Science and Mathematics Education Centre

Science Education and the English Second Language Learner

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This thesis is presented for the Degree of
Doctor of Philosophy
of
Curtin University of Technology

September 2006

Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

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ABSTRACT

The growing diversity of school populations around the world means that for many students the language of instruction in mainstream classrooms is not their first language. Content-based second language learning in a context such as a science classroom is considered advantageous as it enables the learner to manipulate a target language such as English in a way which is meaningful. However, science students who have yet to achieve communicative competence in English are disadvantaged when it comes to developing a deep understanding of scientific concepts. Many mainstream science teachers have concerns about this significant group of learners who can be left on the periphery of the class to cope as best as they can. Very often teachers aim to meet the needs of English Second Language (ESL) learners without any specific knowledge of the strategies which would enhance learning and ensure that learning environments encourage participation and interaction. The students themselves have not only to deal with language and sociocultural issues but must face the cognitive demands of science including negotiating its specialised language.

The study had two main purposes. The first goal was to describe the current situation with respect to nine ESL learners of science and their teachers in selected learning environments in Australia. The secondary purpose was to bring about improvement in the students' situations by employing specifically designed interventions. The study had three focal areas: the language; the teaching and learning environment; and the ESL student. It was conducted in three phases. Phase one involved investigating the current situations in the three focal areas. Phase two involved reflection, planning and development of the broad interventions and specific strategies which were used to assist teaching and learning. In phase three the strategies were implemented and their effectiveness was analysed using a multidimensional interpretive framework. Changes in communicative competence, interactional and participative competencies and academic competence were observed. The interventions which were intended to promote communicative competence for the language focus, involved integration of language and literacy instruction with science education. To improve participation and interaction in the teaching and learning environment, individual assistance was provided. In order to promote academic competence for the students, content, process and/or product

modifications were made to science courses. Data for the qualitative case studies was collected using classroom observation, teacher and student interviews, checklists of strategies and language errors, and portfolios of student work.

Observations of the science classes in phase one revealed that, even for the students with very limited English language proficiency there was little ESL specialist support available. Mainstream subjects like science provided opportunities for language development, with biology lessons consistently including more activities which involved a combination of speaking, listening, reading and writing than did chemistry or physics classes. However, there was no coordinated approach to integrating language education with science education. The development of cognitive/ academic language took longer than 10 years for some of the students in the study. The non-technical language used in science lessons affected the students' understanding much more than the teachers were aware. Teachers' attitudes and beliefs strongly influenced the interaction and participation of ESL students in science classrooms. Developing language skills prevented ESL students asking and answering questions in class and academic progress in science was impeded by limited opportunities for ESL students to clarify their understanding. Achievement in science was affected by assessment instruments which were infused with specific linguistic or cultural knowledge.

After the introduction of the interventions, improvements in communicative competence occurred for all students with the greatest progression occurring in the students with less developed language skills. Interaction and participation improved markedly in the science classrooms where teachers provided individual assistance to students. Academic competence increased in all cases. The most promising approaches included: addressing the specific language needs in a particular unit of work; the development of customized materials; the provision of weekly tutorials; and the revision of assignment drafts.

Key Words – Science education, Science, Language, English Second Language (ESL)

ACKNOWLEDGEMENTS

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CHAPTER 1 INTRODUCTION

A few years ago, I had the good fortunate to meet three very interesting students. They were from very different backgrounds and ranged in age from thirteen to thirty-one years but they had two things in common. All were highly motivated science students who were eager to do well in their chosen fields and for all three, English was their second language. Their individual problems were very complex and new to me as a science educator. The following accounts outline how I met Cliff, Lenny and Anna.

It was my first day at a new school. The school, a private co-educational one was situated in the state of Queensland in Australia. I was teaching a large Year nine Junior Science class. When I called the roll I noticed one boy, Cliff, failed to respond. The other students told me that he was new and could speak no English. Because I was still unfamiliar with the administrative procedures, it took me a few days to establish that the school was without an English Second Language (ESL) teacher. It subsequently emerged that Cliff was from Taiwan and had only been in Australia for six weeks. Although I was an experienced teacher of science in Queensland schools, this situation was a unique one for me. Like all teachers in Australia, I was encountering more ESL students in my classes each year. However, in other schools I had never been responsible for a student whose mastery of English was such that he was unable to participate in basic classroom routines. I was not prepared to leave Cliff to sink or swim. Cliff forced me to think about the importance of second language development within the science classroom.

In the same year I met a second ESL student who needed specialised assistance. Anna, who came to Australia from Hong Kong at the age fifteen, had undergraduate degrees in Pharmacy and Dentistry. She was thirty-one years old, working part-time as a general dental practitioner and at the end of a three year Masters course in Dentistry which would make her an Orthodontist. Although her everyday communication was very good and her academic English was such that her examination results to date had been excellent, Anna was having difficulty with the writing of her final thesis. She had designed and carried out her research but was in despair as her Professor refused to assess her work. He said it was too full of

grammatical errors for him even to consider. She had taken her work to an expert in scientific writing but this was not successful as it was necessary to have an understanding of the specialist dental language and the relevant practical experience in order to ensure that the meaning was clear and that there was proper continuity in the writing. She felt she was in danger of not passing her course. Although I no longer practise as a dentist and have no postgraduate qualifications in that field, my undergraduate degree is a Bachelor of Dental Science and I am still familiar with the terminology, anatomical landmarks and basic procedures involved. Anna was aware that I had done some academic writing and together we embarked on a revision of her thesis which involved many hours of oral explanations, negotiation and rewriting. From Anna I learnt about the difficulties that specialised academic writing poses for ESL students.

The third student was Lenny. She was a 28- year-old Columbian dentist who had been in this country for four years. Australia had become her permanent home since marrying a Brisbane architect two years previously. Consequently she wished to be able to pursue her chosen career of dentistry. To become registered as a dentist, Lenny was required by the Australian Dental Council to demonstrate her competence to practise dentistry in Australia. The assessment procedure consists of three components. The first is an Occupational English Test, which is designed to assess the candidate's understanding and use of English in the workplace. The second component consists of two papers in multiple-choice question format and a paper of five short answer questions. The Final Examination tests the candidate's practical clinical skills. I met Lenny when she approached me, eight weeks prior to the first examination. She wanted my assistance to prepare for the test. She hoped that I could act as a tutor. From Lenny I learnt about the difference between language for everyday communication and that needed for academic study.

For me, the linguistic, sociocultural and academic struggles of these three students formed the basis for what has become a personal search for strategies with which to help them and other ESL students. During the past few years I have had the privilege of visiting many science classrooms and working with different ESL students and their science teachers. It has been a very rewarding journey and allowed me to view my own teaching with new eyes.

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Rationale

In 2003, over 300,000 students from all over the world came to Australia to study in various educational institutions around the country (International Education Network, 2003). Along with these international learners, there are also those students who are refugees, immigrants and the children of immigrants for whom English is a second language. In the 2001 census, 11.5% of Queenslanders reported speaking languages other than English in their homes (Australian Bureau of Statistics, 2002). This growing diversity is by no means unique to Australia and means that in many areas of the world mainstream teachers of content areas such as science are called upon increasingly to accommodate ESL students in their classes. As well as learning science, the aim for these students is that the science classroom will provide a meaningful use for their English and through this medium they will acquire the structures and forms of the language (Larsen-Freeman, 2000).

Short (2000) states that when the language of instruction is English, there persists a significant difference between the academic achievement levels of ESL students and those of native English speakers. This was supported by a study in Western Australia (Education Department of Western Australia, 1994) which reported that the science achievement of ESL students in Year 10 was statistically lower than that of students who were proficient in English. There are many reasons for this. Although ESL students often make up a significant component of many mainstream classes, Lee and Luykx (2003) report, "most teachers working with culturally and linguistically diverse students feel that they are not adequately prepared to meet their students' learning needs particularly in academically demanding subjects such as science" (p. 21). According to Gutierrez (2002), secondary school teachers' main loyalty appears to be to their subject area, with the students' other needs a secondary concern. Although ESL students are using science as a means of achieving communicative competence, her research showed that student's linguistic experience plays an insignificant role in the learning of content in subject areas.

For the students themselves the challenge of mastering academic content in a language which they are still learning can be overwhelming and lead to feelings of confusion and frustration. Students who have not yet achieved communicative

competence in English are certainly disadvantaged when it comes to developing a deep understanding of science with its specific cognitive demands and special language. Achieving at a high academic level in science involves reading English well, understanding scientific discourse, writing coherently, and speaking English at cognitively abstract and complex levels. Additionally ESL students must deal with the normal transitions of adolescence combined with the many sociocultural differences which they encounter.

The influence that social and affective factors have on language acquisition forms the basis of Schumann's (1986) model of acculturation. Acculturation involves the social and psychological integration of the learner with the target group. He proposes that the learner will acquire the second language only to the degree that he or she acculturates. The implications of this model for the science classroom are that as well as acquiring communicative competence, and academic competence, there is a need for the learner to acquire what Carrasquillo and Rodriguez (2002) term "participative competence" and "interactional competence" (p. 14). Participative competence involves responding appropriately to class tasks and demands, and interactional competence means that the learner can follow social rules and interact properly with peers and adults. Vine (1997) supports integration into mainstream classrooms as the best means of achieving these competencies.

Although the learning of science poses many problems for the ESL student which no amount of prior practice in ESL classes can alleviate, there are many reasons why science is well suited to students for whom English is still developing. Rosenthal (1996) explains that it is often mathematically based, which removes some linguistic barriers. Commonly employed scientific learning experiences such as demonstrations, group work, collaborative and hands-on activities like experiments, and the use of visual aids like diagrams, specimens and videos all serve to reinforce words and text. Language development is assisted by the opportunities for speaking, listening, writing and reading which exist in most lessons. Additionally, the technical language or jargon of science is often *foreign* to all students, native speakers and ESL students alike. So if it is accepted that the science classroom can provide valuable learning experiences for the ESL student, the challenge for science educators is to assist the learners to close the academic gap. To do this it is

necessary to acknowledge the importance and interdependence of the three areas of language acquisition, acculturation and academic progress for the ESL science learner. These will be elaborated upon in Chapter 2.

Background

The educational research which informs this study is drawn from three main areas. Firstly, a knowledge of the theory on language and language acquisition provides the background to understanding the journey that all English language learners must travel. The second area relates more specifically to matters surrounding content-based language learning in mainstream classrooms. The third seeks to outline the major issues specific to ESL learners of science and their teachers. The major points will be summarised under three research foci: 1. language; 2. the teaching and learning environment; and 3. the ESL student.

Language

Today's second language teachers have moved away from explicitly teaching the rules, patterns, definitions and other knowledge about a language and instead teach students to communicate genuinely and meaningfully in the second language using the methodology known as *communicative language teaching* (Larsen-Freeman, 2000). The goal for the ESL learner of content-based language instruction is the development of communicative competence (Canale, 1983; Canale & Swain, 1980). To achieve communicative competence ESL learners must improve their proficiency or skill in using the second language in different tasks (Ellis, 1994). Allwright and Bailey (1991) explain that second language learners are thought to progress along a continuum, the two poles of which are the first language and the target language. One of the goals of content-based language instruction must be to move the learner towards the target language end of the scale. The continuum is marked by a series of stages which are defined by the types of errors that the learner makes at each stage. Selinker (1972) uses the term "interlanguage" (p. 201) to describe these various stages. From the constructivist point of view, language is the chief means used by children to build knowledge (Bruner, 1966). Vygotsky (1978) claimed that social interaction through language is a prerequisite to cognitive development. Brown

(2000) explains that cognitive and linguistic developments are inextricably intertwined with dependencies in both directions.

Wellington and Osborne (2001) believe that the special language of science is one of the major barriers to developing an understanding of scientific concepts, not only for ESL learners but for native speakers as well. O'Toole (1982) explains that the language used by scientists when they discuss science has a specialised vocabulary and a distinct structure. Because of its specialization and attendant complexity, it causes difficulties for a wide range of students, with second language learners experiencing particular difficulties.

The Teaching and Learning Environment

The implications of Schumann's (1986) model of acculturation in the science classroom mean that the ESL student must interact and participate appropriately in order to improve communicative and academic competencies. Clegg (1996) maintains that mainstream classrooms can be harsh places for ESL learners and Levine (1990) stresses the need for teachers to be hospitable. Indeed, Gutierrez (2002), Buck, Mast and Franklin (2003) and Lee and Luykx (2003) state that many teachers have not developed teaching strategies to support ESL students. Carrasquillo and Rodriguez (2002) say that the first step is for teachers to craft their own set of beliefs and guidelines. Gutierrez (2002) found that successful mainstream teachers watched, listened and interacted with students in a way which respected their culture and encouraged positive attitudes in other students. Amaral, Garrison and Klentschy (2002) promote inquiry-based science as a good approach for ESL learners because it involves cooperative learning and students share common experiences.

ESL Learners

The academic success of ESL students in science hinges upon how well they can manipulate language in the variety of contexts and for the specific purposes required by science instruction. That is, to achieve academic competence students must be able to acquire new skills, assimilate new information, and construct new concepts.

As Cummins (1994) points out, although ESL students may acquire basic conversational skills in English quite quickly, it may take them up to five years to acquire academic proficiency comparable to their native speaking peers. If ESL students are to catch up academically, their cognitive growth and mastery of academic content must continue while English is being learnt. Therefore, for the ESL science student, it is imperative that science lessons become language lessons as well.

Purpose

The thesis had two main purposes. The first, which constituted phase one of the study was to interpret the experiences of ESL science learners and their teachers in Queensland educational institutions with regard to the three foci: 1) language; 2) the teaching and learning environment; 3) the ESL student. Specific strategies were designed to promote language development, acculturation and understanding in science and this constituted phase two. The second purpose, which was addressed in phase three, was to bring about change by introducing specially designed strategies within the classroom setting and evaluating their effectiveness.

Research Questions

Phase One

1a.   What are the difficulties for ESL students with respect to the language used in science classrooms?

1b.   How do science teachers assist ESL students to interact and participate in science learning environments in Australian schools?

1c.   What difficulties do ESL students encounter when constructing an understanding of scientific concepts?

Phase Two

2a.   What teaching and learning strategies are likely to assist the language development of ESL students in science classrooms?

2b. What teaching and learning strategies are likely to improve the interaction and participation of ESL students in science classroom?

2c. What learning strategies are likely to enhance ESL students' understanding of scientific concepts?

Phase Three

3a. What impact do strategies specifically designed to address language development in the science classroom have on ESL students' communicative competence?

3b. What impact do strategies specifically designed to improve the science teaching and learning environment have on ESL students' interactional and participative competencies?

3c. What impact do strategies specifically designed to assist ESL students' understanding of science have on academic competence?

Definitions

The terms used in the literature relating to culturally and linguistically diverse students vary extensively from author to author and country to country. A glossary of some of the commonly encountered terms related to the education of ESL students is provided in Appendix A. However, at this stage, a clear explanation of the key terms will serve to reduce ambiguity and justify some of the individual choices made in this paper.

With reference to the students themselves the most frequently encountered terms are: *English second language (ESL); Language minority student (LMS); English language learners (ELL); Limited English proficiency (LEP); Non-English speaking background (NESB)* and *Limited English speaker (LES)*. Because in Australian classrooms, *English second language* or *ESL* is the term most commonly used, it will be employed in this thesis.

In a busy science classroom, ESL students are sometimes not easy to identify. Flugelman (1986) points out that all ESL students have two things in common. They

all come from non-English speaking backgrounds and their understanding and production of spoken and/or written English is limited enough to constitute a disadvantage at school.

With respect to classrooms, according to Rosenthal (1996), mainstream classrooms are designed for native speakers who in this study are persons who speak English as their first language. *Mainstreaming* occurs when students are moved out of a program of English as a second language and into content-area courses in which English is the language of instruction (Rosenthal, 1996).

The Educational Resource Information Centre (ERIC) thesaurus defines *competence* as an individual's capacity to perform. Competence involves possession of knowledge, skills and personal characteristics needed to satisfy the special demands of a particular situation.

In 1974, Hymes explained his term *communicative competence* as that aspect of competence that enables a person to convey and interpret messages and to negotiate meanings interpersonally within specific contexts. To achieve communicative competence four separate components need to be considered. Firstly, *grammatical competence* is the knowledge of lexical items and the rules of morphology, syntax, sentence-grammar, semantics and phonology. Secondly, *discourse competence* involves intersentence knowledge. Thirdly, *sociolinguistic competence* is the knowledge of the sociocultural rules of language and discourse. Finally, *strategic competence* involves the strategies that can be called into action to compensate for breakdowns in communication (Canale, 1983; Canale & Swain, 1980).

Participative competence describes the extent to which students are able to respond properly to class rules and to complete class tasks. If students are able to interact appropriately with adults and peers by following classroom and social rules of discourse, they are demonstrating *interactional competence* (Carrasquillo & Rodriguez, 2002).

A student's ability to acquire new skills, assimilate new information and construct new concepts contributes to *academic competence* (Tikunoff & Ward, 1991). In this

study, academic competence was measured against the criteria set out by the various work programs applicable to the classrooms involved. In Years 10 to 12 this measurement involved the three assessment categories of *Knowledge, Scientific Process and Complex Reasoning.* In Year 9, in one of the schools only the first two areas were used for assessment purposes.

A definitive definition of a *strategy* is difficult. Oxford (1990) explains that the term comes from the ancient Greek term *strategia* which means *generalship* or *art of war.* In this strict sense strategies involve the optimal management of the troops, ships, or aircraft in a planned campaign. A different but related word is *tactics* which are tools to achieve the success of strategies. The terms are often used interchangeably, sharing the common characteristics of planning, competition, conscious manipulation, and movement towards a goal. Oxford (1990) and O'Malley and Chamot (1990) agree that language learning strategies are actions, behaviours, steps or techniques taken by language learners to control and improve their own learning. However, for the purposes of this study a wider definition is required as the strategy users are teachers and science learners as well as language learners. Therefore, *strategies* are defined as plans, steps, techniques or specific actions that are used, often consciously, towards the achievement of objectives.

Significance of the Study

Each year Australia welcomes large numbers of international students to its universities, institutes, colleges and schools. Internationally, Australia ranks in the top five of educational providers. Between 1994 and 2003, the number of international enrolments increased from 93722 to 303324 with an 11 % increase between 2002 and 2003. Students mainly come from the Asian Pacific region with students from China accounting for 19 % of total foreign enrolments. These students have a very positive impact on the Australian economy. Provisional estimates are that revenue of $5.7 billion was derived from educational exports in 2003 (Australian Government, Department of Education, Science and Training, 2003). In 2001, Australian exports of international education services generated more income than wool and almost equalled that of wheat and beef in terms of value. This makes education Australia's third largest export service industry after tourism and

transportation and it is predicted that it will grow faster than either of these industries in the coming decade (Australian Government, Department of Foreign Affairs and Trade, 2003).

These students, for whom English is a second language, bring to Australian classrooms a wide range of educational experiences, and cultural and linguistic diversity. It is essential for teachers to learn more about the kinds of students they are teaching and to develop methods and strategies that are effective for today's diverse students especially those studying new subject matter like science in a language they are still acquiring.

Recent science education reform efforts have emphasised scientific literacy for all, including ESL students, as a key goal of science education (Goodrum, Hackling & Rennie, 2000; National Research Council, 1996; Rutherford & Ahlgren, 1993). Lee and Fradd (1996) explain that becoming scientifically literate means being capable of applying scientific knowledge to real life situations, recognising the diversity and unity of the natural world, understanding strengths and weaknesses of technological applications, and exploring scientific questions. Scientific literacy is necessary for people to participate fully in modern society. Investigating situations which might help ESL students achieve scientific literacy is therefore worthwhile on both an individual and societal level.

Barba and Reynolds (1998) state that science education should aim to produce a society in which all individuals have the opportunity to participate in science careers. Mainstream science teachers recognise that ESL students have problems in coping with the academic demands of science, however, the nature of the problems are not always clear. Given that Hassan and Treagust (2003) report that there are decreasing numbers of students opting to study science both at school and university levels in Australia it is important not to exclude a significant group of potential science students because of unspecified and ill-defined difficulties. It is important to investigate and clearly outline the problems faced by ESL science learners.

