspects of the traditional teaching and learning strategies based on indigenous cultures into the existing approaches to teaching and learning so that teaching and learning is improved, and the efficacies of making science curriculum sensitive to aspects of the indigenous cultures of students. In such research lies the possibility that students may gain improved understanding of canonical science which lays a strong foundation for further advanced studies at tertiary levels or for use of basic science ideas in their community to improve their lives in Papua New Guinea by students unable to continue their education or can not find employment in the urban centres.

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Appendix A

VOSTS questionnaires used to gather data on students' views on science (Section 3.7.3.1).

Views on Science, Technology and Society (VOSTS)

The aim of this instrument is to understand the viewpoints that high school students hold on the complex topic of "science, technology and Papua New Guinean society".

Instructions:

Each question of the VOST inventory begins with a statement about science technology-society topic. Most of these statements express an extreme view on the topic. You may happen to agree strongly with this view; you may happen to disagree vigorously; or your own view may be between the two.

Next, there is a list of positions (or view points) on the issue stated. Read the statement carefully and then check through the different positions expressed on the issue.

Finally, circle the one (ONE ONLY) that is the same or the closest to your personal view.

There are no "right" or "wrong" answers; this is not a test and will NOT affect your grades in class in any way.

PLEASE WRITE YOUR NAME AND OTHER DETAILS BELOW

Name:………………………… Male/Female:……………….. Date:………………

Home Province:…………………………………………..

---

1. Defining science is difficult because science is complex and does many things. But mainly science is:

(Your position)

a)   a study of fields such as biology, chemistry and physics.

b)   a body of knowledge, such as principles, laws and theories which explain the world around us (matter, energy and life).

c)   exploring the unknown and discovering new things about the world and universe and how they work.

d)   carrying out experiments to solve problems of interest about the world around us.

e)   inventing or designing things (for example, artificial hearts, computers, space vehicles).

f)   findings and using knowledge to make the world a better to live in (for example, curing diseases, solving pollution problems and improving agriculture)

g)   an organisation of people called scientists who have ideas and techniques for discovering new knowledge

h)   I do not understand

i)   I do not know enough about this subject to make a choice

j)   none of these choices fits my basic viewpoint

_____

2. When scientists investigate, it is said that they follow the scientific method. The scientific method is:

(Your position)

a)   the laboratory procedures or techniques; often used in a book or journal ;and usually by a scientist

b)   recording your results carefully

c)   controlling experimental variables carefully, leaving no room for interpretation.

d)   getting facts, theories or hypotheses efficiently

e)   testing and re-testing, proving something is true or False in a valid way.

f)   forming a theory then creating an experiment to prove it.

g)   questioning, hypothesising, collecting data and concluding

h)   a logical and widely accepted approach to problem solving

i)   an attitude that guides scientists in their work

J)   Considering what scientists do, there really is no such thing as a scientific method

 k)   I do not understand

l)   I do not know enough about the subject to make a choice

m)   None of the above choices fits my basic viewpoint

3. The more Papua New Guinea's science and technology develop, the wealthier Papua New Guinea will become.

(Your position)

Science and technology will increase Papua New Guinea's wealth:

a)   because science and technology bring greater efficiency, productivity and progress.

b)   because more science and technology would make Papua New Guinea less dependent on other countries. We could produce things for ourselves.

c)   because Papua New Guinea could sell new ideas and technology to other countries for profit.

d)   It depends on which science and technologies we invest in. Some outcomes are risky. There may be other ways besides science and technology that create wealth for Papua New Guinea.

e)   Science and technology decrease Papua New Guinea's wealth because it costs a great deal of' money to develop science and technology.

f)   I do not understand.

g)   I do not know enough about this subject to make a choice.

h)   None of these choices fits my basic viewpoint.

_____

4. In your everyday life, knowledge of science and technology helps you personally solve practical problems (for example, getting a car out that is stuck in the mud, cooking, or personal care and hygiene when you have skin problems or sores on your body).

(Your position)

The systematic reasoning taught in science lessons (for example, hypothesising, gathering data, being logical):

a)   helps me solve some problems in my daily life Everyday problems are more easily and logical solved if treated like science problems

b)   gives me greater knowledge and understanding of' everyday problems However, the problem solving techniques we learn are not directly useful in my daily life

c)   Ideas and facts I learn from science classes sometimes help me solve problems or make decisions about such things as cooking, keeping healthy, or explaining a wide variety of physical events

d)   The systematic reasoning and the ideas arid facts I learn from science classes help me a lot. They help me solve certain problems and understand a wide variety of physical events (for example, thunder or rainbows).

e)   What I learn from science class generally does not help me solve practical problems but it does help me notice, relate to, and understand the world around me.

What I learn from science class does not relate to my everyday life:

f)   biology, chemistry and physics are not practical for me. They emphasis theoretical and technical details that have little to do with my day-to-day world.

g)   My problems are solved by past experience or by knowledge unrelated to science arid technology.

h)   I do not understand

i)   I do not k low enough about this subject to make a choice

j)   None of these choices fits my basic viewpoint.

5. Science and technology can help people make some moral decisions (that is, one group of people deciding how to act towards another group)

(Your position)

Science and technology can help you make some moral decisions

a)   by making you more informed about people and the world around you ilus background ri formation can help you cope with the moral aspects of life.

b)   By providing background information but moral decisions must be made by individuals.

c)   Because science includes areas like psychology which study the human mind and emotions.

Science and technology cannot help you make a moral decision

d)   because science and technology have nothing to do with moral decisions Science and technology only discover, explain and invent things. What People do with the results is not the scientist's concern

e)   Because moral decisions are made solely on the basis of an individual 's values and beliefs.

f)   Because if moral decisions are based on scientific information, the decisions often lead to racism, by assuming that one group of people is better than another group

g)   I do not understand

h)   I do not know enough about this matter to make a choice.

i)   None of' these choices fits my basic viewpoint

_____

6. Science arid technology offer a great deal of help in resolving such social problems as poverty, crime and unemployment.

(Your position)

a)   Science and technology can certainly help resolve these problems. The problems could use new ideas from science and new inventions from technology

b)   Science and technology can help resolve some social problems but not others.

c)   Science and technology solve many social problems, but science and technology also cause many of these problems.

d)   It's not a question of science arid technology helping, but rather it's a question of people using science and technology wisely

e)   It's hard to see how science and technology could help very much in resolving these social problems. Social problems concern human nature, these problems have little to do with science and technology

f)   Science arid technology only make social problems worse. It's the price we pay for advances in science and technology.

g)   I do not understand.

h)   I do not know enough about this subject to make a choice.

i)   None of these choices fits my basic viewpoint.

7. Some cultures have a particular viewpoint on nature and man. Scientists and scientific research are affected by the religious or ethical views of the culture where the work is done.

(Your position)

Religious or ethical views 1)0 influence scientific research:

a)   because some cultures want specific research done for the benefit of that culture.

b)   because scientists may unconsciously choose research that would support their culture's views.

c)   because most scientists will not do research which goes against their upbringing or their beliefs.

d)   because everyone is different in the way they react to their culture. It is this individual differences in scientists that influence the type of research done.

e)   because powerful groups representing certain religious, political or cultural beliefs will support certain research projects, or will give money to prevent certain research from occurring.

Religious or ethical views do NOT influence scientific research:

f)   because research continues in spite of clashes between scientists and certain religious or cultural groups (for example, clashes over evolution and creation).

g)   Because scientists will research topics which are of importance to science and scientists, regardless of cultural or ethical views.

h)   I do not understand.

i)   I do not know enough about this subject to make a choice.

j)   None of these choices fits my basic viewpoint.

_____

8. Science rests on the assumption that the natural world can not be altered by a supernatural being (for example, a God).