Current research by Buck et al. (2003) and Lee and Luykx (2003) confirms that most science teachers confess to feeling inadequately prepared to meet the learning needs

of their ESL students. Carrasquillo and Rodriguez (2002) argue that preparing science educators to work with the growing numbers of ESL students is a serious educational concern. There is obviously a need to discover how a classroom teacher can develop as a science teacher of ESL students.

The National Centre for Educational Statistics (NECS) in Washington (1997) reported that the gap in science achievement between native speakers and ESL students continues. One of the contributing factors is that mainstream ESL students are being cognitively taxed on several levels. There are the cognitive demands of science and the linguistic demands of processing scientific discourse (Carrasquillo & Rodriguez, 2002). The students are also using content areas such as science as a vehicle for increasing communicative competence. So for the ESL learner, unless the multiple roles of the science curriculum are given consideration the gap in achievement will not close.

Investigating the current situation in selected science classrooms allows specific problems to be identified. It is hoped that progress will be made in developing effective strategies to address participation and interaction, understanding and achievement in science, while simultaneously developing English language abilities. There is potential for the language learning, the teaching, the learning environments, and the science learning in the classrooms in question to be enhanced.

In order to promote interest, involvement and conceptual understanding in science for ESL learners, it is necessary for the teacher to carefully design and implement comprehensive learning activities to set the stage for simultaneous language acquisition and academic mastery. Lynch (2000) reported that research-based curricula focussing on science inquiry with diverse learners were yet to be developed. As part of this study several supplementary units were designed. The approaches, materials, learning activities and practical activities were developed to meet the needs of individual students and teachers. These are potentially useful for other teachers and students at the schools involved in the study.

Finally, ESL students like Cliff, Anna and Lenny experience feelings of loneliness, sadness and frustration. Science teachers are often at a loss as to how to help them.

It is hoped that the strategies employed in this study may assist in catering to the students' individual needs. If they alleviate some of the isolation experienced by these students they may go some way to improving their self-esteem.

Overview of the Thesis

The study was carried out in three phases using an interpretive methodology based on a modified action research approach in naturalistic settings. The findings are presented in part as case studies, in order to provide the reader with a concrete sense of the personal and shared challenges the students and their teachers faced.

This first chapter has attempted to present an overview of the major themes that characterise this study and also to clearly define the key terms. Chapter 2 presents a literature review. The methodology is outlined in Chapter 3. Chapter 4 addresses Research Questions 1a, 1b and 1c and consequently describes the situation at the onset of the study with respect to language, the teachers and the learning environment, and the ESL students themselves. Findings are presented as case studies under the thesis themes of language, learning environment and student. Chapter 5 outlines the strategies which were adopted to improve teaching and learning and provides a rationale for these by answering Research Questions 2a, 2b and 2c. Chapter 6 addresses Research Questions 3a, 3b and 3c by considering the effectiveness of the strategies against a multidimensional interpretive framework which measures changes in communicative competence, participative and interactional competences, and academic competence. The findings are discussed in Chapter 7. Finally, Chapter 8 provides an overview of the study, summarises its main findings, and discusses some possible implications. A glossary of terms is provided in Appendix A. The literacy materials which were developed as part of the research are contained in Appendices F to N.

CHAPTER 2 LITERATURE REVIEW

Introduction

Research in both language acquisition and science education has been rich and productive during the past 30 years. Herrell and Jordan (2004) explain that both linguists and educators have discovered some effective methods of supporting students when they are learning a new language and content knowledge simultaneously. The literature which informs this study falls into three distinct areas: the theories on language and language learning; content-based language learning in mainstream classrooms; and the work which is specific to ESL students of science.

The first purpose of this thesis was to interpret the experiences of ESL science learners and their teachers in Queensland educational institutions and the second purpose was to improve the situation for these students. Birch (1997) summarised the problems succinctly when he found that to expect ESL students to adapt to a learning environment which is culturally alien to them, to undertake studies in academic fields which are cognitively demanding and to do all this via a medium of a language in which they lack fluency in its spoken and or written forms "is to engineer for these students classic conditions of failure" (p. 101). In order to address the dual purposes of the study, it was necessary to utilise a theoretical framework which supported the linguistic, sociocultural and academic needs of the students.

Short (2000) identifies a gap in the academic achievement levels of ESL students and those of native English speakers. Amongst the complex issues involved in this inequality, the obvious difference between the two groups is their language skills. The language in science classrooms forms an obvious focal point for investigation and represents the language learning aspect identified in the literature. To this end the theories on language and language learning were represented by the first focus on *language*. The focus on *teaching and learning environments* corresponded to the body of literature on content-based language learning in mainstream classrooms. Erickson's (1986) explains that interpretive research should focus on "the immediate and local meanings of actions as defined from the actor's point of view" (p.119). Consequently, it is clear that the cognitive demands in mainstream science

classrooms should be viewed from the students' perspective. As the third important area identified in the literature, the area of science and the ESL learner was represented by the focus on *ESL students.*

Selection of three foci does not imply that the author believes the issues to be separate entities. Indeed, once inside a classroom, their interdependence is immediately evident. Although the choice of the foci would seem to evolve naturally from both the main bodies of literature and the problems identified by practitioners such as Birch (1997), further support of these choices can be obtained from the constructivist theorists. Piaget (1972) made the claim that language depends upon and springs from cognitive development. However, it is the work of the social constructivists like Vygotsky (1963, 1978) which emphasise that the three areas of language, social interaction and cognitive development are linked. The basic belief that the knowledge constructed by the ESL student in a science classroom is a result of langauge use and the social interaction between peers and teachers provides validity for the selection of the three foci of langauge, the teaching and learning environment and the ESL student.

The literature review will be presented under the three foci headings of the language; the teaching and learning environment; and the ESL student. However, literature relevant to this study falls into three quite distinct areas. The first involves the theories on language and language learning. The second is related to matters surrounding content-based language learning in mainstream classrooms. The third outlines the specific issues for ESL learners of science and their teachers. Together these three areas provide a theoretical basis or rationale for the strategies which were adopted to improve the teaching and learning of science for the ESL students in this study.

Table 2.1

Summary of literature review

1. Language	2. The teaching and learning environment	3. ESL student
Components of language	The classroom environment	Who are they?
Language learning	The teacher	Science for all and scientific literacy.
The role of language in science and science education	Language teaching in science	Specific language acquisition issues
Characteristics of science language	Classroom strategies	Sociocultural issues
Difficulties associated with science language	Assessment	Cognitive demands

Language

The possession of language distinguishes humans from other animals. To know a language is to have an understanding of a special sound system and structure, to have access to an extensive mental dictionary, and to be able to use this knowledge creatively (Fromkin, Blair and Collins, 2000). However, a language is more than this. Language empowers an individual and is a vital part of his or her identity. According to Chomsky (1972), the study of linguistics encompasses the study of the distinctive qualities of the mind or of human essence. For Lemke (1989), language is a resource system for making meaning. Corson (1988) explains that language only develops through purposeful use. For ESL students, focussed learning such as occurs in science occurs through talking, reading, writing and listening and contributes to language development as well as cognitive growth.

In order to promote understanding for ESL science students, the science educator must first gain an overall view of the components of a language, the role that language plays in science classrooms, the characteristics of science language and the problems it poses for ESL students. Furthermore, there are several important features of second language acquisition theory, which have implications for the teaching and learning of science. These will be outlined where applicable.

Components of language

Fromkin et al. (2000) say that speakers of a language use a finite set of rules to produce and understand an infinite set of possible sentences. These rules comprise the grammar of the language. When a person acquires a language they have access to: the sound system (the phonology); the structure of the words (the morphology); how words may be combined into phrases and sentences (the syntax); the ways in which sounds and meanings are related (the semantics); and the words (the lexicon). From the point of view of learning a language, Ur (1996) explains that teachers and learners need to attend to the four primary skills (known as macroskills) of listening, reading, speaking and writing and the associated microskills of vocabulary, spelling, pronunciation and syntax.

Language learning

In the last few decades considerable research has been carried out in the area of second language (L2) learning. Much of the work has been based on studying how competence in the first or native language (L1) is acquired in the first few years of life and drawing analogies between this and L2 learning. The works of Chomsky (1965; 1972), Krashen (1973; 1977; 1981; 1982; 1985; 1997), Cummins (1983, 1994, 1996)), Kaplan (1966) and Canale and Swain (1980) are particularly relevant to the present study.

Chomsky (1965) stressed the importance of innate properties of language which explain a child's mastery of L1 in such a short time despite the highly complex and abstract rules involved. In his view each learner is credited with a *language acquisition device (LAD)* which directs the process of acquisition. This device

allows the learner to distinguish speech sounds from other sounds in the environment, to organise linguistic data into various classes that can later be defined and contains information about the possible form that the grammar of a language can take. *Universal Grammar* is the term used by Chomsky (1972) to refer to the abstract knowledge of language which children bring to the task of learning their native language and which constrains the shape of the particular grammar they are trying to learn. Universal Grammar consists of the various principles which govern the form the grammatical rules can take.

Although they are not universally accepted, Krashen's hypotheses (1973; 1977; 1981; 1982; 1985; 1997) provide a comprehensible theoretical framework for understanding the process of second language acquisition. In 1981 he suggested a distinction between language learning and language acquisition. He used the term *acquisition* to refer to the spontaneous and incidental process of rule internalization that results from natural language use, where the learner's attention is focused on meaning rather than form. In contrast language learning is a conscious process in which learners attend to form and rules. He states that the conditions that are present when one learns a first language are much the same as those required to learn subsequent languages. Moreover, for Krashen, (1982) the conscious learning process and the unconscious acquisition are mutually exclusive. He coined the term *comprehensible input* to point out that not all input is understood by the learner (Krashen, 1977). Allwright and Bailey (1991) define *input* as the language to which the learner is exposed. Krashen's monitor hypothesis (1977) states that the L2 learner has a device for editing, altering and correcting linguistic output. He further claimed that the best acquisition will occur in environments where anxiety is absent or where the *affective filter* is low. He contends that affective variables such as emotion, motivation and anxiety can promote or inhibit language development and that once the acquirer has built up enough comprehensible input language will emerge.

Whether it is accepted that there is a difference between learning and acquisition or not, the process of learning a second language is much more complex than learning the first language. L2 is acquired by individuals who are older and more complex than when they acquired L1. The affective filter may restrict the processing of input

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through factors such as anxiety, culture shock and culture stress. Input which makes it through may be processed through a monitor. This monitor also acts as a conscious check on the learner's output. The implications of the above key principles for the science classroom are that it becomes the teacher's job to provide comprehensible input in the form of authentic materials, exposure to different kinds of text, and as many opportunities for different kinds of interaction as possible. The classroom environment should be a supportive one which identifies with and accepts the students' cultures. There is also a need for second language consciousness raising with incidental grammar teaching in mainstream classrooms (Rosenthal, 1996).

As a result of the above hypotheses, today's second language teachers teach students to communicate genuinely and meaningfully in the second language. This methodology with its focus on meaning not form is known as *communicative language teaching* (Larsen-Freeman, 2000). From the language perspective, content-based language teaching such as that which occurs in science classrooms comes under the umbrella of the strong form of communicative language teaching (Richards & Rodgers, 1986). This means that the content area provides a meaningful use for language and through this medium the learner acquires the structures and forms of the language. Brinton, Snow and Wesche (1989) outline further advantages of content-based instruction. They explain that a content-based language curriculum takes into account the interests and needs of the learners. It incorporates the eventual uses the learner will make of the target language. It builds on the students' previous learning experiences, while allowing a focus on use.

Content-based language learning can have many forms. In immersion classes a foreign language is taught through the medium of an academic subject. In an adjunct model, content and language instruction are integrated. The students enrol simultaneously in an academic subject and a linked language course. In sheltered-language instruction, both native and non-native speakers follow a regular academic curriculum. However, language instructors, through the use of instructional materials and techniques support the ESL student. Finally, many students are merely placed in a school and expected to use English as a vehicle with which to study the science and other academic subjects (Larsen-Freeman, 2000). Brisk (1998) reports

that 50% of all ESL students in the United States are in classrooms where no special services are provided for them. She calls their situation *sink or swim or submersion* education. Larsen-Freeman (2000) claims that with no extra support this method of studying is very nearly an impossible undertaking.

Communicative competence is the aim of content-based language instruction such as that which takes place in science classrooms. This concept rests on the premise that language is not just a set of grammatical structures but a whole communication system. In order to use language effectively the user must possess not only knowledge of language but also how to use it appropriately, feasibly and correctly in a given context (Hymes, 1974). To achieve communicative competence the four separate components which were defined in Chapter 1 need to be considered. These are: 1. grammatical competence 2. discourse competence 3. sociolinguistic competence 4. strategic competence (Canale, 1983; Canale & Swain, 1980). Although ESL students may use science as a medium to improve their language, from the science teacher's point of view, students who have not yet developed communicative competence in English are at a distinct disadvantage when it comes to developing a deep understanding of scientific concepts taught in English.

Adamson (1993) states that many ESL (English Second Language) students who can speak English fluently have great difficulty in content courses because they are unable to use the language effectively for academic purposes. To help explain this phenomenon, Cummins (1983, 2000) distinguishes between two types of language proficiency. Basic interpersonal communication skills (BICS) are the skills required for oral fluency and sociolinguistic competence. Cognitive/academic language proficiency (CALP) consists of the linguistic knowledge and literacy skills necessary for academic work. The main distinction between the two is the extent to which the communication is context embedded or context reduced. BICS refers to context embedded speech which is accompanied by cues such as facial expression and experiential activities, while CALP involves the ability to manipulate concepts and solve problems, and so takes place in a context reduced environment. The differences between BICS and CALP are summarised in the figure below.

<table>
<tr><td colspan="2" align="center">**Cognitively Undemanding Language**</td></tr>
<tr><td>Social conversation
(with gestures)
Storytelling with props</td><td>Social phone call

Note left on the refrigerator</td></tr>
<tr><td colspan="2" align="center">**Basic Interpersonal
Communication Skills**</td></tr>
<tr><td>**Context-embedded language**</td><td>**Context-reduced language**</td></tr>
<tr><td>Math lesson
(with manipulatives)
Geography lesson with maps</td><td>Social studies lecture

Multiple choice test</td></tr>
<tr><td colspan="2" align="center">**Cognitive Academic
Language Proficiency**</td></tr>
<tr><td colspan="2" align="center">**Cognitively Demanding Language**</td></tr>
</table>

Figure 2.1 Cummins Quadrant Demonstrating the Dimensions of Language (Cummins, 1996 p. 10)

ESL learners need to be encouraged to move from the context embedded situations to more cognitively demanding situations. Carrasquillo and Rodriguez (2002) suggest that science is a good vehicle for this because of its relatively high contextual support in the forms of visuals, artefacts, and scientific apparatus. Furthermore it requires learners to engage in manipulative tasks and group work, and involves focussed activities.

Difficulties when learning English

Allwright and Bailey (1991) explain that it is useful to think of language learners as progressing along the interlanguage continuum, the different stages of which are marked by the errors the learner makes. The term *Interlanguage* (p. 201) was coined by Selinker in 1972. Obviously different individuals progress along the Interlanguage continuum at different rates and with varying degrees of success.

Error analysis is consequently very important and if learners are to progress thought must be given as to how learner errors are addressed. Allwright and Bailey (1991) describe an error as the production of a linguistic form, which deviates from the correct structure. They stress the importance and relevance of error analysis and correction in the classroom. McKay and Tom (1999) state that errors are a normal

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and necessary part of learning. They explain that indiscriminate error correction can intimidate learners and perhaps it is best initially for the students to have only those errors, which interfere with meaning corrected.

With regard to spoken language, three types of error analysis, phonological, morphological and syntactical, help to reveal the difficulties experienced by English language learners. As the sound system of a language, phonology is the component of a grammar that includes the inventory of sounds and rules for their combination and pronunciation (Fromkin et al., 2000). Ur (1996) states that learners make errors in pronunciation for two main reasons. Firstly, a particular sound may not exist in the mother tongue so that the learner is not used to forming it and therefore substitutes the nearest equivalent. Secondly, a sound does exist but not as a separate phoneme. Therefore the learner does not perceive it as a distinct sound that makes a difference to meaning. She says that on the whole the second problem is the most difficult to overcome.

Morphology is the study of the structure of words. It investigates the shape, formation and internal organization of words. Part of one's linguistic competence includes knowledge of the language's morphology. This includes information about the morphemes, words, their meanings and how they are combined (Fromkin et al., 2000). Typical errors might include: inserting extra suffixes; problems with plurals; absent, extra or incorrect form of auxiliaries; problems with co-ordinate construction; and the incorrect use of tense. These problems can arise because some Asian languages, for example, do not make distinctions by means of grammatical endings and do not distinguish the time or aspect of actions. This makes the English tense system very difficult for such students (Asian language notes, 1979).

Syntax is the component of the mental grammar that represents a speaker's knowledge of the structure of phrases, clauses and sentences. Fromkin et al. (2000) state that to adequately explain the knowledge that speakers have about the syntax of their language, a grammar must describe knowledge of the role words play in combination with others (intra word cohesion), phrase structure rules, and a set of transformational rules describing structure dependent patterning. In short, while morphology deals with the form of words, syntax is concerned with their

grammatical relationships or combination into groups such as phrases, clauses and sentences. Examples of syntactical errors might include: problems using the correct preposition in phrases; adjectives following nouns; difficulty expressing time; leaving out verbs; and missing pronouns.

Cunningham and Terrill (2003) outline the following levels of literacy and explain that a person's literacy level in L1 has an effect on his or her ability to learn L2. A preliterate individual has a native language which as yet has not developed in written mode. This is the case for a Bantu from South Africa, for example. A nonliterate person's native language has a written form but the learner may not have had access to any education and so has no literacy. The semiliterate learner may have experienced interrupted schooling and has minimal literacy in the native language. A nonalphabet literate is a person who is literate in a language which is not alphabetic, for example, Chinese. In this case, difficulties arise for the individual because the letters or characters in their own language represent pictures but not sounds. When a learner's native language uses an alphabet other than Roman, for example, Arabic, they are considered to be non-Roman alphabet literate. Finally, learners whose L1 is for example German or French are classed as Roman alphabet literate. It is obvious that these diverse levels of literacy will cause varying degrees of difficulty for those students attempting to learn English.

Campbell (1995) provides a comprehensive list of potential *troublespots* for ESL learners of science. Her list includes: tenses; American English versus British English; modals; correct use of prepositions; number like qualifiers; adverbs of frequency; idioms; subject-verb agreement; collective nouns; active and passive voice; infinitives; participles; gerunds; multisyllable words; nominalisation; and pairs of confusing words e.g. *affect, effect*.

Kaplan (1966) also noted how the native language of students influences their writing in English. When learners whose L1 is a Semitic language write in English, their paragraphs are characterised by considerable repetition because of parallel construction. English writing of Chinese and Korean students is marked by indirection and by descriptions of what things are not rather than what they are. Native French and Spanish speakers digress and include extra information when they

write in English. Kaplan (1966, p. 15) summarises paragraph construction of various language groups using the following diagrams.
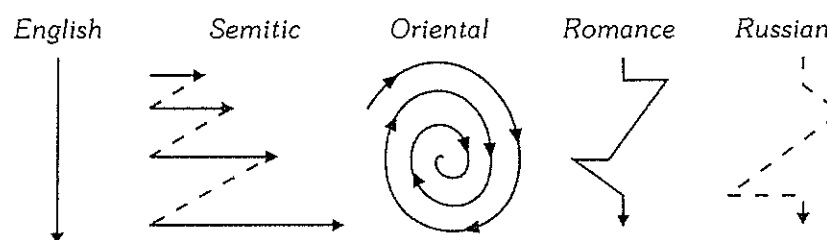
Figure 2.2 Kaplan's graphical representation of paragraph development in various linguistic systems.

In summary, there are several important points which are of particular relevance to teachers of ESL students with respect to L2 learning/acquisition. Teachers must remember that the language learning process is complex, gradual, dynamic and non-linear. Students learn when they are ready to do so and rely on the knowledge and experience they already have about their first language. Error correction may be helpful or harmful depending on how it is done. Complete mastery of L2 may be impossible and certain aspects of the new language may be especially difficult to master. Moreover, there is tremendous individual variation among individual language learners. Finally, learning language is social phenomenon and is acquired by interaction with other members of society (Larsen-Freeman, 1991).

The role of language in science and science education

It takes little effort to envisage the importance of language as the medium of classroom communication and as the vehicle of instruction. However, what is not so obvious is the contribution language makes to the development of understanding and meaning. Bruner (1972) argued that there are three ways of knowing something: in terms of a skill or by doing; by putting matters into imagery; or by translating skills and images into language.

Kulkarni (1988) explains that:

> The human mind is endowed with an ability (not shared by other species) of abstracting from natural experience an essence in an abstract form and

articulating it in a manner that permits its transmission and manipulation. It is this facility to manipulate knowledge in a symbolic framework that enables humans to derive deeper meaning from their experiences and to generate new knowledge which natural experiences in their raw form could never reveal (p. 154).

The emergence of language, the invention of script and the application of mathematics (symbolic language) to natural science were important milestones in natural history. While speech has been internalised, higher language skills such as writing, using mathematics, and constructing complex arguments, assume considerable importance in the context of science education (Kulkarni, 1988).

Bruner (1966) viewed language as essential for the building of knowledge and Vygotsky (1978) regarded it as a mediator of thought. He claimed that social interaction through language is a prerequisite to cognitive development. Barnes (1971) suggests that it difficult to separate learning the concepts and processes of a subject from learning to use the language to represent these concepts and processes. Brown (2000) explains that cognition and linguistic development are difficult to differentiate between.

With respect to science education, Wellington and Osborne (2001) suggest that there are two principle uses of language. While the first involves using the language as teachers and pupils to communicate and structure learning, the second entails learning to use language as a scientist would. Jarrett (1999) labels these two types of language conventions, social language and academic language. Social language which could be equated to Cummins' (1996) BICS is highly contextualised enabling ESL students to infer meaning and interpret visual cues and body language. Meanings in the social context of the science classroom are thus collaboratively constructed. On the other hand academic language, or what Cummins (1996) calls CALP is more abstract and common words can take on specialised meanings. In academic discourse students are often individually responsible for constructing meaning and must rely on their own understanding of both language and the concepts involved. Jarrett (1999) points out that while students can be proficient in everyday discourse they should be explicitly taught to use academic language.

Lemke (1989) explains that teaching science consists of teaching students to speak, interpret, read and write the language of science. As a social process, science teaching aims to bring students into the community of people who talk science. Talking science does not mean talking about science but doing science through the medium of language (Lemke, 1990). Carrasquillo and Rodriguez (2002) explain that science is a way of thinking, doing, acting, investigating, gathering, organising and evaluating. Consequently, scientific English is a distinguishable style of language, versions of which are used by scientists, science teachers, science students and science textbooks. Halliday and Martin (1993) state that this language of science has evolved to do these various forms of cognitive and semiotic work which everyday language is unable to perform and in so doing allows for accurate communication. O'Toole (1996) explains that the specific style characteristics were chosen in response to the demands of precision, clarity and brevity.

Characteristics of the scientific style

O'Toole (1992) examines the scientific style of writing on several levels. At the word level, the intellectual processes associated with science tend to generate numerous new terms which become the specific technical vocabulary associated with the subject. Wellington and Osborne (2001) have produced a taxonomy of science words which is summarised in Table 2.2.

As well as having this specialised vocabulary, the language used by scientists has distinctive sentence and paragraph structure, and employs highly conventional formats such as laboratory reports, science essays and textbook chapters. Scientists describe, hypothesise, record, compare, contrast, explain, classify, define, instruct, question, speculate, infer, predict, illustrate, conclude, argue, analyse, design, and theorise about how the natural world appears to them (Carrasquillo & Rodriguez, 2000; O'Toole, 1996). Lemke (1989) attributes the characteristic scientific style to the grammar, choice of words, idioms, metaphors, long nominal groups, a preference for the passive voice and abstract nouns being derived from verbs. Gardner (1978) explains that a typical passage of scientific writing may have the following attributes: numerous concepts linked within clauses by large number of function words such as

and, or, of and *in*; repetition of key concepts; and propositions linked by logical connectives such as *hence, since, thus* and *indeed.*

Table 2.2

Taxonomy of words in science

Level	Sublevels
1. Naming words	Familiar objects with new names e.g. *windpipe and trachea*
	New objects and new names e.g. *beaker, conical flask, cell.*
	Names of chemical elements
2. Process words	Capable of ostensive definition e.g. *evaporation.*
	Not capable of ostensive definition e.g. *evolution.*
3. Concept words	Derived from experience (sensory concepts) e.g. *red.*
	With everyday and scientific meanings e.g. *work.*
	Theoretical constructs (total abstractions, idealizations and postulated entities e.g. *elements, electron.*
4. Mathematical words	E.g. *sine, cosine*

Difficulties associated with science language

If learning the language of science is a major part of science education it should follow that every science lesson is also a language lesson. Unfortunately, Wellington and Osborne (2001) believe that science language is one of the major barriers to developing an understanding of scientific concepts. Halliday and Martin (1993) are quick to point out that science education did not create the problem. The issue lies with the discourse itself. O'Toole (1992) believes that if the style is not understood then the concepts it wishes to convey are unlikely to be understood either.

There are several levels on which science language causes problems for both native speakers and second language learners. Wellington and Osborne (2001) outline many reasons why reading scientific text is often more difficult than other reading which students are required to complete. The extensive specialist vocabulary of science is an obvious area of difficulty for many science students. Gardner (1974) outlines two specific situations which can cause problems when learning technical language. He says that terms are sometimes introduced which are too abstract to be understood by students at their particular level of cognitive development. Secondly, the concrete experiences needed for comprehension can be neglected. Halliday and Martin (1993) explain that definitions supplied in scientific texts are often interlocking. This means that understanding the definition is dependent upon comprehension of other terms within the statement. For example, if *Ecology* is defined as *the interaction of communities and their environment*, unless a student has an understanding of the terms *community* and *environment* the definition is useless. Another area of confusion with vocabulary arises when scientists employ everyday words in technical contexts (for example *force, energy, mass, weight* and *field*).

Gardner (1975) points out that it is important to be aware that science students do not only encounter problems with technical scientific vocabulary, but also with non-technical terms. These include certain words in ordinary English, which are crucial to the understanding of science. His research resulted in an extensive list of ordinary words, often found in scientific discourse which were not understood by a substantial number of students at various levels of schooling. For the most part they are words which describe objects, processes, activities or properties. Pickersgill and Lock (1991) conducted similar research and they provide a list of 20 words which they say are commonly used in science classrooms but are not accessible to many 14 to 15 year olds. Their word list is as follows: *abundant, adjacent, concept, conception, contract, convention, converse, disintegrate, diversity, emit, factor, incident, liberate, linear, negligible, retard, spontaneous, stimulate, tabulate,* and *valid*. This list and the ones in Gardner's (1975) work make surprising reading and throw light upon the communication gap that can open up when teachers use everyday English language without careful thought.

At the sentence level, students encounter different uses of articles and prepositions, modifiers, nominal groups, and long dense sentences in science texts. Passive voice, past tense and third person are also often employed and students are expected to reproduce this unfamiliar sentence construction in laboratory reports (O'Toole, 1992). Gardner's research (1978) also identified logical connectives items such as *moreover, consequently,* and *if only* as having the potential to impair a student's understanding of written scientific text. He acknowledged that these occur in all forms of writing but pointed out that because science deals with causes, effects and inferences they occur more frequently in scientific contexts. Sequencing and frequent use of referral words also impede understanding at the paragraph level. Halliday and Martin (1993) cite syntactic ambiguity and semantic discontinuity as further reasons why students might have trouble interpreting scientific text.

For mainstream ESL learners, science provides a meaningful and authentic use of the second language. Opportunities for speaking, listening, reading and writing which exist in most science lessons provide comprehensive input, as do the use of visual cues like specimens, graphs, tables, videos and hands on experience. However, unless science teachers are aware of the current theories of L2 acquisition the learners may not receive the assistance they require to help them to progress along the interlanguage continuum. Furthermore, although all science learners should strive to use the language employed by scientists, the special nature of the discourse does cause many problems for native speakers and ESL students alike. O'Toole (1992) outlines two methods to overcome the barrier to understanding of scientific discourse. He says it can be removed either by simplification or by helping students to understand the specific demands of the language. Halliday and Martin (1993) support the latter as they fear that less adept students will be disadvantaged when it comes to making social decisions regarding science if the former is employed.

The teaching and learning environment

To be successful the ESL learner needs to be comfortable within the learning environment (Larsen-Freeman, 2000). In Chapter 1, Schumann's (1986) model of acculturation was outlined as the degree to which the learner is able to integrate with the target group and the implications for the science classroom were explained.

Participative competence was defined as the learner's ability to respond appropriately to class tasks and demands. Interactional competence was explained as the learner's capacity to follow social rules and interact properly with peers and adults (Carrasquillo & Rodriguez, 2002). Vine (1997) supports integration into mainstream classrooms as the best means of achieving these competencies.

The classroom environment

The traditional approach to the education of ESL students separated English language development from content instruction because it is assumed that English language proficiency was a prerequisite for subject matter learning. Many educationists (Rosenthal, 1996; Stoddart, Pinal, Latske & Canaday, 2002) take the alternate view and support mainstreaming because they argue that if language use is to be purposeful, content-based language learning is an obvious choice. Furthermore, many feel that it is discriminatory to prevent ESL learners from joining mainstream classes and that the integration of inquiry science and language acquisition if done properly can enhance learning in both domains (Carrasquillo & Rodriquez, 2002). Cummins (1994) points out that if language instruction and content learning are separated by a period of time, ESL students fall behind and do not have the opportunity to develop academic language.

Unfortunately, according to Clegg (1996), mainstream classrooms are sometimes harsh places for ESL learners. Often students are left to manage as best they can on the periphery of the class. This too seems discriminatory and uneducational. No matter what stand is taken in the mainstreaming debate, in today's science classrooms it is an educational reality. If ESL science students are to develop participative and interactional competence in science classrooms and so acculturate, an accommodating learning environment is essential.

Rennie (1993) names supportive whole school contexts and active learning settings that are academically challenging as attributes that are characteristic of effective programs for ESL students. Carrasquillo and Rodriquez (2002) suggest four general guiding principles for mainstream classrooms which provide a good starting point for nurturing inclusive environments. Firstly, mainstreaming should provide a full range

of educational opportunities to all students, eliminating social and racial barriers. Secondly, the mainstream classroom should support social interaction between English language learners and their English proficient peers. Thirdly, opportunities should be provided for groups to function effectively once successful instructional strategies have been employed. Finally, all teachers, not just English and ESL teachers need to consider the language demands of every student in the classroom.

More specifically, provision of a language rich environment with opportunities to speak, listen, read, write, view, and perform is suggested by Heney (1996). Furthermore, the classroom environment should assist the ESL student to gain a positive self-image. A supportive attitude towards the learner by other class members is essential as is the cultivation of a strong classroom support structure. Rennie (1993) places emphasis upon functional communication between teacher and students and among fellow students.

Cummins (1994) supports inquiry-based learning as a particularly powerful instructional context for the integration of academic context and language development for English language learners. He says inquiry-based learning promotes students' construction of meaning through exploration of scientific phenomenon, observations, experiments, and hands-on activities while providing an authentic context for language use. Amaral et al. (2002) also promote inquiry-based science as a good approach for ESL learners because it involves cooperative learning and so students share common experiences through frequent interaction. Moreover, this type of learning encourages common thinking skills and provides time to build context. For these reasons it creates a more comfortable learning environment and creates positive attitudes to learning. Unfortunately, according to Lee (2000) there is currently little information available on successful approaches for preparing teachers to teach inquiry science to second language learners.

Cummins (1994) emphasises that modifications to instructional programs required to teach content in a manner appropriate for ESL students should not entail a dilution in the conceptual or academic content of instruction, but rather requires the adoption of instructional strategies that take account of students' academic backgrounds and ensure comprehension of the material being presented. Organization of the

instruction of basic skills and academic content around thematic units is useful (Rennie, 1993). Gutierrez's research (2002) supported the following recommendations for the development of supportive classroom structures for ESL students: allowing students to work in their primary language when appropriate; building on students' previous knowledge; restating problems; helping students to understand how a more experienced person connects ideas; and modelling styles of discourse.

In summary, because language and understanding are constructed socially, a supportive classroom environment should be created in order to promote participation and interaction of ESL students in science. Strategies should be utilised which serve to motivate and involve ESL students in learning. The acquisition of the concepts and skills of science ought to be allowed to occur simultaneously with the development of the English language. Care must be taken to ensure that science material is understandable while remaining academically challenging and meaningful.

The teacher

The American National Board for Professional Teaching Standards (2005) states as one its five core propositions that teachers must believe that all students can learn and act upon that belief. Success depends on the belief in the dignity and worth of all human beings and in the potential that exists within each child. Teachers must be attentive to human variability and its influence on learning. With respect to ESL students in mainstream classes this means that science teachers must work responsibly to simultaneously promote students' linguistic, social and academic development. Lee (2002) calls this process of mediating academic disciplines with linguistic and cultural experiences *instructional congruence*.

Despite these admirable goals, Lee (2002) reports that most teachers are unaware of how language and science can be integrated. Buck et al. (2003) state that many teachers have not developed the necessary teaching strategies to support ESL students. According to the National Centre for Educational Statistics (1997) most science teachers have received no training in order to address the particular learning

needs of ESL students. In a similar manner, Lee and Luykx (2003) reiterate that science teachers feel inadequate when dealing with ESL students. According to McLaughlin, Shepard and O'Day (1995) a complex set of teachers' beliefs and classroom practices are necessary if ESL students are to achieve academically while developing English language literacy.

Teacher beliefs

Research on teacher thinking reveals that teachers' beliefs on teaching and learning are important in determining roles in the classroom and decision making regarding interactions with students (Richardson & Placier, 2001). For example, according to Gutierrez (2002), secondary school teachers' main loyalty appears to be to their subject area, with the students' other needs a secondary concern. Her research showed that student's linguistic experience plays an insignificant role in the teaching of subject areas.

Bryan and Atwater (2002) report that many teachers continue to respond in ways that inadequately address the complexities of teaching and learning in a multicultural classroom. According to them, teachers graduate with a world view that is situated and remains within their own sociocultural background. They assert that there is a need for teachers to examine critically their beliefs about student characteristics, external influences on learning and appropriate responses to diversity if the situation is to improve. Carrasquillo and Rodriguez (2002) agree that in order to meet the academic needs of ESL science students, it is necessary for teachers to craft their own set of guidelines. To do this they require knowledge about language and language learning issues, and ideas and strategies to help create a supportive learning environment. However, in practice, quite often teachers are unaware of the linguistic levels and cultural diversity of the students in their classes.

Heney (1996) says that when teachers have solid knowledge of their ESL students and respect individual identities and specific needs, they are more likely to develop strategies that will support such students. She argues that where cultural diversity is celebrated, understood and planned for, students will thrive and be successful. However, if those directly responsible for a student's learning do not believe a

learner will succeed then they probable will not. It is an extreme but not rare belief, according to Bryan and Atwater (2002) that failure is simply inevitable for some students.

Lee (2004) explains that teacher change is necessary if teachers are successfully to integrate language and literacy into content areas such as science. With respect to the teacher change and instructional congruence, there are three key issues. Firstly, there should be modifications in teacher's beliefs about: academic content and children's abilities to learn it; the role of language and culture in instruction; and the teacher's own self-efficacy (Franke, Fennema & Carpenter, 1997). Secondly, the change should involve continuous, reflective and generative processes. Thirdly, teachers must not operate on routine or superficial procedures, but principled understandings which need to be applied to academic tasks, student groups and classroom settings (Richardson & Placier, 2001). Lee (2004) makes the point that if change is to occur, then teachers need access and opportunities to gain an understanding of these principled ideas in the form of professional development. Rennie (1993) says that mainstreaming is only effective if there is intensive staff development programs designed to assist all teachers.

Effective science teachers of ESL students

Carrasquillo and Rodriguez (2002) state that successful mainstream teachers of ESL students exhibit: good organization and delivery of instruction; knowledge of the second language acquisition process; knowledge of students developmental language practices; familiarity with students' native language and cultural background; familiarity with learning and cognitive styles; effective classroom management; high expectations of their students; and facilitation of parental involvement. Rennie (1993) reiterates the importance of expert instructional leaders and teachers who have a high commitment to the educational success of all students.

Levine (1990) could be accused of stating the obvious when she stresses the need for teachers to be hospitable to ESL students and to learn how to pronounce their names. Gutierrez (2002) found that successful mainstream teachers watched, listened and interacted with students in a way, which respected their culture and encouraged

positive attitudes in other students. Ensuring entrances to conversations, including students in classroom activities, encouraging ESL students to express ideas, thoughts, and experiences, and respecting language skills all have important affective influences on ESL students according to Jarrett (1999).

Language teaching in science

Because science is a meaning-making process, unless science instruction includes a focus on literacy development, ESL students are often excluded (Westby, Dezale, Fradd & Lee, 1999). From the language point of view, an inquiry-based learning approach provides opportunities for students: to ask for repetition and meaning to; tell others how to do things; to verify and compare; listen and participate in discussion; provide feedback; express an opinion and explain reasoning (Jarrett, 1999). However, this is not enough. It would appear that effective linguistic scaffolding by teachers is also essential if school science is to be accessible to ESL students. This is because in order for second language acquisition to occur the learner must receive messages in the new language, which are essentially understandable. That is, the input must be comprehensible (Krashen, 1977). The learner receives language in the form of classroom materials, instructions, discussions and in texts (Rosenthal, 1996). Carrasquillo and Rodriguez (2002) suggest that second language learners need a great deal of input.

If the ESL learner is to simultaneously acquire scientific understanding and improve communicative competence, Larsen-Freeman (2000) stresses the need for the teacher to have clear language objectives as well as content learning objectives. The specific language of a unit should be identified and then an effort to decode it for students should be made. She suggests focusing on a particular language need and ensuring that there are plenty of opportunities for practising that skill. Tiffunoff and Ward (1991) suggest several ways to promote English language development while pursing the acquisition of subject matter content and skills. They advise that the students' attention should be called to the language used in the classroom. The structure of the language used in the lesson should be presented as well as its meaning. Newly acquired or applied words should be summarised at the end of the lesson. Questions

should be asked which require extended answers and encourage students to expand upon and classify their answers.

Larsen-Freeman (2000) says that the use of customised materials or value-added resources will probably be necessary in order to mediate between the primary source material and the student. Brisk (1998) describes good materials as having characteristics such as text coherence, appropriate headings and illustrations, aids to facilitate reading including vocabulary overviews, graphic organisers, and prediction guides. The following list of strategies for the mainstream content-area teachers provided by Richard-Amato and Snow (1992) serves as a useful checklist and summary when considering material development: use visuals; use simplifications, expand ideas, direct definitions and comparisons to build in redundancy; reinforce key concepts over and over in a variety of situations and activities; avoid overly detailed explanations; summarise and review frequently; check understanding often; increase possibilities for success; clearly identify key terms; be aware of linguistic demands; incorporate group work; and teach academic information processing skills such as concept mapping.

Brisk (1998) says that while the use of good materials support implementation of curriculum and facilitate instruction, inappropriate materials can frustrate students and make the work of teaching more difficult. She suggests while there are some commercially produced products available, it will be necessary to customise materials by making use of a variety of resources including literature, subject area textbooks, visuals, and technology. She explains that technology increasingly offers a variety of materials for all disciplines and native languages and the internet makes it possible to connect to classrooms around the world.