(Your position)

Scientists assume that a supernatural being will NOT alter the natural world:

a)   because the supernatural is beyond scientific proof. Other views, outside the realm of science, may assume that a supernatural being can alter the natural world.

b)   Because if a supernatural being did exist, scientific facts could change in the wink of an eye. BUT scientists repeatedly get consistent results.

c)   It depends. What scientists assume about a supernatural being is up to the individual scientist.

d)   Anything is possible. Science does not know everything about nature. Therefore, science must be open-minded to the possibility that a supernatural being could alter the natural world.

e)   Science can investigate the supernatural and can possibly explain it. Therefore, science can assume the existence of supernatural beings.

1)   I do not understand

g)   I do not know enough about the topic to make a choice.

h)   None of these choices fits my basic viewpoint.

Appendix B

MCI questionnaires used to gather data on classroom environment (Section 3.7.3.2)

_____

MY CLASS INVENTORY

Student Actual Short Form

Directions

This is not a test. The questions are to find out what your class is actually like.

Each sentence is meant to describe what your actual classroom is like. Draw a circle around

YES   if you AGREE with the sentence

NO   if you DONT AGREE with the sentence.

Please answer all questions. If you change your mind about an answer, just cross it out and circle the new answer.

NAME:_____SCHOOL_____ CLASS_____

Remember you are describing your actual classroom	Circle Your Answer	For Teacher's Use
1. The pupils enjoy their schoolwork in my class.	Yes No	____
2. Pupils always are fighting with each other.	Yes No	____
3. Pupils often race to see who can finish first.	Yes No	____
4. In my class the work is hard to do.	Yes No	____
5 In my class everybody is my friend	Yes No	____
6. Some pupils are not happy in my class.	Yes No	R ____
7. Some pupils in my class are mean.	Yes No	____
8. Most pupils want their work to be better than their friends work.	Yes No	____
9. Most pupils can do their schoolwork without help.	Yes No	R ____
10. Some pupils in my class are not my friends.	Yes No	R ____
11. Pupils seem to like my class	Yes No	____
12. Many pupils in my class like to fight.	Yes No	____
13. Some pupils feel bad when they don't do as well as the others.	Yes No	____
14. Only the smart pupils can do their work.	Yes No	____
15. All pupils in my class are close friends.	Yes No	____
16. Some pupils don't like my class.	Yes No	R ____
17. Certain pupils always want to have their own way.	Yes No	____
18. Some pupils always try to do their work better than the others.	Yes No	____
19. Schoolwork is hard to do.	Yes No	____
20. All pupils in my class like one another.	Yes No	____
21. My class is fun.	Yes No	____
22. Pupils in my class fight a lot.	Yes No	____
23. A few pupils in my class want to be first all of the time.	Yes No	____
24. Most pupils in my class know how to do their work.	Yes No	R ____
25. Pupils in my class like each other as friends.	Yes No	____

For Teachers Use Only: S _____ F ____ Cm ____ D _____ Ch _____

MY CLASS INVENTORY

Student Preferred Short Form

Directions

This is not a test. The questions are to find out what your class is actually like.

Each sentence is meant to describe what your actual classroom is like. Draw a circle around

YES   if you AGREE with the sentence

NO   if you DONT AGREE with the sentence.

Please answer all questions. If you change your mind about an answer, just cross it out and circle the new answer.