Classroom strategies

In Chapter 1 *strategies* were defined as plans, steps, techniques or specific actions that are used, often consciously, towards the achievement of objectives. There are numerous strategies which can be used in a mainstream science classroom. These can be roughly grouped as teacher strategies and those which can be used by

students. In order to make some sense of the enormous amount of information available in the literature and to assist and focus classroom observations which were part of the research process a checklist of strategies was developed along with a classification scheme. The scheme was devised to mirror the multidimensional interpretive framework which measured changes in communicative competence, participative and interactional competences, and academic competence in phase three of the study. The specific detail of the strategies suggested in the literature is contained in this checklist which is described in full as a data collection instrument in Chapter 3. General information about strategies and some examples are summarised below.

Teacher strategies

The information in the literature about teacher strategies shows great diversity depending on where the authors' interests lie. Advice to teachers ranges from broad general statements about whole state and school policies to information about how to deal with specific science vocabulary issues. This makes the approaches suggested quite difficult to review and categorise and Herrell and Jordan (2004) are two of the few authors who attempt it. They have developed a general list of 50 strategies for teaching ESL learners and group them as strategies for: enhancing instruction through planning; supporting student involvement; building vocabulary and fluency; and building comprehension. This is a useful taxonomy especially because they provide a cross check with the Teaching English to Teaching English to Speakers of Other Languages (TESOL) ESL standards (1997). However it is not subject specific. For the present study, viewing strategies as enhancing communicative competence, participative or interactional competences, or academic competence was deemed a more useful way to classify them.

Some of the strategies suggested in the literature for improving communicative competence include: conducting a needs analysis for individual students (Oxford, 1994); incorporating reading, writing, listening and speaking activities in all lessons (Ur, 1996); pre-teaching vocabulary (Ur, 1996); demonstrating new vocabulary with objects and actions (Chamot & O'Malley, 1994); creating wordbanks (Heney, 1996); providing exercises in word synthesis and analysis (Dalton & O'Toole, 1984);

paying particular attention to logical connectives e.g. *consequently, moreover* (O'Toole, 1992); and developing student awareness of differences (Walqui, 2000).

It is reported that participative competence can be enhanced by: providing model written answers (Rosenthal, 1996); providing copies of written notes (Rosenthal, 1996); building on students' previous knowledge (Gutierrez, 2002); structuring activities so students can participate at a level of comfort (Herrell & Jordan, 2004); encouraging peer tutoring (Herrell & Jordan 2004); and providing possibilities for success for all students (Richard-Amato & Snow, 1992). Students can be encouraged to interact by the teacher: incorporating retelling activities (Heney, 1996); ensuring entrances to conversations (Jarrett, 1999); introducing a buddy support program (Heney, 1996); creating a classroom environment that is not dominated by teacher-student interaction (Buck, 2000); and being patient (Rosenthal, 1996).

Practising with some language functions such as reflecting, predicting, inferencing, and hypothesising (O'Toole, 1992); ensuring that students understand language functions such as compare, explain, describe, show, demonstrate, discuss, state, outline (Park, 1982); using a controlled vocabulary, with fewer pronouns and simple language structures (Jarrett, 1999); avoiding idiomatic expressions and words that have double meanings or synonyms (Jarrett, 1999); demonstrating new concepts with hands-on experiments and activities (Buck, 2000); using simplications (Ur, 1996); rewriting tests (Cuttell, 1982); providing individual assistance (Herrell & Jordan 2004); and accepting an oral performance or presentation (Tannenbaum, 1996); are all teacher strategies reported in the literature as enhancing academic development in science and other subjects.

Student strategies

Brown (2000) reports that as a result on the work in the seventies on what constituted a successful second language learner, lists of characteristics of good language learners were developed. From such lists a distinction was made between language learning strategies and communication strategies. The former relate to how input is processed, stored and retrieved. The latter pertain to the output or to how meaning is

expressed and messages delivered to others. Oxford (1990) reported a lack of a coherent, well accepted taxonomy for describing and classifying strategies. She went on to develop a system specifically designed for language learning strategies as did O'Malley and Chamot (1990). These strategy check lists are student-centred and will be discussed more fully in the third section of the literature review on ESL students and in Chapter 3.

Much of the work on the application of student learning and communication strategies to classrooms has come to be known as Strategy Based Instruction (SBI). Materials have been developed by various authors with the idea of training learners to use effective language learning strategies (Chamot & O'Malley, 1986; Oxford, 1990; Wenden, 1991; Cohen, 1998; Chamot, El-Dinary, Beard, & Robbins, 1999). Of special note is the work of O'Malley and Chamot (1990). Their *cognitive academic language learning approach* (CALLA) is an attempt to include strategy training as part of a content-centred approach. Cohen (1998) outlines the possible methods of teaching language learning strategies to students. His findings are summarised in the following diagram.

```
                          ┌──────────┐
                          │ Strategy │
                          │ teaching │
                          └──────────┘
                   ┌───────────┴───────────────────────┐
             ┌──────────┐                         ┌──────────┐
             │ Explicit │                         │Implicit in│
             │ teaching │                         │ language │
             └──────────┘                         │ teaching │
          ┌───────┴────────┐                      └──────────┘
    ┌──────────┐     ┌──────────────┐
    │ Separate │     │  Integrated  │
    │  strand  │     │ into teaching│
    └──────────┘     └──────────────┘
  ┌─────┬───┴────┬──────┐      ┌─────┴──────┐
┌──────┐┌────────┐┌────────┐ ┌────────┐┌──────────┐
│Study ││Awareness││Videotaped││Textbook││Strategies│
│skills││training ││mini     ││materials││based    │
│course││in       ││courses  ││        ││instruction│
│      ││lectures ││         ││        ││          │
│      ││and      ││         ││        ││          │
│      ││workshops││         ││        ││          │
└──────┘└────────┘└────────┘ └────────┘└──────────┘
```
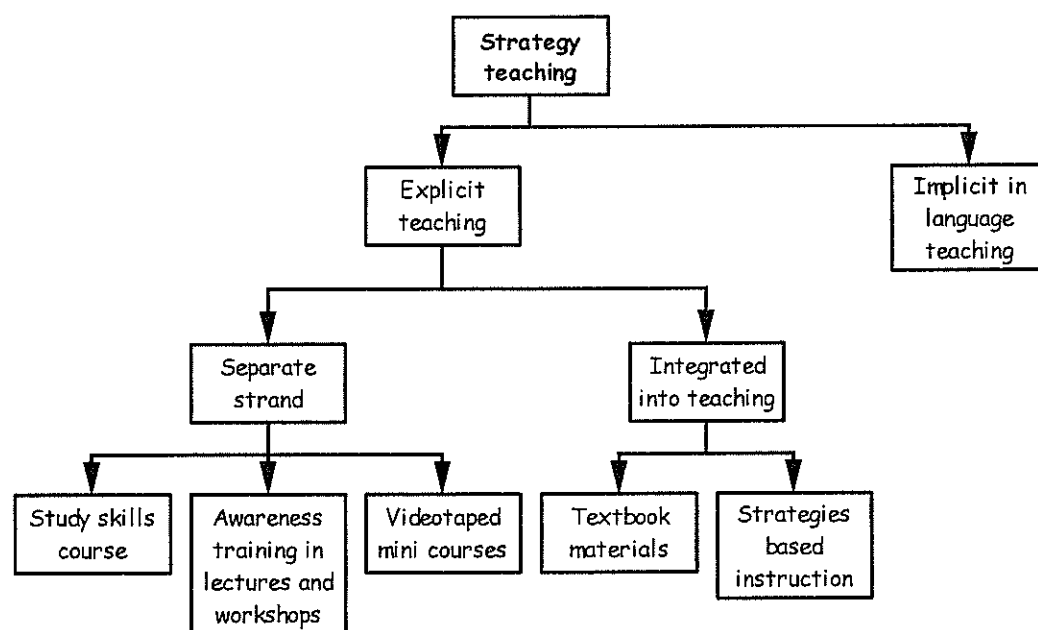
Figure 2.3 Cohen's methods of strategy training

He argues that explicit instruction is preferable to implicit instruction. Although the experts on strategy teaching (Oxford 1990; O'Malley & Chamot; 1990) all agree that the most efficient explicit method is by having teachers provide strategies based instruction to students as an integral part of the language curriculum, research into the effectiveness of explicit teaching and the best method to achieve this report mixed results. A study by O'Malley, et al. (1985) found that while explicitly teaching metacognitive strategies to a group carrying out a speaking task improved performance, explicit cognitive strategy teaching made no difference to a listening task post-test. In 1990, Oxford could only say that a fair number of learners receiving strategy training had shown improvement. McDonough (1999) concluded that improvements in language proficiency caused by strategy training were weak and only showed up on certain measures. Gu (1996) stated that literature on the effectiveness of strategy training had not produced definitive results with regard to the relationship between strategy use and actual performance. Cohen (1998) admitted that there was little empirical evidence to determine the best overall method for conducting strategy training. Most researchers agree that decontextualised separate strand courses such as the one attempted by Wenden (1987) have little value and are largely unsuccessful. Ellis (1994) also agreed that there was little proof that explicit strategy training was effective.

Assessment

The reasons for assessment of ESL students are threefold. Teachers need to have information in order to guide classroom placement, to improve instruction and to identify academic progress (Carrasquillo & Rodriguez, 2002).

To guide classroom placement

McKay and Tom (1999) explain that before a student enters the classroom a great deal of information regarding the student should have been collected. Brisk (1998) says that in order to interpret a students' performance, schools must first obtain background information on language proficiency, the level of schooling, and the level of native language literacy. In order to be thorough, initial language testing should cover grammatical, sociolinguistic, discourse and strategic competences.

Formal or standardised tests generally focus on the student's proficiency in English. Interviews allow assessment of speaking and listening skills while allowing the interviewer to learn more about the learner's background. A writing sample can provide further data about literacy levels. Ideally the science teacher should be aware of, have access to and understand all this information.

There are several formal methods of assessing language proficiency prior to placing students in classes. Developed in Australia by Ingram and Wylie in 1979, the International Second Language Proficiency Ratings (ISLPR) was previously known as the Australian Second Language Proficiency Ratings (ASLPR). It is a set of four subscales for the macroskills of speaking, listening, reading and writing that describe the development of second language proficiency in adolescent and adult learners. These subscales outline the development of the target language from 0 (no ability to communicate in the target language) to 5 (indistinguishable from a native speaker of the same sociocultural background). There are intermediate 'plus' or 'minus' levels, giving a total of 12 levels in each subscale. The descriptions at the various levels include a statement of the tasks that people at that level can perform and the kinds of language forms they use when performing those tasks. The descriptions assume real-life, communicative language use (Wylie & Ingram, 1999). Details of this scale are contained in Chapter 3.

The scales can be used in either a test or non-test setting. In a test situation listening and reading as well as speaking are tested in a face-to-face interview while writing tasks can be designed specifically to relate to the needs and interests of the learner. Assessment can also be made by external raters in naturalistic situations such as police stations, legal chambers and call centres. As part of the validation of the testing process used with overseas-trained teachers seeking registration in Australia, test developers visit schools to observe applicants interacting with children in actual teaching activities. ISLPR reporting is in the form of a profile, with speaking, listening, reading and writing indicated separately e.g. S:2+ L:2+ R:3 W:2 (Ingram & Wylie, 1991). A number of simplified versions of the ISLPR subscales can be used in non-threatening non-test situations. Wylie (1997) reports that some forms are even designed for self-assessment. Some of these self-assessment scales have been translated into a number of learners' first languages to make them more

accessible. The ISLPR levels can also provide a framework for language programs, guiding administrators and curriculum developers and teachers in overall program and course planning for English in second and foreign language learning situations and schools (Wylie, 2000).

The International English Language Testing System (IELTS) is another internationally recognised English language assessment tool. The system is owned, developed and delivered through a partnership of the British Council, International Development Program (IDP) Education Australia, IELTS Australia and the University of Cambridge. It is often used for international students who are intending to study in Australia, Canada, New Zealand and the United Kingdom. Like the ISLPR it provides a reliable assessment of a candidate's ability to read, write, speak and listen in English. The system consists of modules and tests. The Academic Module assesses whether an individual is ready to study at an undergraduate or postgraduate level. The IELTS General Training Module is applicable to students who are competing secondary education or for immigration purposes (International English Language Testing System, 2005).

To improve instruction

In order to tailor science instruction to suit the individual needs of the ESL learner the concerned teacher might wish to know a lot more than what level of language proficiency the student has reached. *How much has the student learnt since her arrival? How well is he coping? Should other methods be tried? How much content and what concepts does the student know in her own language? Does a student who is not achieving have problems with language or do his difficulties stem from psychological, physical, or emotional problems?* Brown (1998) suggests there is a need for multiple data types in order to increase the accuracy of diagnosis and evaluation of ESL students. He divides data collection into structured and unstructured types.

As well as placing a student correctly, the ISLPR and the IELTS can offer a structured method of assessing a student's language progress. Probably of more use to teachers hoping to improve instruction for the ESL students in their science classes are the National Languages and Literacy Institute of Australia (NILLIA) ESL

bandscales which provide descriptions of ESL learner progress at junior, middle and upper primary and secondary age levels (McKay, 1994). The bandscales give the classroom teacher an understanding of the nature of ESL learner development in schools and could be used to monitor and report on English language progress. For each of the three broad phases of schooling, there are scales for the four macroskills. For each macroskill, there are eight possible levels. It is hoped that learners move from the beginning level one to the upper limit of level eight. The bandscales are descriptive and are broadly placed within the personal, social and academic groups for each age of schooling. The TESOL standards (1997) outline the goals for ESL students in the United States. As these are student centred goals they will be discussed in more detail in the next section of the literature review which relates specifically to the ESL student.

As well as the structured type of information collection suggested above, unstructured data can provide valuable insight into the skills of students in the areas of language proficiency and development, and acquisition of content knowledge. Since language takes place in a number of different contexts, for a variety of purposes observations should involve as many different types of literacy events as possible (Brown, 1998). Types of assessment and classroom activities for ESL students should include portfolios, journals, conferences, self-assessment, peer assessment, test taking and test making. In the mainstream classroom, Brown (1998) emphasises the need to evaluate reading, vocabulary, writing, grammar, listening, speaking, pronunciation and notetaking in an unstructured manner.

To identify academic progress

Of necessity, almost all assessment items test both the content and the student's language ability. Even in practical tests science students need to understand written questions. At a minimum, most science assessment items require reading, comprehension and writing. In order to assess students' learning educators need to ensure that students have enough language proficiency to understand the content being used for assessment. According to Brinton et al. (1989) it is difficult to isolate one feature from the other.

Content-based instruction poses certain special problems in evaluating how well the ESL student has mastered the subject matter. In theory, assessment should be the same for all students. However, Jarrett (1999) explains that teachers need to consider whether a student who has mastered the academic content will be disadvantaged because of weak second language skills or lack of relevant cultural background. If a test has demanding time limits or requires accurate and exacting language the student may not be able to demonstrate his or her content knowledge. This will be true for complex writing, reading or oral tasks. Timed tests involving long readings or tricky multiple choice distractors, essay test questions, research papers, and oral presentations are all examples of items which will often disadvantage L2 learners. One possible answer suggested by Brinton et al. (1989) is to emphasise briefer and less verbally demanding items. Other suggestions include: basing student assessment on a number of tasks and not just one; marking assignments for meaning and not language; being sensitive to errors in discourse organization or the misuse of idioms; integrating practice exercises; guiding library research; marking drafts; and tutorial help (Jarrett, 1999).

Abedi, Lord, Hofstetter and Baker (2000) found that there is a high correlation between reading ability in English and academic achievement. Therefore they concluded that there is a need for some accommodation when it comes to assessing ESL students. Stansfield and Rivera (2001) list possible accommodations as: offering extra time; providing bilingual dictionaries; supplying a customised dictionary that does not contain words that assist students with test content; allowing the teacher to clarify the meanings of words on tests when they do not relate to the content; making environmental conditions more comfortable for students; letting the student take the test in familiar surroundings or with a familiar teacher; shortening tests sessions or giving breaks; reading the tests aloud; repeating directions; and simplifying and clarifying language.

Abedi et al. (2000) conducted research into mathematics testing for ESL students by employing four assessment accommodations. In the first instance they simplified English language test items. Secondly, they supplied a glossary of nonmathematical words or phrases. Thirdly, an extra 25 minutes of time was provided. The fourth accommodation involved a combination of the glossary and extra time. The authors

found that ESL students test scores were higher in all types of accommodations except the glossary only example. However, accommodations also helped native speakers who were randomly assigned to groups. The only type that narrowed the achievement gap was the simplified English strategy. This involved modifying the word problems for difficult generic vocabulary without changing the mathematical vocabulary.

While the science classroom can provide an excellent opportunity for ESL learners to develop their communicative competence, it must be born in mind that ESL students have many hurdles to overcome. Firstly, there is the obvious problem of language acquisition. Secondly, there are numerous sociocultural obstacles to negotiate. Finally, they must deal with the cognitive demands of science and its special language. In a non-supportive teaching and learning environment this can become a near impossible task. Teachers need to pay attention to the linguistic development of these students by ensuring that science lessons are language lessons as well. Additionally the classroom environment must encourage situations in which the students can interact and participate appropriately in order to acculturate.

ESL learners

As well as integrating into the science classroom and working towards communicative competence, the ESL science student aims to develop an understanding of scientific concepts. Their academic success relies upon being able to manipulate language in different academic contexts (Carrasquillo & Rodriquez, 2002). The complexity of the language question becomes evident when it is considered in conjunction with the learner's educational background, personality, culture and cognition.

Who are they?

Although certain generalisations can be made about teaching and learning environments, and language learning, the same cannot be said about the ESL learners themselves. They come from a myriad of cultural backgrounds and have very individual needs. But they all have two things in common. They all come from non-

English speaking backgrounds (NESB) and their understanding and production of spoken and/or written English constitutes a disadvantage at school (Flugelman, 1986).

Both Brown (2000) and Flugelman (1986) stress the importance of understanding the learner's backgrounds. McKay and Scarino (1992) state as one of their principles of language teaching and learning, that ESL students learn best when they are treated as individuals with their own needs and interests. Knowledge of their native country and language, level of literacy in their native language, time in Australia, level of competency in English, previous exposure to English, and prior experience of school and science, all help to interpret accomplishments and establish needs.

McKay (1994) describes four key secondary ESL learner groups as being recognised in Australian schools. They are: L1 school literacy background learners; students with low literacy backgrounds; learners transferring from primary school; and ESL learners with learning difficulties.

L1 school literacy background learners have had an education in their first language and their proficiency in their first language matches that of an average native speaker of comparable educational background. Although they are probably new to English they have skills which will allow them to acquire English in the school context. They may still experience culture shock but will probably have positive expectations of learning in English. Within this group McKay (1994) identifies a further subgroup. She recognises the *academically focused learners* or *maverick learners*. They are usually secondary school students who have high literacy levels in L1 and very good background knowledge in specific content areas such as the sciences and mathematics. They make conscious decisions to improve their English and are determined to do well in their academic studies. They do have residual difficulties with language tasks which require solid proficiency in a range of contexts. Learners in the low literacy background group have had disrupted schooling in their first language. The knowledge, skills, and attitudes they bring may vary and affect their approach to learning. Learners transferring from primary school may not have the same skills as other children of their age. There may be gaps in their L1 development and they may exhibit difficulties with the academic demands of high

school. Diagnosis of ESL learners with learning difficulties may be difficult because of low English proficiency. Additionally, these learners may have problems learning English because of their specific learning difficulties (McKay, 1994).

Science for all

The Queensland science syllabus for Years 1 to 10 reinforces that science is essential to the education of all students.