NAME:_____SCHOOL_____ CLASS_____

Remember you are describing your actual classroom	Circle Your Answer	For Teacher's Use
1. The pupils would enjoy their schoolwork in my class.	Yes No	____
2. Pupils always would be fighting with each other.	Yes No	____
3. Pupils often would race to see who can finish first.	Yes No	____
4. In my class the work would be hard to do.	Yes No	____
5 In my class everybody would be my friend	Yes No	____
6. Some pupils would not be happy in my class.	Yes No	R ____
7. Some pupils in my class would be mean.	Yes No	____
8. Most pupils would want their work to be better than their friends work.	Yes No	____
9. Most pupils would be able to do their schoolwork without help.	Yes No	R ____
10. Some pupils in my class would not be my friends.	Yes No	R ____
11. Pupils would seem to like my class	Yes No	____
12. Many pupils in my class would like to fight.	Yes No	____
13. Some pupils would feel bad when they don't do as well as the others.	Yes No	____
14. Only the smart pupils would be able to do their work.	Yes No	____
15. All pupils in my class would be close friends.	Yes No	____
16. Some pupils would not like my class.	Yes No	R ____
17. Certain pupils always would want to have their own way.	Yes No	____
18. Some pupils always would try to do their work better than the others.	Yes No	____
19. Schoolwork would be hard to do.	Yes No	____
20. All pupils in my class would like one another.	Yes No	____
21. My class would be fun.	Yes No	____
22. Pupils in my class would fight a lot.	Yes No	____
23. A few pupils in my class would want to be first all of the time.	Yes No	____
24. Most pupils in my class would know how to do their work.	Yes No	R ____
25. Pupils in my class would like each other as friends.	Yes No	____

For Teachers Use Only: S _____ F ____ Cm ____ D _____ Ch _____

Appendix C

QTI used to test teacher-student interactions in class (Section 3.7.3.3)

Questionnaire on Teacher Interaction

This questionnaire requires you to describe your teacher's behaviour in class. Your cooperation is greatly appreciated.

DO NOT WRITE YOUR NAME, for your responses are confidential and anonymous. THIS IS NOT A TEST

Your teacher will NOT read your answers and they will NOT affect your grade in any way in class. The teacher will only receive the average results of the class, not individual student scores.

On the next two pages you will find 64 statements. For each statement, clearly circle the choice you think best applies to your science teacher.

For example:

	Never				*Always*
The teacher expresses himself/herself clearly	A	B	C	D	E

If you think your teacher always expresses himself/herself clearly. circle letter E.

If you think your teacher never expresses himself/herself clearly, circle letter A.

You can also choose letters B, C, or D, which are in between.

If you want to change your answer after you have circled, please put a cross over the letter clearly and circle your new letter.

Thank you for your cooperation.

```
NEVER                           ALWAYS

A        B        C        D         E
_____

1. The teacher is strict                                                    A B C D E

2. We have to be silent in his/her class                                    A B C D E

3. The teacher talks enthusiastically about his/her subject                 A B C D E

4. The teacher trusts us                                                     A B C D E
_____

5. The teacher is concerned when we have not understood what he/she taught us. A B C D E

6. If we do not agree with the teacher, we can talk about it.                A B C D E

7. The teacher threatens to punish us                                        A B C D E

8. We can decide on some things in his/her class                            A B C D E
_____

9. The teacher demands more from us                                         A B C D E

10. The teacher thinks we cheat.                                            A B C D E

11. The teacher is willing to explain things again.                        A B C D E

12. The teacher thinks we do not know anything.                            A B C D E
_____

13. If we want something the teacher is willing to cooperate               A B C D E

14. The teacher's tests are hard.                                          A B C D E

15. The teacher helps us with our work                                     A B C D E

16. The teacher gets angry unexpectedly                                     A B C D E
_____

17. If we have something to say, the teacher will listen                   A B C D E

18. The teacher sympathises with us.                                       A B C D E

19. The teacher tries to make us look foolish.                             A B C D E

20. The teacher's standards are very high.                                A B C D E
_____

21. We can influence the teacher.                                          A B C D E

22. We need the teacher's permission before we speak.                      A B C D E

23. The teacher seems uncertain.                                           A B C D E

24. The teacher looks down on us.                                          A B C D E
_____

25. We have the opportunity to choose class exercises that are most interesting to us. A B C D E

26. The teacher is unhappy.                                                 A B C D E

27. The teacher lets us fool around in class.                             A B C D E

28. The teacher puts us down.                                              A B C D E
_____

29. The teacher takes a personal interest in us.                          A B C D E

30. The teacher thinks we can not do things well.                         A B C D E

31. The teacher explains things well.                                     A B C D E

32. The teacher realises when we do not understand.                       A B C D E
_____
```