> Science is part of the human quest for understanding and wisdom and reflects human wonder about the world. The study of science as a "way of knowing" and a "way of doing" can help students reach deeper understandings of the world. (Queensland School Curriculum Council, 1999, p.1)

Science education is presently being investigated all over the world. Globally, the conclusion is that science should be for all including students with learning difficulties and culturally and linguistically diverse students (Lee, 2003).

Goodrum, Hackling and Rennie (2000) in their report on science education in Australia concluded that priority must be given to developing scientific literacy in Australia if the country is to experience social and economic well-being. In the United Kingdom the goals for science education have been expressed in the 1998 report *Beyond 2000: science education for the future* (Millar & Osborne, 1998). The first recommendation of this report is also focused on the fact that the science curriculum should enhance scientific literacy. This is taken to mean that students should be comfortable, confident and competent with scientific matters. More specifically, the curriculum should provide sufficient knowledge to enable student to read simple newspaper articles about science and to follow TV programs on new advances in science with interest. It should also enable them to express an opinion on any important social and ethical issues with which they will be confronted.

In the United States the American Association for the Advancement of Science (AAAS) founded *Project 2061* in 1985 in order to help all Americans become literate in science. The publication *Science for All Americans* which came out in 1989 set out recommendations for what all students should know and be able to do in science by the time they graduate from high school. It defined a scientifically literate person

as one who: is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands the key concepts and principles of science; is familiar with the natural world and recognises both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes. *Benchmarks in Science Literacy* published in 1993, translated the literacy goals into learning goals for grades K-12 (American Association for the Advancement of Science, 1993). The conclusion reached was that rather than prepare students exclusively for careers in science, the focus of science education should be to enhance citizenship for all (Fensham, 1985).

There seems to be a general consensus on the importance of scientific literacy. However, while it is suggested that *science for all* is necessary to ensure a literate populace, there appear to be few suggestions on how to achieve this for ESL students who may be struggling with everyday L2 literacy issues. Lee and Fradd (1996) provide some goals. They say that science education for ESL learners should aim to enable them to apply knowledge to their individual lives, recognise the diversity and unity of the natural world, understand strengths and weaknesses of technical applications, and explore scientific questions rather than getting the answers right. However, even though Lee and Luykx (2003) report on teachers' feelings of inadequacy there is little assistance on how to help ESL students achieve scientific literacy in the literature. Lee and Luykx (2003) conclude that the multicultural literature does not provide much specific detail on academic disciplines like science and the TESOL literature focuses on literacy development and not on developing concepts in science.

Specific language acquisition issues

Many of the issues relating to L2 acquisition have been covered in previous sections of this literature review. There are a few which because of their student-centred nature are included below.

McKay and Tom (1999) suggest it is important to reflect upon what the learner brings to the classroom. Knowledge of the learner's expectations, learning styles and strategies, confidence, motivation, personality and personal circumstances can all be

used by effective instructors to inform their teaching. Richards and Lockhart (1996) point out that learner's beliefs, goals, attitudes and decisions all influence the approach that they take to learning. Brown (2000) provides a list of personality factors which all contribute in some way to the success of language learning. Individual differences in levels of self-esteem, inhibition, risk-taking, anxiety, empathy, extroversion and motivation have all been shown to have an effect on L2 learning.

Chamot (1987) says "Second language learners are not mere sponges acquiring the new language by osmosis alone. They are thinking, reflective beings who consciously apply mental strategies to learning situations both in the classroom and outside it" (p82). Expert strategy researchers (Chamot et al. 1999; Cohen, 1998; O'Malley and Chamot, 1990; Oxford, 1990), all agree that effective language learners use more learning strategies than ineffective learners. It seems logical to presume that all students would benefit from better use of strategies.

Both O'Malley and Chamot (1990), and Oxford (1990) provide comprehensive taxonomies of language learner strategies. O'Malley and Chamot (1990) classify strategies into the three broad categories; the *metacognitive* strategies, which involve planning, monitoring or evaluating a learning activity: the *cognitive* strategies, which entail direct manipulation or organization of new information; and strategies, that are assisted by social interaction termed the *social-affective* strategies. Oxford's (1990) taxonomy divides learning strategies into *direct* ones, which she likens to the actors in a play; and *indirect* strategies, which she equates with the directors. The former directly involve the target language while the latter assist by focusing, planning, evaluating, encouraging cooperation and controlling anxiety. Direct strategies can be *memory, cognitive* or *compensation* strategies. Indirect ones include *metacognitive, affective* and *social* strategies. O'Malley and Chamot (1990) suggest that the implicit inclusion of some such strategies in content materials such as science may assist the learner and serve to make them more autonomous learners.

The TESOL standards (1997) outline three overarching goals for ESL students in the United States. These involve the development of social language, academic language and sociocultural knowledge. The standards are used to guide curriculum

development but also provide a picture of student's linguistic progress in mainstream situations. The goals and associated standards are shown in the table 2.3.

Table 2.3

TESOL standards

Goal	Standard
1. Use English to communicate in social settings.	1. Use English to participate in social interactions.
	2. Interact in, through and with spoken and written English.
	3. Use learning strategies to extend communicative competence.
2. Use English to achieve academically.	1. Use English to interact in the classroom.
	2. Use English to obtain, process, construct, and provide subject matter information in spoken and written form.
	3. Use appropriate learning strategies to construct and apply academic knowledge.
3. Use English in socially and culturally appropriate ways.	1. Use the appropriate language variety, register, and genre according to the audience, purpose, and setting.
	2. Use non-verbal communication appropriate to audience, purpose and setting.
	3. Use appropriate learning strategies to extend sociolinguistic and sociocultural competence.

Sociocultural factors

Brown (2000) defines culture as a system of ideas, skills, arts and tools that are characteristic of a certain group of people. He suggests that although the resultant scheme of integrated patterns largely remains below the threshold of consciousness it

strongly governs human behaviour. A person's culture as an ingrained set of behaviours and modes affects his or her communication and perception. Because language is part of a culture and culture is part of a language cultural issues can have a significant effect on language learning (Ellis, 1994).

Ur (1996) describes three types of culture which she says can all have an impact on language learners. Each type may from time to time overlap or interact with the others. The first is the *anthropological* or *way of life* culture. This is concerned with culture in the broadest sense and involves understanding the context of language in use. The second is culture as a *social discourse* (sociolinguistic competence). It involves giving linguistic realization to the social reality which exists in the context in which language is being used. The third type is termed *high culture* and involves literature, art, music, etc.

Australia is considered a multicultural society and the essence of multiculturalism is that all the groups which make up society have different historical, social and cultural backgrounds. Hofstede (1986) says that while all cultures share the same values, differences arise when different emphasis is placed on the various values. He suggests four conceptual categories which can be used as a backdrop for understanding cultural differences. *Individualism* means that a person primarily looks after himself and his immediate family as opposed to a collectivist society where individuals are looked after by a group. *Power distance* defines the extent to which a less powerful person in society accepts inequality in society as normal. *Uncertainty avoidance* defines the extent to which people within a culture are made nervous by unstructured situations. *Masculinity* refers to the social roles attributed to males and females in society. A masculine society strives to maximise distinction between what men and women are expected to do. Teachers who are charged with educating students whose cultural backgrounds are different from their own would do well to develop an awareness of these differences in order to properly understand and cater for these students.

Cultural differences can be of particular significance because unless the language used reflects the complex pragmatics involved, miscommunication will result, with both sides considering the other rude or uncooperative. In an ESL context, it is likely

that the non-native speaker will be influenced by the pragmatics which would apply in their L1 cultural context and unintentionally break rules, the consequences of which can be more serious than the breaking of linguistic rules (Ur, 1996).

All ESL students have to cope with cultural differences between home and school. Identity confusion or crisis can occur when their traditional cultures come into conflict with mainstream cultures at school (Brown, 2000). For example, many East Asian parents expect their children to obey the authority of the teacher and the textbook, to work hard and to succeed academically (Caplan, Choy & Whitmore, 1992). Evans and Fisher (2000) found that Australian students from homes where Chinese-based languages are dominant perceive their teachers more positively than do their peers. They suggest that these students may be culturally influenced to perceive the teacher as a more powerful, centralised figure than their mainstream peers. Caplan et al. (1992) say that such students often experience socialization problems as a consequence. Lee (2002) explains that in the sociolinguistic context of the classroom care must be taken to extend the learner's sociocultural competence by finding ways to enhance social and emotional adjustment. So for the ESL science student learning science in another language also involves learning the new norms, behaviours and beliefs that are appropriate for the culture of the science classroom.

From the academic perspective engagement with scientific information is mediated by students' prior linguistic and cultural knowledge (Giles & Franklin-Stokes, 1989). For mainstream students the knowledge they acquire at home is largely continuous with the expectations and assumptions of the school. For some ESL students their linguistic and cultural knowledge may be inconsistent with the scientific orientation toward knowledge, the nature of specific science disciplines or the way they are taught at school. Such inconsistencies can create significant problems for these students (Aikenhead & Jegede, 1999). With respect to science education Evans and Fisher (2000) found that the cultural content of science can have a greater effect on the learner than the course content. Lee (2002) suggests that there is a need for teachers to be attentive to potential cultural bias in curriculum materials and assessment items. She contends that science assessment is often infused with specific cultural knowledge that is not equally accessible to all groups of people.

Lee (1997) outlines the problems which can arise when teachers stereotype students. She explains how the large numbers of Asian students studying in America are often described as the *model minority* for their academic achievements. She suggests that this stereotyping often becomes a burden and is capable of producing complex pressures. As well as parents, the media, teachers, and fellow students all place high academic expectations on these students (Kember & Gow, 1991). Some teachers assume that these students will live up to these high expectations, and not require help. Consequently they often ignore their emotional needs such as perfectionism, stress and anxiety (Lee, 1997). Just as in America, a large number of students come from all over the world to study in Australia (International Education Network, 2003). All of their backgrounds are different from each other and in many cases drastically different from mainstream students' backgrounds. Science teachers need to look beyond stereotypes for a better understanding of the strengths and weaknesses of all students in order to promote science achievement as well as ways to enhance their linguistic, social and emotional adjustment (Lee, 1997).

Cognitive demands

In addition to developing communicative, participative, and interactive competence, ESL learners, just like their mainstream counterparts attend school to become academically competent (Saville-Troike, 1984). While in general, native speakers come to the classroom with the prior knowledge and reading and writing skills necessary to access content material, this is not the case for many ESL students. Cummins (1994) says that it may take ESL learners up to five years to acquire cognitive/academic language proficiency comparable to their native speaking peers. However, if ESL students are to catch up academically, their cognitive growth and mastery of academic content must continue while English is being learnt.

Carrasquillo and Rodriquez (2002) found that the cognitive development of ESL students is influenced by the following factors: literacy in their first language; their educational and personal experiences; the involvement of their parents; the richness of the academic content of the school; and how well they can manipulate L2 in a variety of contexts. Saville-Troike (1984) points out that specifically academic factors affect academic performance. Adamson (1993) maintains that as well as

background knowledge of content material effective study skills are essential if ESL students are to succeed. Dudley-Evans and St John (1998) define the skills needed for academic English as five macroskills: reading; listening to monologues (as in a lecture); listening and speaking (a two-way interaction); speaking (as in making a presentation); and writing. They argue that each of these macroskills consists of a number of microskills and that they should be specifically taught but in an integrated fashion.

Constructivism in the mainstream science classroom

For all students learning is a process which involves interaction between what is already known and the current learning experience. Science education stresses the role of prior knowledge and experiences in new learning (Wellington & Osborn, 2001). The essence of the constructivist theory of learning is that knowledge is a construction in the mind of the learner and reality is based on what the senses perceive. It is therefore impossible to judge how well mental images correspond to reality (Bodner, 1986). Gunstone (1995) points out that the relevance for teachers is that learners have ideas and beliefs about their world, which are personal constructions and that these have a major impact on the way they learn. The learner uses them to interpret the ideas to be learned and to link ideas with what is already known and believed. To achieve academic competence students must be able to acquire new skills, assimilate new information, and construct new concepts. If the learner's cultural background is different from the teacher's, understanding of scientific concepts could be affected (Giles & Franklin-Stokes, 1989). Driver et al. (1994) explain that scientific knowledge is both symbolic and socially negotiated. Gunstone (1978) says that language plays a basic role in the development of understanding concepts. Bodner (1986) maintains that active students learn more than passive ones.

Of particular relevance to the present study is the fact that the social constructivists contend that social interaction is foundational to cognitive development (Vygotsky, 1978). Piaget (1972) made the claim that language depends upon and springs from cognitive development. Vygotsky (1963, 1978) emphasises that the three areas of language, social interaction and cognitive development are linked. It is this basic

belief that the knowledge constructed by the ESL student in a science classroom is a result of langauge use and the social interaction between peers and teachers that provides validity for the selection of the three foci of langauge, the teaching and learning environment and the ESL student which are the threads which bind the thesis together. Of additional importance to this study is the idea that the construction of individual learner discourse depends upon the specific experiences to which the learner is exposed and particular interactions which take place. This means that active language use and social interaction between members of the class is essential for the learning process that takes place in science classrooms. Therefore, the development of interactional and participative competences is necessary if ESL students are to develop appropriate understanding of scientific concepts and learner discourse (Tikunoff &Ward, 1991).

The principles of learning in science are the same for all learners, native speakers and ESL students alike. Firstly, to be effective science learning must connect with prior knowledge because learners construct knowledge on a foundation of what they already know. Cultural differences may make this more difficult for ESL learners. Secondly, meaningful learning occurs in a social context where learners support and help each other by talking and interacting. Teachers guide, structure, scaffold and support. So although learners construct their own knowledge other people are important. For ESL learners, science lessons must also be language lessons if this is to be successful. Finally, best learning occurs when learners are aware of their own learning (Carrasquillo & Rodriquez, 2002). Development of academic study skills and the metacognitive strategies suggested by Chamot and O'Malley (1990) and Oxford (1990) may be an effective method of achieving this final goal.

Chapter summary

One of the purposes of this literature review was to provide a theoretical basis or rationale for the strategies which were adopted to improve the teaching and learning of science for the ESL students. To this end the three foci headings of language; the teaching and learning environment; and the ESL student were deemed to provide a suitable framework. However, at the onset of the chapter it was stated that the literature falls more readily into three distinct areas; the theories on language and

language learning; content-based language learning in mainstream classrooms; and science and the ESL student. In order to provide a slightly different perspective this outline will be employed for the summary.

Theories of language learning

Learning a language is a complex process because the learner needs to access the phonology, the morphology, the syntax, the semantics and the lexicon (Fromkin et al., 2000). Much of the work on L2 acquisition has been centred upon how competence in the L1 is acquired in the first few years of life and comparing this to L2 learning. Even though they are not universally accepted, the ideas of Krashen (1973; 1977; 1981; 1982; 1985; 1997) and Chomsky (1965, 1972) have been particularly influential. Chomsky (1965) contributions include descriptions of the *language acquisition device* and *Universal Grammar*. Krashen put forward many hypotheses including; the distinction between language learning and language acquisition (1982); *comprehensible input* and the *affective filter* hypothesis (1977). Selinker's (1972) term *interlanguage* which describes a continuum marked by a series of stages, which are defined by the types of errors the learner makes at each stage is widely employed.

The result of all this work is that teachers of second languages have moved away from teaching grammar and form and instead try to mirror how L1 was acquired by starting with meaningful use of language. For adolescent ESL learners this means they acquire the structures and forms of English by studying mainstream subjects at school (Richards & Rodgers, 1986). This approach is termed communicative language teaching and the ultimate aim is that the learner acquires communicative competence (Larsen-Freeman, 2000). Canale and Swain (1980) explain that this type of competence consists of the four separate components of grammatical competence, discourse competence, sociolinguistic competence, and strategic competence. Knowledge of these strands can help to provide a basis for considering what is necessary for effective ESL teaching and learning. Social and affective factors have also been shown to influence language acquisition (Ellis, 1994). The basis for Schumann's (1986) model of acculturation is that the learner will acquire the second language only to the degree that he or she integrates with the target group.

A great deal of research has been undertaken on language learner strategies in the last few decades. Chamot & O'Malley (1986); Oxford (1990); Cohen (1998); and Chamot et al. (1999) all contend that successful language learners use language-learning strategies well. They suggest that inclusion of such strategies in instruction may assist language learners and serve to make them more autonomous.

Content-based language learning in mainstream classrooms

Even though mainstreaming is an educational reality, there is disagreement in the literature about the effectiveness of content-based ESL teaching. Short (2000) states that when the language of instruction is English, there persists a significant difference between the academic achievement levels of ESL students and those of native English speakers. Carrasquillo and Rodriquez (2000) explain that the traditional approach to the education of language minority students separates English language development from content instruction because it is assumed that English language proficiency is a prerequisite for subject matter learning. ESL students do not always have an easy time in mainstream classes (Clegg, 1996) and most teachers of content areas feel that they have not been adequately prepared to deal with the students' needs (Lee & Luykx, 2003).

However, Stoddart et al. (2002) suggest that if language instruction and content are separated ESL students fall behind and do not have the opportunity to develop the cognitive/ academic language described by Cummins (1983). Cummins (1994) suggests that although modifications to content programs are necessary for ESL learners this does not entail a dilution in the conceptual or academic content of instruction. Rather he suggests the adoption of instructional strategies that take account of students' cultural, linguistic and academic backgrounds and ensure comprehension of the material being presented.

From the sociocultural and sociolinguistic perspectives, Heney (1996) stresses the need for teachers to respect individual identities and specific needs and Lee (1997) reminds of the dangers of stereotyping. Teachers' beliefs in students' success were found to have a profound influence (Bryan & Atwater, 2002). Hospitable teachers encourage the participation and interaction of ESL students which is necessary if

they are going to acculturate (Levine, 1990). Because language is a social activity interaction with teachers and peers in mainstream classrooms is necessary not only to improve linguistic skills but for cognitive development (Vygotsky, 1978). Gunstone (1978) says that language plays a basic role in the development of understanding concepts.

Science and the ESL student

Science education has been under review and three decades of constructivist research have resulted in a move away from teaching content and a move towards encouraging students to engage with science while using language to organise, recognise, and internalise information (Their, 2002). There has also been recognition of the significance of developing scientific literacy for all learners including ESL students. This is seen as important if Australia is to develop social and economic well-being (Goodrum et al. 2000).

For all students learning science consists of learning to speak, interpret, read and write the language of science (Lemke, 1989). However, Wellington and Osborne (2001) believe that science language is one of the major barriers to developing an understanding of scientific concepts. Gardner (1975) points out that it is important to be aware that science students do not only encounter problems with technical scientific vocabulary, but also with non-technical terms. These include certain words in ordinary English, which are crucial to the understanding of science.

Rosenthal (1996) explains although the language of science causes problems for all students especially ESL learners, there are many reasons why science is well suited to students for whom English is still developing. Inquiry-based learning which is commonly employed in teaching science is a particularly powerful instructional context for the integration of academic context and language development for English language learners. Inquiry science promotes students' construction of meaning through exploration of scientific phenomenon, observations, experiments, and hands-on activities and provides an authentic context for language use (Stoddart et al., 2002). Other commonly employed scientific learning experiences such as demonstrations, group work, hands-on activities like experiments, and the use of

visual aids like diagrams, specimens and videos all serve to reinforce words and text (Rosenthal, 1996). Language development is assisted by the opportunities for speaking, listening, writing and reading which exist in most lessons. Additionally, the technical language or jargon of science is often *foreign* to all students, native speakers and ESL students alike (O'Toole, 1992).

CHAPTER 3 METHODOLOGY

The purpose of this chapter is to describe in detail the design and methods of this study. It is divided into seven major sections. The first section describes the conceptual issues surrounding the use of qualitative methods and the research paradigm. The second describes the theoretical framework. The third outlines the research design. The research methods section follows. This is devoted to describing the participants, the data sources and the procedures used in the study. The fifth section describes the ways in which the data were interpreted within the multidimensional framework. The last two sections address how the trustworthiness of the research was ensured and the ethical issues involved. Table 3.1 on the next page outlines the approaches taken.