33. The teacher lets us get through a lot in class.	A B C D E
34. The teacher is hesitant.	A B C D E
35. The teacher is friendly.	A B C D E
36. W a lot from the teacher.	A B C D E
37. The teacher is someone we can depend on.	A B C D E
38 The teacher gets angry quickly.	A B C D E
39. The teacher acts as if he does not know what to do.	A B C D E
40. The teacher gets our attention.	A B C D E
41. The teacher is too quick to correct us when we break a rule.	A B C D E
42. The teacher lets us boss him/her around.	A B C D E
43. The teacher is impatient.	A B C D E
44. The teacher is not sure what to do when we fool around.	A B C D E
45. The teacher knows everything that goes on in the classroom.	A B C D E
46. It is easy to make a fool out of the teacher.	A B C D E
47. The teacher has a sense of humour.	A B C D E
48. The teacher allows us a lot of choice in what we study.	A B C D E
49. The teacher gives us a lot of free time in class.	A B C D E
50. The teacher can take a joke from students.	A B C D E
51. The teacher has a bad temper.	A B C D E
52. The teacher is a good leader.	A B C D E
53. If we do not finish our homework, we are scared to go to his/her class.	A B C D E
54. The teacher seems not satisfied.	A B C D E
55. The teacher is shy.	A B C D E
56. The teacher is patient.	A B C D E
57. The teacher is very strict when marking student's work.	A B C D E
58. The teacher is suspicious of students.	A B C D E
59. It is easy to pick a fight with the teacher.	A B C D E
60. The teacher's class is pleasant.	A B C D E
61. We are afraid of the teacher.	A B C D E
62. The teacher acts confidently.	A B C D E
63. The teacher is sarcastic (i.e., makes unkind remarks).	A B C D E
64. The teacher is not strict.	A B C D E

FINALY, FILL IN THE SPACES BELOW:

I am a…………….. student. I come from……………… province of Papua New Guinea.

    (male or female)   *(name of province. If not from PNG, write name of country)*

THANK YOU!

Appendix D

Two-tier Diagnostic Test on Understanding in Electricity questionnaire used to test students' prior knowledge (Section 3.7.3.4)

Secondary Students' Understanding of Electric Current

The aim of this exercise is to understand students' prior knowledge of electricity before instruction commences. It is not a test and will not affect students' progress in class in any way.
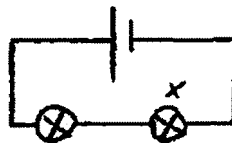
Name: **▪▪**

Male/Female **▪▪▪▪▪▪▪▪▪▪▪▪▪▪**   Date: **▪▪▪▪▪▪▪▪▪▪▪▪**

Home Province: **▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪**

Instructions:

There are 10 questions to be answered. Each question has 2 parts. The first part is multiple choice where you select the correct response. The second part allows you to give your reasons for selecting your answer.

Example:

Light bulb X will:

' a)   **be normal brightness**
. b)   **be extra bright**
  c)   **light dimly**
  d)   **not light at all**
  e)   **blow**

Reason:

1.   **There is only one battery in the circuit.**
2.   **The wire connecting light bulbs to battery is long**
3.   **The light bulbs are connected in series, that is one after the other**
4.   ………………………………………………………………………………

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1. In the four circuit arrangements a, b, c, and d shown below, which would experience electric current flow?

a)　　　　　　　b)　　　　　　　c)　　　　　　　d)
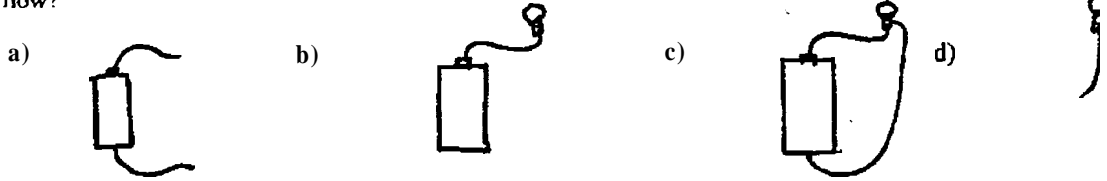
Reason:

1. An electric current flows as long as a piece of wire is attached to the battery terminals.
2. An electric current flows as long as the circuit is a closed loop.
3. An electric current flows because ....