Conceptual issues surrounding the use of qualitative methods

Science teachers encounter any number of challenges every time they step inside the classroom. *How do I assist students to link new concepts with existing knowledge? How do I encourage true scientific inquiry and assist with scientific literacy? How do I ensure meaningful integration of technology in the classroom? How can I help my ESL students gain a better understanding of science?* Not only do they come across these problems, but as classroom practitioners they solve them on a daily basis.

Educational research must be more than solving everyday dilemmas. It must produce knowledge about the world (Merriam, 1998). Mouly (1978) explains that research goes one step further towards seeking truth than merely experiencing and reasoning. Shulman (1997) offers further explanation when he says, "Method is the attribute that distinguishes research activity from mere observation and speculation (p.7)." Educational research then could be described as an organised and disciplined attempt to uncover truth and seek answers to educational problems.

In an effort to solve these problems, a researcher must gather new data by accurate observation and description. Procedures must be carefully designed and the data should be rigorously and objectively analysed for the purposes of describing,

explaining, generalising or predicting. Each example of research must deal with the issues of precision and generalization, and be carefully recorded, reported and communicated if it is to contribute to new understanding in educational practice (Anderson, 1998; Cohen, Manion and Morrison, 2000; Punch, 1998).

Table 3.1

An outline of the research approach taken in this study

Aspects of the Research Process	Approach taken in this Study
1.Research paradigm	Qualitative interpretive research in a naturalistic setting
2. Theoretical framework	Social constructivism
3. Research design	Modified action research
4. Data collection	Construction of case studies
	Participant and non-participant observation
	Strategy checklist
	Interviews
	Portfolios of student work
5. Data interpretation	The interlanguage continuum
	Acculturation
	Cognitive Development
6. Trustworthiness	Truth value
	Triangulation
	Dependability
	Confirmability
	Transferability
7. Ethical issues	Informed consent
	Exchange of information
	Confidentiality
	Trustworthiness

The inexperienced investigator could be initially overwhelmed by the thought of designing and carrying out a piece of research. However, Hitchcock and Hughes (1995) give good advice when they suggest that ontological assumptions should give

rise to epistemological assumptions, which in turn determine methodical considerations and these in turn give rise to instrumentation and data collection.

Alternative paradigms

Guba and Lincoln (1994) referring to social science research define a paradigm as a "basic belief system or world view which guides the investigator, not only in choices of methods but in ontologically and epistemologically fundamental ways" (p. 105). Anderson (1998) explains that although educational research emerged from underlying social or natural science disciplines there is a need to recognise that education is not a single discipline. Consequently different methods of inquiry must be used to ask different kinds of questions in order to solve problems for different purposes. The approaches employed in educational research are numerous and varied and there are several different ways of categorising these approaches or paradigms. The literature appears to classify them using the following methods: contrasting perspectives of human behaviour; the settings used for studies; the degree of control and intervention; and the methods of data collection.

Anderson (1998) focuses on two dominant paradigms, which he labels the *positivist* and the *post-positivist* paradigms. The positivist approach, which has its groundings in the scientific method, asserts that knowledge is based on sense experience and things are only meaningful if they can be observed and measured. This paradigm is characterised by objectivity, measurability, predictability, controllability, patterning and the construction of laws and behaviours. The post-positive paradigm is more subjective and takes into account the fact that humans have feelings and make choices, which influence what happens in any situation. It tries to understand and interpret behaviour in terms of the individual.

Cohen et al. (2000) refer to the *normative, interpretive* and *critical educational research* paradigms. Normative studies are positivist whereas any theories constructed within the context of the interpretive paradigm tend to be antipositivist. Thus the normative paradigm asserts that human behaviour is rule governed and should be investigated by the methods of science. Interpretive approaches are concerned with the individual and try to come to understanding from within the

person. Critical educational research tries to take into account the political and ideological contexts of many educational studies.

Allwright and Bailey (1991) who are specifically interested in language classroom research describe the approaches used as *experimental, naturalistic or action research.* They point out that experimental research involves intervention and a high degree of variable control. A naturalistic enquiry is typically non-interventionist and non-controlling, and action research involves intervention but a low degree of control. Investigations of the last type also take place in naturalistic settings rather than the experimental conditions, which characterise the positivist investigation.

The division into *qualitative* and *quantitative* methods is one with which all scientists are conversant. At the most basic level, quantitative data are information about the world in numerical form and is characterised by comparing groups or relating variables (Punch, 1998). In contrast, qualitative data are usually expressed in words. However, the distinction is one, which means a lot more than just the type of data to be collected. The process of choosing which type of measurement to make tends to reflect whether the researcher has a positivist or antipositivist view of the world. This of course affects the problem to be investigated and the subsequent design.

Theoretical paradigm

The following will outline the author's beliefs regarding: the nature of reality; how knowledge is acquired; how humans react to the environment; and what kind of methodology will best uncover the information being sought and the type of information that will be collected. It important to reiterate that the first purpose of this thesis was to interpret the experiences of ESL science learners and their teachers and that the second aim was to bring about change. These goals have a direct effect on the choice of theoretical paradigm.

Nature of reality

There is no better way of observing how individuals interpret the world in different ways than to watch learners in the process of learning science through the medium of

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a language they are still acquiring. It soon becomes obvious that the students have what is known as very different world views (Cohen et al., 2000). There is no one true version of a language. The value to the learner lies in being able to use and manipulate words in endless combinations as a means of communication. As well as speaking, listening, reading and writing, to know a language involves understanding the sociolinguistic rules of the associated culture and this knowledge can only be acquired by individual experience (Ur, 1996). Because of interpretation issues, teachers of ESL students cannot assume that the science concepts they are conveying will be directly transferred and they have to design learning experiences based on constructivist principles. The nature of language ensures that science students construct concepts and build their own version of science knowledge. The student's own understanding of science concepts will of necessity be mediated by prior understanding and his or her language experiences.

How humans react to their environment

The literature (Carrasquillo & Rodriguez, 2002; Schumann, 1986) stresses the importance of participation and interaction for both linguistic and cognitive development. Communicative language teaching where students learn a second language in authentic contexts instead of the rote learning behaviourist situations of the past assumes that individuals react to their own environment and make conscious decisions about their own learning (Richards & Rodgers, 1986). While a language must be, by its nature built up by an individual, it is only constructed through socially mediated interaction. A person's individual vocabulary, for example, is influenced directly by personal experiences. In the science classroom it rapidly becomes apparent that students are experiencing things differently based on language, cultural knowledge and social experiences. Giles and Franklin-Stokes (1989) found that from the academic perspective engagement with scientific information is mediated by both the students' prior linguistic and their cultural knowledge. Evans and Fisher (2000) reported that the cultural content of science can have a greater effect on the learner than the course content.

Choice of methodology

It is clear from the above discussion that the social world of the science classroom is best understood from the viewpoint of the individuals who are part of the on-ongoing action. The feelings, behaviours and choices of the ESL students and their teachers influence what happens in the learning situation. Understandings of an individual's interpretations of the world have to come from the inside by a researcher who is sharing their frame of reference. This view is consistent with the post-positive perspective of human behaviour (Cohen et al., 2000).

If it is accepted that in science classrooms each ESL learner is experiencing things differently and constructing their own understanding by linking new ideas to existing ones, a methodology that focuses on interpreting meaning in context will be necessary. Merriam (1998) explains that in interpretive research, education is considered as a process and school is a lived experience. The dynamic nature of interplay between learners and their peers, and learners and their teachers means that there is a need to interpret happenings from different perspectives. This study tries to ascertain the goals of the participants, understand the behaviours they exhibit and the beliefs associated with the behaviour. It endeavors to interpret change and the reasons for that change.

Research design

The second purpose of this study was to bring about change within the classroom setting and so it would be considered to be interventionist in that it sought a solution to a real need. Cohen et al. (2000) say that to carry out action research means to "plan, implement, review and evaluate an intervention designed to improve practice" (p. 79). With regards to Allwright and Bailey's (1991) experimental, naturalistic or action research paradigms, the present study would be best described as action research because it involved intervention but with a low degree of control. However, the action research could be considered to be limited or modified as there was only one cycle of investigation and one person gathering data.

Merriam (1998) explains that the key assumption upon which all qualitative research is based is that reality is constructed by individuals interacting socially. As the intent of qualitative methods, according to Anderson (1998, p. 90) is to "uncover implicit meaning in a particular situation from one or more perspectives" this was the framework of choice. Because the study was primarily concerned with individual teachers, students and their language in their natural classroom environment, data collection instruments, which are sensitive to uncovering that underlying meaning, were employed.

Theoretical framework

The difficulties faced by ESL science students are many, complicated and interdependent. Developing language skills impact on learners' academic achievement and their ability to relate to teachers and peers (Short, 2000). However, Schumann (1986) maintains that students must interact and participate appropriately in order to extend academic and communicative competencies. Social interaction through language is necessary not only to improve communicative competence but is also a prerequisite to cognitive development (Piaget, 1972) and so the circle continues. The work of the social constructivists like Vygotsky (1963, 1978) affirms that the three areas of language, social interaction and cognitive development are linked. In order to make some sense out of the complex loop of circumstances surrounding the students and their teachers in this study, development of a theoretical framework was necessary. This basic belief that the knowledge constructed by the ESL student in a science classroom is a result of langauge use and the social interaction between peers and teachers provides validity for the selection of the three foci of langauge, the teaching and learning environment and the ESL student.

The literature which informs this study and was reviewed in Chapter 2, falls into three distinct areas: the theories on language and language learning; content-based language learning in mainstream classrooms; and science and the ESL student. It was decided that if the experiences of ESL students and their teachers were to be interpreted comprehensibly, each of these three areas would have to be attended to by giving them a specific focus.

Short (2000) identifies a gap in the academic achievement levels of ESL students and those of native English speakers. Amongst the complex issues involved in this inequality, the major difference between the two groups is their language skills. Gardner (1978); O'Toole (1982); Wellington and Osborne (2001) all explain how the language of science poses problems for all students. The language in science classrooms forms an obvious focal point for investigation and represents the language learning aspect identified in the literature. To this end the theories on language and language learning were represented by the first focus on *language*.

Birch (1997) maintains that to expect ESL students to adapt to a learning environment which is culturally alien to them, to undertake studies in academic fields which are cognitively demanding and to do all this via a medium of a language in which they lack fluency in its spoken and or written forms "is to engineer for these students classic conditions of failure" (p. 101). He identifies that the learning environment is an area worthy of consideration. The focus on *teaching and learning environments* corresponded to the body of literature on content-based language learning in mainstream classrooms.

Erickson's (1986) explains that interpretive research should focus on "the immediate and local meanings of actions as defined from the actor's point of view" (p.119). Consequently, it is clear that the happenings in mainstream science classrooms should be viewed from the students' perspective. As the third important area identified in the literature, science and the ESL student was represented by the focus on *ESL students*.

Research design

The study was carried out in three phases using an interpretive methodology based on a modified action research approach in naturalistic settings of the students' own classrooms. Phase one of the study involved investigating the current situation with respect to language, science teachers and learning environments, and ESL students via the following Research Questions.

1a.   What are the difficulties for ESL students with respect to the language used in science classrooms?

1b.   How do science teachers assist ESL students to interact and participate in science learning environments in Australian schools?

1c.   What difficulties do ESL students encounter when constructing an understanding of scientific concepts?

Phase 2 involved reflection, planning and development of strategies to improve the teaching and learning of science for ESL students. It aimed to answer the following questions.

2a.   What teaching and learning strategies are likely to assist the language development of ESL students in science classrooms?

2b.   What teaching and learning strategies are likely to improve the interaction and participation of ESL students in science classroom?

2c.   What learning strategies are likely to enhance ESL students' understanding of scientific concepts?

Research Questions 3a, 3b and 3c were examined in phase three where implementation and evaluation of strategies took place against a multidimensional interpretive framework. These are as follows:

3a.   What impact do strategies specifically designed to address language development in the science classroom have on ESL students' communicative competence?

3b.   What impact do strategies specifically designed to improve the science teaching and learning environment have on ESL students' interactional and participative competencies?

3c.   What impact do strategies specifically designed to assist ESL students' understanding of science have on academic competence?

Modified action research

Kurt Lewin (1946) who is credited with being the founding father of action research maintained that research which only produced books is inadequate. According to

Somekh (1995) action research is often viewed as the bridge between research and practice. Lewin (1946) described action research as a series of spiralling steps each of which is composed of planning, action and evaluation. Cohen et al. (2000) define action research as "a small-scale intervention in the functioning of the real world and a close examination of the effects of such an intervention" (p. 186). While McKernan (1991) reiterates the cyclical nature of the process, Kemmis and McTaggart (1992) argue, "to do action research is to plan, act, observe and reflect more carefully, more systematically, and more rigorously than one usually does in everyday life" (p.10).

Kember (2000) describes the characteristics of action research as: concerned with social practice; aimed towards improvement; a cyclical process; pursued by systematic inquiry; a reflective process; participative; and determined by the practitioners. Stringer (1996) explains that the processes involved in action research are: rigorously reflective or interpretive; engage those who are interested as active participants in the research process; and result in a practical outcome for the participants. Kemmis and McTaggart (1992) suggest that action research is not only concerned with changing the lives of individuals but may also involve changing the culture of groups.

The literature provides many different perspectives on how to implement action planning and research. While the National Education Association of the United States (1959) suggests only diagnostic and therapeutic stages, for Lewin (1946) action research involves the four stages of planning, acting, observing and reflecting. Kemmis and McTaggart's (1981) stages of action involve: the development of a general idea; a decision regarding a field of action; reconnaissance of the circumstances in the field; generating a general plan which includes the first action step with an idea of how to monitor; evaluation, revision of the plan and then a second action step; and implementation and evaluation. They stress that the spiral of action, monitoring, evaluation and replanning is ongoing. Cohen et al. (2000) offer practical advice with their eight stage process for action research. Their steps include: identification, evaluation and formulation of the problem perceived as critical in everyday teaching; preliminary discussions with interested parties; review of the literature; modification and redefinition of problem; selection of research

procedures; evaluation procedures; implementation of the project; and interpretation of data

Patton (1990) maintains that purpose is the controlling force of research. The general idea for this thesis rested in the author's own quest for strategies to improve the linguistic, sociocultural and academic experiences of ESL students encountered in science classrooms. The first phase of the study involved interpreting the experiences of ESL science learners and their teachers in Queensland educational institutions. This involved careful planning, observing and reflecting in selected classrooms including the author's own. However, the purpose was not merely to understand and interpret but to bring about change. A methodology which allowed for some intervention was called for and Cohen et al., (2000) report that action research is a powerful tool for change and improvement at a local level.

Another feature of the action research philosophy is that it should actively involve those most likely to be affected by the changes (Carr & Kemmis, 1986). Lee (2004) explains that teacher change is necessary if teachers are successfully to integrate language and literacy into content areas such as science. If the actions employed in this study were to bring about change then the students and other teachers needed to be active participants. Not only did there need to be modifications in teacher's beliefs about academic content and children's abilities to learn it but the change needed to involve continuous, reflective and generative processes (Franke et al. 1997). As the biggest stakeholders, it was essential that the students articulated their needs if the changes were to be perceived as beneficial (Oxford, 1994). Additionally, in order to assist in informed decision making, teachers and students needed to be involved in the data interpretation process. By allowing for the cycles of action and reflection, action research provided the flexibility necessary for trialling an intervention in the complex social setting of the learning environments of ESL students.

Kemmis and McTaggart (1988) state that action research is not research which is carried out on other people. Although the present study did involve not only the author's students but other teachers and students, the decision to employ a modified action research methodology was justified for a number of reasons. Cohen et al.

(2000) say that "Action research may be used in almost any setting where a problem involving people, tasks, and procedures cries out for a solution" (p.226). The problem which provided the impetus for this study had its foundations and was grounded in the researcher's own teaching practice. The study combined diagnosis but with reflection, intervention but with a low degree of exerted control, and taking an action which was followed by systemic observation of what followed. This was all in keeping with the spirit of action research (Strickland, 1988). The study was collaborative in that the other participants, both students and teachers, shared the concerns which prompted the project. Kemmis and McTaggart (1988) explain that although action research is by definition collaborative, the action research of a group can be achieved through the critically examined action of individual group members.

Method

Participants

Cohen et al. (2000) suggest that judgements about sampling have to be made around four key factors. These are: the sample size; the representativeness of the sample; access to the sample; and the sampling strategy to be used. As detailed case studies were to be undertaken, it was decided to limit the size of the sample to seven school students, two postgraduate students and one teacher. This size was deemed manageable by a single researcher. Obviously, this is a small sample and as such it raises the question of how well these students represent the wider population. Care was taken to choose students who came from different backgrounds and age groups. There was also a range of language proficiencies. All were science students.

As education is now Australia's third largest export service, each year Australia welcomes large numbers of international students not only to its schools, but to its universities, institutes and colleges. These students bring to Australia a range of educational experiences and talents, and cultural and linguistic diversity. It is important that teachers learn more about the kinds of students they are teaching and to develop methods and strategies that are effective for today's diverse students. Science teachers not only play a role in teaching that discipline in schools, but must also help to develop skills which are transferable to undergraduate and postgraduate

studies. It is therefore important to gain an understanding of the problems faced by undergraduate and postgraduate ESL science students. Two postgraduate students are thus included in this sample with the intention of broadening the understanding of the specific problems associated with English for academic purposes.

Three different schools in the Brisbane area were approached and agreed to participate in the study. The schools included: 1. a private girls' school in the central city; 2. a smaller private coeducational school which has several ESL students; 3. a new private coeducational school in the outer suburbs, which has an affiliation with an international school. The author had worked at all three schools at different times and at the time of the study was employed part-time at the last college. These past affiliations facilitated access to the institutions.

It is possible that the fact that all the students in the study were attending private schools might have some influence on the effect of the interventions. It must be acknowledged that the students from these schools are more likely to have had education in their home countries which was of a high standard when compared to those attending government schools. However, it would be incorrect to assume that teachers in government schools would be less willing to introduce the interventions. Additionally, had the students been attending government schools in Queensland, specialist ESL support would have automatically been provided. In Queensland, the ESL Program in government schools operates according to quite strict Commonwealth Guidelines for Schools, under an agreement between Education Queensland and the Department of Education, Science and Training (Department of Education, Training and the Arts, 2006). There are no such guidelines governing what happens in private schools.

The selection of the secondary students for the study was achieved by observation and discussion with the Heads of Department and the science teachers. At the first school the Head of the Department nominated a senior student called Aya for the study. Her teachers were then approached and agreed to participate in the classroom research. At the second school, observation of lessons and a discussion with the science teachers identified two senior students, Min and Claire, who might benefit from extra assistance. The Head of Department then provided information on which teachers taught the girls and they were approached and agreed to take part. At the

third school the students were taught by the author, identified by observation or nominated by other teachers. The students at this school were Cliff, Patricia, Simon and Yan. Patricia and Yan were senior students and Cliff and Simon were both in Year 9. Because, one teacher, Julia, had a special interest in science and language, she volunteered to be the subject of a case study. After the initial six months observation period it was decided that in the case of the senior students most emphasis would be placed on designing strategies specifically for biological science as this is where the author's expertise lies. Consequently, the biology teachers Pam, Phil, Mary and Julia made a further commitment to be involved in phase three. Both postgraduate students approached the author for assistance and their problems were also examined. Table 3.2 contains the teachers of each student involved in phase one. An overview of the students' profiles is presented in Table 3.3. Table 3.4 shows the students and teachers involved in phase three. Because the postgraduate students' experiences are different they are not included in Tables 3.2 or 3.4.