2. A battery is connected to a light bulb with wires. Select the diagram which best describes current behaviour.

a)　　　　　　　　There will be current flowing from the battery to the light bulb as shown.

b)　　　　　　　　Current will flow in a direction toward the light bulb in both wires.

c)　　　　　　　　Current flows in direction shown and is less in the return wire.

d)　　　　　　　　Current flows in direction shown and will be the same in both wires.

Reason:
1. Current flowing to the light bulb is used up completely.
2. Current flowing to the light bulb is almost used up and the small amount remaining returns to the battery.
3. Current is never used up.
4. Current ....

3. Consider current flow in the electric circuit below:
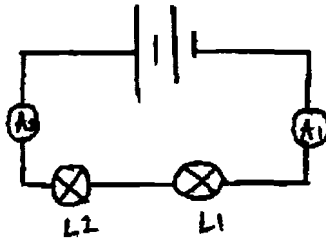
If ammeter A_1 reads 1 amp, then ammeter A_2 will show a current

a) greater than 1 amp

b) less than 1 amp

c) of 1 amp

d) of any value depending on the resistance of circuit components

Reason.

1. The current decreases in magnitude because some of it gets used up in the circuit
2. The current remains the same at any point in the circuit.
3. The magnitude of current is unpredictable at any point in the circuit.
4. ………………………………………………………………………………

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4. For the circuit below, the current readings in the ammeters will be
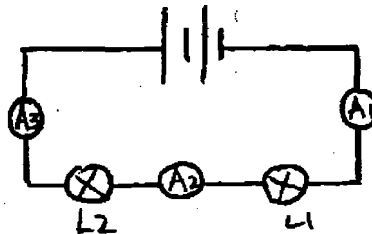
a) Greater at A_1, less at A_2 and least at A_3.
b) Greater at A_3, less at A_2 and least at A_1.
c) The same at A_1, A_2, and A_3.
   The same at A_1, and A_3 but less at A_2.

Reason:
……

**5.** For this question refer to the two circuits shown below. The right bulbs and batteries are identical.

If bulbs in both circuits light up, current at point P should be

a) more than current at point Q
b) same as current at point Q
c) less than current at point Q
d) impossible to predict in relation to current at point Q

Reason:

    1. Two light bulbs will use more current than one light bulb.
        Total resistance of circuit 1 is less than that of circuit 2.
    3. ....

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6. In the following circuits light bulbs and batteries have equal values.
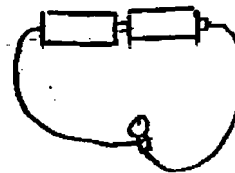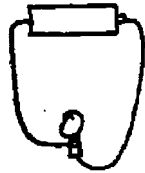
The current in circuit 1 is

a) greater than current in circuit 2
b) same as current in circuit 2
c) less than currant in circuit 2
d) unpredictable in relation to current in circuit 2

Reason:

1. Circuit 1 has only one battery compared to circuit 2
2. Both circuits have one bulb each.
3. ....

7. If a current of 1 amp flows in a series circuit whcre the battery voltage is 1.5 volts, then the resistance of the light bulb must be
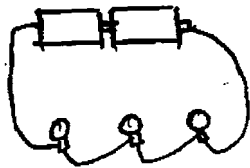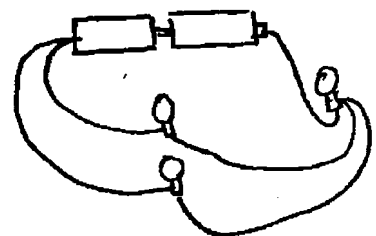
a)   1 ohm
b)   1.5 ohm
c)   2 ohm
d)   3 ohm

Reason:

....

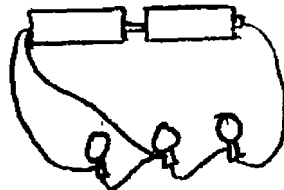8. For the four circuits shown below when all light bulbs and batteries have equal values, which circuit have the brightest light bulbs?
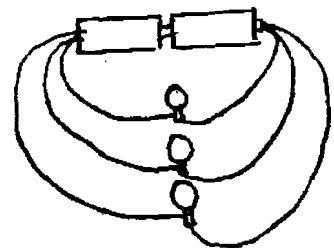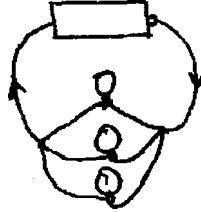
a)

b)

b)

d)

Reason:

....

9. For a parallel circuit with three light bulbs and a battery connected as shown, which of these statements is NOT true:

a) The voltage across each light bulb is the same.
b) If the light bulbs have equal values of resistance the current through each light bulb remains the same.
c) Currcnt passing through the battery has the same value as those passing through each light bulb
d) If one light bulb blows the other two will remain lit.

Reason:

………………………………………………………………………………………………

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10. In a simple electric circuit consisting of a battery, wires and a light bulb, it may be stated that energy is being transferred from

a) battery to all parts of the circuit
b) light bulb to all parts of the circuit
c) battery to the light hulb
d) bulb to the battery

Reason:

………………………………………………………………………………………………………

THANK **YOU, YOU** HAVE REACHED *THE* **END OF THIS**

Appendix E

Student Artefact: A personal copy of a student's notes on electricity kept during the study.

2. Cumulus Clouds – are dense, white clouds with flat bases. They looks like heaps of cotton wools. They can hide the sun causing shadows on Earth. They are low altitude clouds found at about two and a half kilometre above the earths surface.

3. Stratus clouds – are layered clouds, which form a sheet covering the whole sky. They cause grey skies.
They form at low altitudes around two and a half kilometres.

Topic: Electricity   Tuesday
Terms and Definition   Date: 6th /03/001

1. Cell – A source of Electrical energy
2. Connecting Wire – Wire used to join up parts of a circuit, usually Insulated and made of copper.
3. Complete Circuit – a circuit without any gaps and is a complete part of Electric current.
4. Electric Current – is a flow of electrons.
5. Switch – a device for switching the current on and off.

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6.	Lamp	— A device that changes Electric energy to light and heat eg
7.	Series and Parallel Circuits	— two different ways of necking an Electric cir
8.	Conductors	— Substance that allows Ele city to flow through. eg copper wire.
9.	Insulators	— Substance that will not c an Electric current.
10.	Resistance	— the opposition to the flow Electric current.

Activity:

List example of an Insulator and conductor.

	Conductors		Insulators
1.	~~Dry~~ ~~wood~~ Iron	/	Dry wood /
2.	~~Plastic~~ ~~Trees~~ copper	/	Plastic /
3.	water ~~paper~~	/	glass /
4.	wire	/	paper /

Two different ways of connecting Electric

a) Series Circuit   b) Parallel Circuit

a single cell   single

a switch   reistor
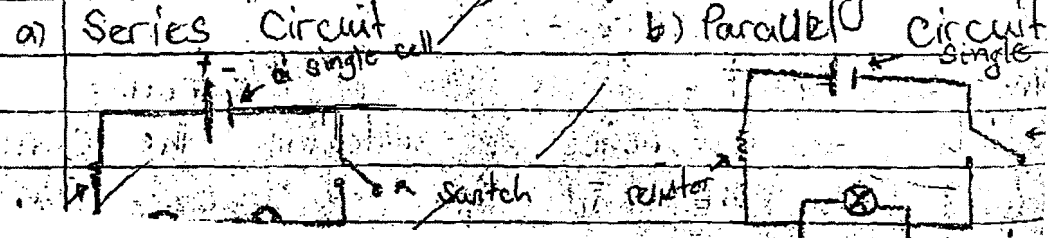
Topic: STATIC ELECTRICITY

Electricity - is the flow of Electrons

Static Electricity - is Electricity at rest

Static Electricity is caused by positive negative charges. When ever electric charge are produced the positive and negative ch occure in equal ammounts. Normally objects ha no charges on them because the number of negative charges balances the number o positive charges. How ever when some substance are rubbed together negative charges can b moved from one substance to another. This negati charges are called Electrons. This is how elect ity is formed.