Table 3.2

The students and their teachers who were involved in phase one

Student	Junior science	Chemistry	Physics	Biology	ESL
Cliff	Author	x	x	x	Lisa
Min	x	Rayleigh	Dave	Pam	Lisa
Claire	x		Narelle	Phil	x
Aya	x	Carla, Jeff	Alan, Rachael	Mary	x
Patricia	x	Susan	x	Julia	x
Simon	Author, Susan	x	x	x	Cheryl
Yan	x	Susan	John	Author	Cheryl

Table 3.3

Overview of student profiles

Student	Country of birth	First language	Age at the onset of study	Date of arrival in Australia	Science Subjects
Cliff	China	Cantonese	14	2002	Year 9 Science
Min	Taiwan	Mandarin	15	2001	Chemistry, Physics, Biology
Claire	Taiwan	Mandarin	16	2002	Chemistry, Biology
Aya	Japan	Japanese	17	1989	Chemistry, Physics, Biology
Patricia	Germany	German	16	2002	Chemistry, Biology
Simon	Taiwan	Mandarin	14	2002	Year 9 Science
Yan	China	Cantonese	16	2002	Chemistry, Physics, Biology
Anna	Hong Kong	Cantonese	32	1988	Orthodontics
Lenny	Columbia	Spanish	28	2001	Dentistry

Table 3.4

The teachers and students involved in phase three

Student	Junior science	Biology
Cliff	Author	x
Min	x	Pam
Claire	x	Phil
Aya	x	Mary
Patricia	x	Julia
Simon	Author	x
Yan	x	Author

Data sources

Patton (1990) explains that qualitative methods generally consist of three kinds of data collection: in-depth open-ended interviews; direct observation; and written documents. McKernan (1993) in his list of appropriate methods for action research includes: participant and non-participant observation; anecdotal records; case studies; journals; field notes; checklists; audio and video taping; rating scales; attitude scales; interviews; document analysis; and group discussions. The types of data collected in this study included: case studies, non-participant and participant observations recorded in field notes and in a journal ; a strategy checklist; interviews of both students and teachers; and analysis of samples of student work including in class work, tests and scientific reports. Data were obtained to correspond to the three foci of the study. Data sources which converged on the three areas were used to compose a rich vivid description of the students' language, learning experiences and science education.

Use of case studies

Yin (2003) defines a case study as an inquiry which investigates a contemporary phenomenon in a real-life context. It can be used to explore situations in which the

intervention being evaluated has no clear single set of outcomes. He goes on to say that it relies on multiple sources of evidence with data which converge in a triangulating fashion and that it can be used to explain casual links in real-life interventions that are too complex for survey or experimental strategies. Stake (1985) explains that it can be the study of a single case or a bounded system. For Yin (2003) case studies are single or multiple, and each of these can be holistic with a single unit of analysis or embedded with multiple units of analysis. Because the present study involves the investigation of three foci for a number of students it would be considered a multiple embedded case study.

McKernan (1991) explains that a case study when used in action research is "a formal collection of evidence presented as an interpretive position of a unique case and includes discussion of the data collected during fieldwork and written up at the culmination of a cycle of action or involvement in the research" (p. 74). He says that the advantages of case studies include reproduction of phenomenological world of participants through a detailed description of events. Additionally, they can present a credible account of the setting and action. Case studies also employ multiple methods to corroborate and validate results. Finally they tell a story in language that is easy to read. The findings in this study are presented in part as case studies, in order to provide the reader with a concrete sense of the personal and shared challenges the students and their teachers faced.

Non-participant and participant observations

All students except the postgraduate ones were observed over a period of at least one year. This was necessary as noticeable changes in language skills can be slow. Although in most cases observation took place once per week, usually several lessons were observed each day. In the cases of the author's own students they were seen for four or five lessons per week for a minimum of one year. The total number of lessons observed for each student is recorded in Table 3.5.

In the first phase of the study, when in classrooms other than her own, the researcher assumed the role of non-participant observer. In these instances the teacher introduced the researcher as someone who was interested in science and language

and this seemed to be well accepted by the students. Junior Science, Chemistry, Physics, Biology and ESL lessons were all observed. This period lasted for six months. During this time suitable students were identified and teachers who were willing to implement strategies volunteered.

Table 3.5

Observation schedule

Student	Teachers	Total Number of Lessons Observed
Cliff	Author	152
Min	Pam, Dave, Rayleigh	63
Claire	Phil, Narelle	59
Aya	Carla, Jeff, Alan, Rachael, Mary	84
Patricia	Julia, Susan	80
Simon	Author, Susan	155
Yan	Author, Susan, John	198
Anna	Professor of dentistry	20 hours
Lenny	Author	25 hours

In her own classroom the author assumed the role of teacher as researcher. In other teacher's classrooms detailed field notes were kept on each occasion. Field notes focused on: the ways in which language was used in the classroom; student participation and interaction; linguistic scaffolding; adaptations of communication including verbal, gestural, written, and graphic means; difficulties with language; opportunities for reading, writing, speaking and listening and development in English language and literacy. After classroom observations, teachers' feedback and insights into the lessons were obtained and recorded in the researcher's journal. In the author's own classroom the journal was employed to record anecdotal evidence. This was completed as soon as possible after each encounter with the students and also documented the processes involved in strategy development in the second phase of the study. Data from the field notes and the journal were converted into data summaries as soon as possible. A strategy checklist was a structured method used to focus observation and make comparisons between classes.

The second half of the study involved working with teachers in classrooms and in one-on-one situations with teachers and students depending on the strategies being introduced. Often participation in classrooms and practical exercises was necessary in order to assist students. Field notes and the journal were meticulously maintained during this phase and once again converted to data summaries.

Strategy checklist

Oxford (1990) reported a lack of a coherent, well accepted taxonomy for describing and classifying language learning strategies and went on to develop one. A review of the literature revealed much information on the strategies which could be used in a mainstream science classroom. However, these came from many sources. In order to make sense of them development of a framework was deemed necessary. It served not only to guide the literature review in part but proved valuable in focusing classroom observation. Using the TESOL standards (1997) as a guideline, strategies were classified firstly as being student strategies or teacher strategies. They were then further defined as being useful in promoting communicative, interactional, participative and academic competencies. Strategies were chosen on the basis that they were relevant to mainstream science classrooms and were observable. At times this classification proved difficult. Some strategies fitted snugly into a definite category whereas some could have been applicable to more than one. Where precise categorization was difficult, in order to avoid repetition, a decision was made based upon where the strategy was most likely to result in change. Because the entire checklist was used for each student, even where strategies may have been relevant to more than one area of competence, consideration was given to that strategy. The checklist appears in Appendix B. Strategies are presented in dot points under the appropriate heading. It is interesting to note that there are many more suggestions in the literature for teacher strategies than for student strategies.

Interviews

Interviews can be a powerful data collection technique for the researcher (McKernan, 1991) and there are several advantages to the use of this method of data collection in a qualitative study. Not only do they involve personal interaction, interviews are

dynamic and bestow personal value to the person being interviewed (Anderson, 1998). They allow for in-depth analysis and the pursuit of details and can be geared for each respondent (Punch, 1998). Cohen et al. (2000) promote interviews as a good method of accessing people's perceptions, meanings, definitions of situations, and constructions of reality. Other strengths include: they provide for depth rather than breadth; they incorporate views of key people; and they can be structured, semi-structured or unstructured (Anderson, 1998; Cohen et al., 2000; Punch, 1998). A range of interviews provided data for this study.

During the course of this study the mainstream science teachers, ESL teachers and the ESL students were interviewed. The list of those interviewed corresponds with the names contained in Table 3.2. In the initial observation period, before the selection of key teachers and students was made many of the interviews were unstructured and informal. Once they had been chosen, semi-structured interviews with students were used to obtain details of their history, to assess needs, to determine what strategies the students employed in their studies and also to gauge communicative competence. Similarly, a semi-structured interview with the key teachers was conducted. Teacher's beliefs, confidence in developing scientific understanding in students; confidence in developing literacy skills were probed. These interviews were taped and transcribed with the permission of those involved. Throughout the study, views of both teachers and students were sought after every classroom encounter and discussed as part of the modified action research process when time permitted. Feedback on the implementation of strategies served to assist with evaluation and inform the next steps of the process. At the end of the phase three the key students and teachers (those listed in Table 3.3) were interviewed again as part of the evaluation process.

Student work

Punch (1998) explains that documents can be a rich source of data in research and an important means of triangulation. For ESL learners the science classroom provides a unique situation for using their second language. Because of this the kind of language the students use during lessons has an important influence of their language development and understanding of scientific concepts. Students use English for a

variety of different purposes within the lesson including interacting and participating with peers and teachers, constructing an understanding of science and using the language to negotiate and complete learning activities and assignments. Classroom observations assist in understanding learner language in terms of communicative functions and to some extent allowed interpretation about developing scientific concepts. Interviews and one-on-one sessions with students provide information about the participants' experiences, reading comprehension, oral language and listening skills. In order to gain an insight into how effectively written language is used for academic purposes and to probe further the construction of scientific understanding, portfolios of students work need to be included in data collection techniques. Accordingly, in collaboration with teachers portfolios of work were collected. Examples of class work, emails, drafts and copies of assignments, and copies of examinations were all included. For each student these were accumulated in phase one and again in phase three so comparisons could be made.

Summary of data sources

The nature of language decrees that data must involve samples of speaking, listening, reading and writing. This was attended to by observation, interview and samples of student work. Data on experiences of teachers and students and instructional practices in the learning environment were obtained using observation which employed the strategy checklist and interviews. The ESL students' wider experiences and history were compiled as case studies. Academic progress was followed by interview, observation and examination of student work.

Data interpretation

In order to assess the impact of the interventions developed in phase two upon the three focal areas, effective methods of comparison between phases one and three were needed. Consequently, a multidimensional interpretive framework was developed to answer research questions one and two. An overview of the interpretive perspectives for each focus area follows.

In Chapter 2 several methods of assessing language proficiency were outlined. In conjunction with the teachers, it was decided to collect and analyse language data using the International Second Language Proficiency Ratings (ISLPR). This scale was chosen because it did not involve additional assessment or stress for the students. Decisions regarding levels were made with the help of teachers using classroom observations, student work and informal assessment. This rating system is a proficiency scale or a set of four subscales for the macroskills of speaking (S), listening (L), reading (R) and writing (W). Each subscale follows the development of learners of a language from 0 (no ability to communicate in the target language) to 5 (indistinguishable from a native speaker). There are 12 levels including intermediate *plus* and *minus* levels. The description of each level includes a statement of the kinds of tasks that people of that level can perform with the contexts they can perform them in. Furthermore, the kinds of language forms they use when performing those tasks are included along with details about accuracy, fluency and appropriateness (Lee, Wylie & Ingram, 1998). A typical profile might appear as S2, L1+, R2, W1. Table 3.6 on the next page contains basic details of the ISLPR levels.

The levels were determined as follows. Phase 1 of the study involved intensive observation by the researcher. Time was spent observing oral interaction within the classroom and interviewing the students individually outside that environment. In this way a decision about speaking levels were reached by the researcher. The interviews also provided evidence for listening levels as did the questions raised by students after science lessons. Student work was analysed in order to determine reading and writing levels. The science teachers, who were more familiar with the students, were then asked to provide their opinions on the levels of the students. Where the students language ability permitted, students were asked to self assess using an alternative form of the ISLPR. In most cases the teachers, students and researcher agreed on the levels chosen. In a few cases, some minor negotiation was required.

The interlanguage continuum, which is defined by the types of errors the learner makes, was used to assess the learners' grammatical and discourse competence.

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Classroom observation, student and teacher interviews, portfolios of student work
and error checklists were used to collect data for analysis of errors in speaking,
listening, reading and writing. The researcher's journal recorded anecdotal evidence
of any sociolinguistic problems. Checklists of strategies were used in conjunction
with student and teacher interviews to determine levels of strategic competence.

Table 3.6

ISLPR Levels

Level	Names of ISLPR levels	Brief summary
0	Zero Proficiency	Unable to communicate in the language.
0+	Formulaic Proficiency	Able to perform in a very limited capacity within the most immediate, predictable areas of need, using essentially formulaic language.
1-	Minimum 'Creative' Proficiency	Able to satisfy immediate, predictable needs, using predominantly formulaic language.
1	Basic Transactional Proficiency	Able to satisfy basic everyday transactional needs.
1+	Transactional Proficiency	Able to satisfy everyday transactional needs and limited social needs.
2	Basic Social Proficiency	Able to satisfy basic social needs, and routine needs pertinent to everyday commerce and to
2+	Social Proficiency	linguistically undemanding 'vocational' fields.
3	Basic 'Vocational' Proficiency	Able to perform effectively in most informal and formal situations pertinent to social and community life and everyday commerce and
3+	Basic 'Vocational' Proficiency Plus	recreation and in situations which are not linguistically demanding in own 'vocational' fields.
4	'Vocational' Proficiency	Able to perform very effectively in almost all situations pertinent to social and community
4+	Advanced 'Vocational' Proficiency	life and everyday commerce and recreation, and generally in almost all situations pertinent to own 'vocational' fields.
5	Native-Like Proficiency	Proficiency equivalent to that of a native speaker of the same sociocultural variety.

The teachers' success in creating supportive learning environments was interpreted from the sociocultural or acculturation perspective. Data concerning how students respond to class tasks and demands, and if the learner can follow social rules and interact properly with peers and adults were gathered by classroom observations, and teacher and student interviews. Collected data were read to identify major patterns and themes. Emerging patterns or themes were verified or modified as new affirming or disconfirming evidence was identified. Any changes in participative and interactional competencies were noted in the researcher's journal and the data summaries. Vignettes of classroom events that were representative of patterns and themes were constructed. The multiple data sources allowed triangulation of data (Mathison, 1998).

The students' cognitive development was assessed by analysing any improvements they have been able to demonstrate in their academic competence. In this study academic competence was measured against the criteria set out by the various work programs applicable to the classrooms involved. In Years 10 to 12 this involved the three assessment categories of *Knowledge, Scientific Process and Complex Reasoning*. The Queensland Board of Senior Secondary School Studies Biological Science Syllabus (1998) defines *knowledge* as the recall of learned material and its simple application. *Scientific processes* are those processes which involve collection and organization of data, processing information, making simple judgments, communicating information in various contexts, and devising and designing simple and single-step investigations. *Complex reasoning processes* are those higher order or more involved problem-solving processes which provide challenge to students and so discriminate across a range of student abilities.

The results are expressed as: *Very High Achievement (VHA); High Achievement (HA); Sound Achievement (SA) Limited achievement (LA) and Very Limited achievement (VLA)*. The nominal cut-offs for Years 11 and 12 are shown in the table.

Table 3.7

Summary of cut-offs for achievement levels for Years 11 and 12

Level	Knowledge	Scientific Process	Complex Reasoning
VHA	80%	80%	60%
HA	65%	65%	40%
SA	45%	45%	>0%
LA	25%	25%	NA
VLA	<25%	<25%	NA

Additionally, each level of achievement is subdivided into 10 levels. For example, a student may achieve an SA1 – SA10 in the sound achievement level.

In Year 9, in one of the schools only knowledge and scientific processes were used for assessment purposes. At the other two schools all three criteria were used. Nevertheless the cut-offs were as follows:

Table 3.8

Summary of cut-offs for achievement levels for Years 8, 9 and 10

Level	Knowledge	Scientific Process	Complex Reasoning
VHA	85%	85%	60%
HA	70%	70%	40%
SA	50%	50%	>0%
LA	25%	25%	NA
VLA	<25%	<25%	NA

It is important to remember that assessment of ESL students cannot be clear cut. When a student is not proficient in the language of the test it is very difficult to gauge if he or she has an understanding of the scientific concepts being tested. The student may not understand the questions or may not have the English to display his or knowledge (Law & Eckes, 1995).

The best assessment that occurs in any classroom is the on-going day-to-day assessment and so as well as using the standard criteria for assessing academic competence, construction of the case studies was an important method of analysing development of academic skills. Consequently, classroom observations, teacher and student interviews and portfolios of student work were used to collect evidence of skill acquisition, assimilation of new information and construction of new concepts. Because the academic success of these students in science hinges upon how well they can manipulate language for the specific purposes required by science instruction, special attention was given to their use of science language in different contexts.

Table 3.9 links together the three foci, the perspective from which each were viewed, and the corresponding competencies which were used for evaluation purposes. The last two columns in the table summarise the data collection instruments and the three tier interpretive framework.

Trustworthiness

In the school laboratory, science students are told that their experimental work should have a clear aim, must be carefully designed and follow a set plan or procedure. Results must be collected in a meticulous manner, and analysed, discussed and reported upon using the correct format. Furthermore, a conclusion which is related to the aim should be reached, the results must be confirmable and the experiment should be capable of reproduction by others. Although most school experiments are quantitative in nature, these rules can loosely be applied to any study.

If a piece of research is to be considered worthwhile it must have clear research questions, a carefully designed method and data collection instruments which are appropriate to the aims. Methods of analysis should be easy for the reader to follow and the research should stand up to the scrutiny of the researcher's peers. In short the author must be able to persuade the reader that the research has integrity and that the results are trustworthy (Punch, 1998).

Table 3.9

Summary of methodological framework and data collection instruments

Focus	Perspective	Competencies	Data collection instruments	Interpretation
1. Language	Interlanguage	Communicative 1. Grammatical 2. Discourse 3. Sociolinguistic 4. Strategic	Participant and non-participant observation Interviews Student work	Interlanguage continuum Construction of case study
2. Teaching and learning environment	Acculturation	Participation Interactional	Participant and non-participant observation Interviews Student work	Construction of case study
3. Student	Cognitive development	Academic	Participant and non-participant observation Interviews Student work	Academic results Construction of case study

Traditional research uses the notions of internal and external validity, reliability and objectivity to persuade the reader that a piece of work is worthy of attention (Merriam, 1998). Lincoln and Guba (1985) suggest that because its aim is to reconstruct the perspectives of those being studied these are not strictly relevant to a naturalist enquiry. They nominate the alternative trustworthiness criteria of credibility, transferability, dependability and confirmability as more applicable. They suggest that problems relating to the trustworthiness of qualitative data can be overcome by such techniques as triangulation, prolonged engagement, persistent engagement, provision of thick description, member checks and peer debriefing.

Triangulation is defined by Cohen et al. (2000) as the use of two or more methods of data collection. Merriam (1998) explains that as well as one or more methods of data collection, multiple methods and multiple investigators can be used to confirm findings. This study aimed to comprehensibly interpret the happenings in science classrooms by having the three foci of language, the teaching and learning environment and the students themselves. The "reality" surrounding the experiences of ESL students in science classes was constructed by consulting teachers and students and by the researcher's observations. Data collection instruments included observations, interviews and examination of student work. Audiotaping of semi-structured interviews was a way of providing referential adequacy. Data were analysed using the three tier multidimensional framework shown in Table 3.9.

Persistent observation was achieved by studying nine different students and talking to many science teachers. All students except the postgraduate ones were observed over a period of at least one year. This was necessary as noticeable changes in language skills can be slow. Although in most cases observation took place once per week, usually several lessons were observed each day. The author's own students were seen for four or five lessons every week for at least a year. The exact number of lessons involved is outlined in Table 3.5. In the end only Phil, Pam, Mary, Julia and the author were involved in implementing the strategies in biology classes, however, many science classrooms were visited and many more science teachers were asked their opinions.

Kemmis and McTaggart (1988) suggest that another way to ensure trustworthiness is to encourage others who have a stake in the improvement to shape the form of the work. Prolonged engagement allowed both the teachers and the students to be involved in the development of the strategies. Persistent and prolonged engagement also provided the opportunity to build trust (Lincoln & Guba, 1985). Adolescent students generally do not like being singled out and it was important to become accepted in classrooms and by students if they were to share their perceptions and feelings and explain the difficulties they were experiencing. The compilation of the case studies allowed for the provision of thick description.

The collection of data from the viewpoints of the key players (students and teachers) served as a check on its authenticity. Providing feedback to the teachers and students involved in the study was an opportunity for verification of data. After each lesson, teachers were consulted, usually on an informal basis, about the researcher's perceptions. One-on-one sessions with students also provided explanation of observations and provided opportunities for clarification. Another technique suggested by Kemmis and McTaggart (1988) was to allow those described in the classroom accounts to challenge them on the grounds of fairness, relevance and accuracy. Mathison (1988) says that data can be convergent, inconsistent or even contradictory and the researcher must actively check for these alternatives. This was important when evaluating introduced strategies for their effectiveness. Finally, discussions with many interested peers with different areas of teaching expertise have allowed the author to view the data from different points of view and helped to shape this thesis. It is hoped that building the techniques of triangulation, prolonged engagement, persistent engagement, provision of thick description, member checks and peer debriefing into the methodology helped to ensure that the work was trustworthy.