The Electrons or negative charges can be used to explain what is meant by electric current because it is the Electrons that cause a current to flow. The negative terminal of a dry cell ha more electrons than the positive terminal. When the dry cell is connected to a circuit, the Electrons travel along the wire from the negative terminal to the positive terminal. So Electric current can be described as a moving negative charge, or a flo

a flow of electrons.

If a plastic ruler is rubbed with a wollen it becomes capable of repelling another plast which is slightly suspended and have also bee The rulers are said to have acquired an charge. 4 rubbed plastic ruler can attrac 4 hair, a paper. It can be concluded there are two kinds of charges and that

i) Like charges — repel

ii) Unlike charges — attract

* When rubbing two things togather this happen

i) Charges removed — material becomes positively (+

ii) Charges added — material becomes negatively (-ve) ch The electrons on the surface atoms of the hair become transfered to the ruler as a result hair is attracted to the rubbed ruler.

Topic: MEASURING CURRENT IN A SERIES CIRCUIT. Day Fr Date: 16

* The unit of Electric current is Amperes or The symbol = I

Topic : Current in a Parallel And
Series Circuit.

1) Electricity (an Electric current) is a flow of
tiny particles called

Topic : Voltage.
What is a voltage ?

- Is a measure of the force which pushes the
Electrons arround the circuit.

* An Electric current is produced by a source of El-
tricity. The force that pushes electricity along the wi
is called the voltage (electron driving force.)

* If the voltage is increased, the force pushing th
Electricity through the circuit is increased, and
the current will also be increased.

* Voltage is measured in volts (V).

* Voltmeter — Instrument that measures voltage.

* The voltmeter is always connected in parallel ac
any electrical device. The positive terminal of th
voltmeter must be connected to the positive side
the Electrical device and negative side of the
meter to the negative side of the electrical de
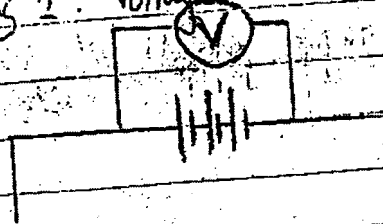
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Reading a Voltmeter
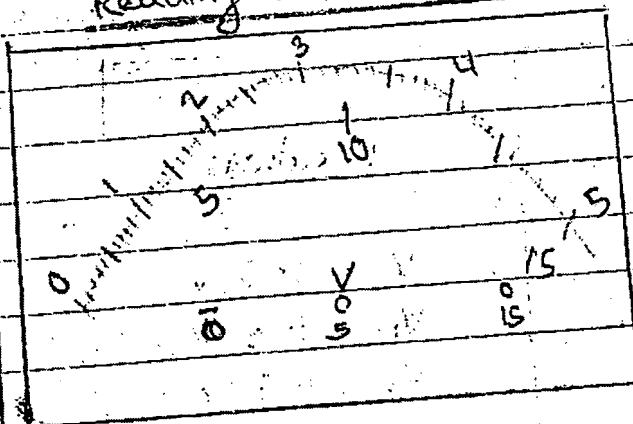
connection

Using $5V = \dfrac{1-0}{10} = \dfrac{1}{10} = 0.1$ volts / unit.

Using $15V = \dfrac{5-0}{10} = \dfrac{5}{10} = 0.5$ volts / unit

Topic: Measuring Voltage In Series And Parallel Circuits

Day: Tues
Date: 27th

Activity 1. Voltage - Series circuit.

Readings

$V = 10 \times 0.5 = 5$

$V_1 = 5 \times 0.5 = 2$

$ = 5 \times 0.5 = 2$

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