Ethical Issues

The Australian Association for Research in Education (AARE) provides some basic principles, which can serve to ensure that planned research is ethical. They suggest that a study must enhance general welfare and its purpose should be the development of human good. Teaching is a profession in which ethical issues must be an ongoing consideration. On an everyday basis, teachers must be sensitive to the culture of the school, and the social and religious beliefs of staff, students and parents. Educators also have an obligation to be conversant with developments in educational theory so that their students can benefit from up-to-date learning strategies. There must be recognition of the uniqueness of each individual student and every effort must be made to cater for individual differences. There can no longer be lessons aimed at the mythical average student. In fact, a major focus of the recent literature on reform (Goodrum et al., 2000; National Research Council, 1996; Rutherford & Ahlgren, 1993) stresses the importance on science education being equally accessible to all. There are certainly ethical implications for a group of learners who, because of

language difficulties, may be left to manage as best they can, often on the periphery of the class.

In addition to these day-to-day considerations, research in the classroom introduces a whole new dimension to the question of ethics. If every researcher wants to contribute knowledge that is believable and trustworthy, then both the subject matter to be investigated and the methods of investigation deserve very close scrutiny. Most importantly, it must be borne in mind that research impacts on the people involved.

In the following sections, the four broad areas that are generally worthy of reflection with respect to the ethics involved in educational research will be outlined. These are equity, impartiality, confidentiality and the rights of the participants (Anderson, 1998; Cohen et al.; Punch, 1998). The specific ethical considerations pertinent to the present study before, during and after the fieldwork will then be summarised.

Equity

A teacher's primary concern must always be for the students. The ultimate aim of most educational research is improved educational practice. A researcher must ensure that no student suffers any harm or is disadvantaged in any way by the study. Students and teachers must not feel that they are being singled out or criticised. Every person's self-esteem must remain intact and the rights of the individuals in the classroom must be preserved. Another point to consider is that some of the materials used during the study may be based upon work developed by others. To be fair, ideas and contributions made by others must be clearly acknowledged. In this study the feelings ad cultural sensitivities of the students involved was taken into consideration and the contributions of others was acknowledged.

Impartiality

There are major implications for the impartially of studies when the teacher turns researcher. Merriam (1988) states that concerns about validity and reliability are likely to emerge during the collection of data and in the dissemination of the

findings. For example, in the evaluation stage of a study it could be possible for researchers to collect only data that confirms the effectiveness of an intervention. To combat this problem Merriam (1988) suggests that researchers should actively seek disconfirming data. Furthermore, problems with the audience being unable to distinguish between data and the researcher's interpretation can arise when a qualitative method is used. Careful thought must be given to the design of the study to ensure that fair interpretation takes place and methical controls must be introduced to reduce bias. Selection of the three foci in the present study allowed the data to be viewed from different perspectives. The beliefs of the student and teacher participants were actively sought to confirm the researcher's impartiality.

Confidentiality

Confidentiality of data is essential, especially if the researcher is critical of some of the happenings occurring. The privacy of the individual must be respected. There should be a clear understanding between the researcher and participants concerning the use to be made of the processed data. The use of pseudonyms protects the participants (Punch, 1998) and these were employed in this study.

Rights of the Participants

Permission for research must be sought from appropriate sources. Students and teachers have a right to be informed of the true purpose of the study. The researcher must ensure that participants are not stressed, embarrassed or harmed in any way. As well as being informed, participation should be voluntary. Burns (1997) outlined the importance of voluntary participation in studies. Interestingly, he contrasts this with some methods of recruitment, which raise ethical issues. These include using prison inmates, paying unemployed persons and coercing university students who participate in order to meet a course requirement. All students and teachers volunteered to take part in this study and care was taken not to stress or embarrass them.

Ethics and action research

Cohen et al. (2000) reported that as well as the general considerations such as those outlined above, action researchers need to be particularly sensitive because of the context in which their research is taking place. Hopkins (1985) explained "Principles of procedures for action research accordingly go beyond the usual confidentiality and respect for persons who are the subjects of enquiry and define in addition appropriate ways of working with other participants in the social organization" (p.135).

Ethical considerations before commencing fieldwork

The relevant persons were consulted about the fieldwork. To this end permission was sought initially from the principals of the schools in question. When this had been obtained, willing teachers were recruited and suitable students identified. Permission and approval was obtained from the students themselves and from parents and/or guardians. As Anderson (1998) suggested a statement was included offering to answer any questions concerning planned procedures.

The aims of the study, possible benefits and how the results were to be used were made clear to all concerned in the study. Kemmis and McTaggart (1981) stressed the importance of making the principles of the procedures known and obtaining agreement to these before beginning. Both teachers and students had a guarantee of confidentiality. They were made aware of the rights in the process such as the right to withdraw from the study at any time. Anderson (1998) also mentioned the issue of the participant's time. Careful planning was needed to minimise the impact that the study had on the busy lives of teachers and students. Another consideration before the study began was the planning required to reduce biases and ensure trustworthiness.

Ethical considerations during fieldwork

Cohen et al. (2000) emphasise the necessity of consulting with those affected by action research. For example, in a particular school not all the science staff wanted to be directly involved and so their responsibilities and wishes had to be taken into

account. As a guest in the classroom, the position of the researcher had to be negotiated with the teachers in question. The extent to which the teacher wanted the researcher to become involved in teaching or group work was established before observations took place. In some cases the researcher caused very little disruption to classroom and daily routine. In other classrooms, she became involved in group work, one-on-one consultations and even taught the whole class on some occasions. In this study the feelings of the students involved had to be of prime consideration. In the beginning, some of the students did not wish to be singled out and it took time to build a rapport. Naturally, cultural sensitivities had to be a consideration when dealing with ESL students.

Kemmis and McTaggart (1981) stress the importance of keeping the work visible and remaining open to suggestions from others by reporting the progress. The aims of the research remained clear throughout the study and the researcher encouraged the teachers and students who had a stake in the improvements brought about by the action research to help shape and form the work. By actively seeking both student and teacher opinions it is hoped that they felt that their views were valued and of consequence.

Ethical considerations after fieldwork

The major considerations for reporting on research have already been mentioned above. The need for confidentiality means that participants must remain anonymous. The use of first names ensured this. The contributions, ideas, work and words of others have been acknowledged and participants were informed of the final outcome in a letters of thanks. Those teachers that requested it were provided with a copy of the checklist. The subject matter and the methods of investigation have been closely scrutinised and the results have been reported both truthfully and objectively. The people involved in the study did not suffer any harm because of it.

Chapter summary

Wolcott (1990) says that doing qualitative research basically involves watching, asking and reviewing. This chapter outlines how this was achieved in the present

study. The issues surrounding the learning and teaching of science for ESL students are varied and complicated. Experiences in the relevant science classrooms need to be interpreted from a number of different perspectives, not measured. A methodology which focuses on meaning in context and data collection instruments that are sensitive to uncovering that underlying meaning needs to be employed. Development of an interpretive framework assisted in evaluation of the impact of introduced strategies. Triangulation, prolonged engagement, persistent engagement, provision of thick description, member checks and peer debriefing served to ensure the trustworthiness of the study. By attending to equity, impartiality, confidentiality and the rights of the participants it is hoped that the study was conducted ethically. The next chapters present some of the understandings that emerged from the data related to the language, the teaching and learning environments and the students in this study.

CHAPTER 4   THE CURRENT SITUATION

The findings of the study are reported in two chapters (chapters 4 and 6) while chapter 5 provides a rationale for the strategies that were introduced to improve teaching and learning. Consequently, this chapter describes the situation in phase one of the study and includes the observations of what was happening in Queensland classrooms with respect to the three focal areas of the language, the teachers and the learning environment, and the ESL students themselves before any intervention took place. It does this by addressing the first three research questions.

1a. What are the difficulties for ESL students with respect to the language used in science classrooms?

1b. How do science teachers assist ESL students to interact and participate in science learning environments in Australian schools?

1c. What difficulties do ESL students encounter when constructing an understanding of scientific concepts?

Question 1a is interpreted from the perspective of communicative competence. As outlined in chapter 3, data was collected and analysed using the International Second Language Proficiency Ratings (ISLPR). This rating system is a proficiency scale or a set of four subscales for the macroskills of speaking (S), listening (L), reading (R) and writing (W). Each subscale follows the development of learners of a language from 0 (no ability to communicate in the target language) to 5 (indistinguishable from a native speaker). There are 12 levels including intermediate *plus* and *minus* levels (Lee et al., 1998). A typical profile might appear as S2, L1+, R2, W1. Table 3.6 contains details of the ISLPR levels.

Question 1b relates to interactive and participative competence. Data concerning how students responded to class tasks and demands was gathered by classroom observations, and teacher and student interviews.

Question 1c is considered from the point of view of academic competence. As detailed in Chapter 3, academic competence was measured against the criteria set out by the various work programs applicable to the classrooms involved. In Years 10 to

12 this involved the three assessment categories of *Knowledge, Scientific Process and Complex Reasoning*. The results are expressed as: *Very High Achievement (VHA); High Achievement (HA); Sound Achievement (SA) Limited achievement (LA) and Very Limited achievement (VLA)*. The nominal cut-offs for Years 11 and 12 are shown in the Table 3.7. Additionally, each level of achievement is subdivided into 10 levels. For example, a student may achieve an SA1 – SA10 in the sound achievement level. In Year 9, in one of the schools only knowledge and scientific processes were used for assessment purposes. At the other two schools all three criteria were used. The cut-offs for Years 8, 9 and 10 were summarised in Table 3.8.

It is intended that the case study methodology used in this section will allow the study to retain the holistic and meaningful characteristics of real life events. In all, studies were made of seven high school science students, Cliff, Min, Aya, Claire, Simon, Yan, and Patricia; and two postgraduate students, Anna and Lenny. While the students and their challenges are central to the study, the concerns of and difficulties faced by their teachers also required highlighting. To this end a specific case study of one of the teachers, Julia, is included to further enhance the reader's understanding of current situation in Australian schools. This portrayal of the happenings in individual learning environments will serve as a preview to the presentation of some generalizations regarding the current situation for ESL learners of science in Queensland. A summary of the findings for phase one of the study will be in the form of specific answers to the research questions. This will be presented at the end of the chapter.

Cliff's story

Background information

Cliff was a 14-year-old boy who began Year 9 at a private coeducational school in suburban Brisbane after arriving in Australia six weeks previously. He was the first ESL student for whom the author was responsible who did not have enough English to participate in basic classroom procedures and routines. The experience of teaching Cliff was one of the prompts that resulted in a personal journey to find strategies to help him and other ESL students. He was from China and spoke

Cantonese at home. He lived with his mother who spoke little English. He had an aunt who taught Chinese at another local school. The aunt's English was quite good and she negotiated with the school on Cliff's behalf and attended parent-teacher interviews. At the beginning of the observation period the school had no ESL teacher and so Cliff was receiving no additional support from the school. His attendance in mainstream classes was his chief method of acquiring communicative competence in English.

The language and communicative competence

In conjunction with his other mainstream teachers it was decided that when Cliff first arrived he was at a 0+ level in listening which meant that he could perform in a very limited capacity within the most immediate, predictable areas of need. However, in the areas of speaking, reading and writing he did not communicate at all. He did not have basic conversational skills and if he was asked to close a window or to stand up he did not understand. He was quick to imitate other students and by the end of the first term his speaking and listening had improved to level 1 but he was still experiencing extreme difficulty with reading and writing. His aunt was assisting him at home with these skills.

Participation and interaction in the teaching and learning environment

During his first term Cliff spent most lessons using or playing with his electronic translator and did not attempt any writing. This activity seemed to give him something to do in a situation where his understanding was so restricted. There were no other Chinese speaking students in Year 9 at this time and so with his limited English Cliff was having a very difficult time in the mainstream science class of 28 students where there was officially no extra accommodation for him. Following classroom procedures, class discussions, written assignments, completing worksheets and independent reading of the textbooks were all impossible tasks for him. Despite his restricted language skills Cliff had a friendly demeanour and was generally accepted by the other students. They invited him to join their groups and tried to explain procedures and requirements to him. He usually participated in group activities and laboratory experiments appropriately. However, unlike most of the

other students in this study Cliff was not a model student. Despite his limited English he behaved like most of the other Year 9 boys and sometimes distracted the others by offering them his electronic translator. Although he had friends in the class, lunch times were spent with other Chinese students.

The student and academic competence

It was not easy to determine the student's academic competence in that first term. The information from Cliff's former school was impossible to interpret. If basic laboratory procedures were demonstrated Cliff experienced no difficulty performing these. It was impossible to discover if the science content being taught had been encountered by Cliff before. As his language skills were so limited no attempt was made to assess him in science that first term.

In summary, Cliff was a happy, friendly Year 9 student who had been submerged in mainstream classes with very limited language skills. He participated and interacted as best he could. He urgently needed ESL support and academic lessons which explicitly enhanced his English language skills.

Min's story

Background information

At the onset of the study Min was a 16-year-old student beginning Year 11. She had been sent to Brisbane from Taiwan six months previously and was attending the same private coeducational school as Cliff. She was living alone in a flat in the central city area of Brisbane close to Chinatown. Her uncle, who was her guardian lived next door but travelled extensively and took little interest in Min. Her father wished her to complete Year 12 in Australia. She was shy, lonely and homesick. She had not obtained a sound achievement in Year 10 science despite having studied science in her homeland and already covering many of the topics in the syllabus. For Year 11 she had opted to study chemistry, physics and biology. For the first month, the researcher just observed Min in her science classes. After this initial period, some interaction took place.

During the first part of the study Min became increasingly introverted and depressed. Brown (2000) explains that a person's world view, self-identity, and systems of thinking, acting, feeling and communicating can be disrupted by contact with another culture. If the disruption is severe the person is said to be in "culture shock". This phenomenon can be associated with feelings of estrangement, anger, hostility, indecision, frustration, unhappiness, loneliness and homesickness. Min exhibited many of these symptoms. When pressed she revealed that her living circumstances were very unhappy. She tearfully confessed to one of her teachers that she was no longer content living alone. The school suggested she might be happier in a home stay situation and found a suitable family. They explained that living with an Australian family would provide company, care and also increased opportunities for speaking English and exposure to Australian culture. Min's father agreed reluctantly.

The language and communicative competence

When Min first arrived in Australia, despite having studied English in Taiwan for three years her language ability was very limited. She was lacking even basic survival skills as evidenced by her description of her first day at school, which she now describes as a *nightmare*. She had never caught a train before and only had a map to find her way to school. She had a vague idea that a ticket was required so managed to purchase one by pointing to her map. She then boarded the first train that came along. Min was very upset and knew that this was not a wise course of action, but did not know what else to do as she could not read where the train was going. She said that her face must have looked terrible as people kept asking her if there was anything wrong but she did not have the language to explain her problems. She stayed on the train until it came to the terminus. A kind railway employee then found her and managed to put her on the correct train and with gestures, mimes and the use of the map conveyed to her where she should get off. The school is about a ten minute walk from the station. She followed a student in a similar uniform to hers and two and a half hours after leaving her flat arrived at school. The journey would normally take twenty minutes. In her first days at school she understood little of what was going on. Often the teacher would give instructions and everyone else

would vacate the room and Min would be left wondering what was happening and where they were going.

Six months later, at the beginning of the observation period, in listening, Min was performing at an L2 level. This means that she was able to understand in routine social situations and limited school situations. She was able to get the gist of most conversations in everyday social situations although she sometimes misinterpreted or needed things to be repeated. Min had some difficulty following extended lines of argument or complex discourse patterns. With regards to speaking, at this early stage Min appeared unable to answer questions in front of the class and was reluctant to speak at all. Ellis (1994) describes how many learners opt for a silent period when first learning a language. Because she was not speaking it was difficult to gauge her ability. In consultation with her other teachers it was decided that she was probably at a S1+ level. This means that she was able to satisfy all survival needs and limited social needs. Her reading was at an R2 level. She was able to read simple prose on subjects within a familiar context with extensive use of a bilingual dictionary. With respect to writing Min was able to satisfy routine social needs and limited school requirements. This equated to a W2 rating.

After the first month of observation, her teachers felt it would be beneficial for the researcher to sit next to Min and assist her in class. Min seemed quite happy about this and it provided the researcher with the opportunity to build a rapport and determine with more accuracy the difficulties that Min was experiencing. After another month, Min started to talk. She spoke very slowly with lots of pauses and needed ample time to express her thoughts in English. When asked why she took no notes she explained that she needed to listen if she was to understand what was going on. She said that unless she concentrated she missed key words and then she often had no idea what happened for the next 15 minutes of the lesson.

"When this happens I can't go home and read in a book because there is nothing in my brain to use."

After she started interacting through speaking, her language did start to improve more quickly.

Her language skills were such that Min missed a lot of important information. Min suggested that she did a lot of guessing where language was concerned. She often asked the researcher to reiterate what was said or explain in more detail. She asked questions such as:

> *"Did she say it was due next Tuesday?"*
>
> *"What does 'observe' mean?"*

On one occasion she was doing a practical exercise involving liver and enzymes. She had done her homework and written down the steps involved but when questioned on what an enzyme was she had no idea.

Reading in English was very difficult for Min for a number of reasons. She found the language of textbooks so inaccessible that she rarely opened them. With respect to the biology text, the following difficulties were most pressing. New vocabulary was often not clearly explained and there was no glossary in the book. There were also not enough opportunities for practice once a new term has been introduced and few prospects for development of specific language skills. The learning sequence in the textbook was different from that being followed in class and there was not enough variety in the activities. Min confessed that she had never read a whole book of any kind in English. It took her too long. She used an English/Chinese dictionary to determine the meanings of words. If she used an English dictionary the explanations did not make sense and she had to follow up so many meanings of words that she forgot what she was originally looking for.

Min also highlighted the importance of clear writing on the board. She told the researcher that her biology teacher, Pam, had messy writing when she wrote in a hurry. Min needed to watch the letters being formed if she was to have any hope of understanding what they meant as they were so different from Chinese characters.

To assist in her language development, Min composed a list every week of words that were new or problematic. The list was in English and was always perfectly spelt. Viewing the list gave the researcher an insight into what Min was learning each week. The week that she moved in with her Australian homestay family, her list included the following: *blender, suitcase, tea towel, generous, grateful, coat hanger, light bulb, lively, honest, pepper grinder, weird, superficial, relaxed,*

reliable, awareness and *briefcase*. For the researcher, this list reinforced how a second language is constructed by life experiences.

Participation and interaction in the teaching and learning environment

Content-based learning situations can be classified using a number of different methods. At the beginning of the study the school was without an ESL specialist so Min was in the difficult situation of being placed in a mainstream classroom with very limited language skills. Brisk (1998) terms this kind of language learning where a student is left to sink or swim as *submersion* (p13). Min was submerged in the language and was expected to use English as a vehicle with which to study science and all her other academic subjects. With no extra support this was very nearly an impossible undertaking. At this early stage Min appeared unable to answer questions in front of the class and was reluctant to speak at all. When asked to participate in a group Min would reluctantly join the students suggested by the teacher but often take no active part in the inquiry. Her interaction and participation only improved when another Chinese student joined the chemistry class.

In biology Min sat alone and had to be placed into a group. She joined in practical exercises but did so silently. She appeared afraid to speak. When she did start to speak to the researcher she explained that when she knew the answer she was afraid that she may not have the language to express it. Pam, the biology teacher was an experienced and dedicated teacher. She had a few strategies that she was conscious of using to assist Min. She explained procedures for practicals by writing the steps, drawing diagrams and then getting a student to explain orally what they were expected to do. She drew a lot of diagrams. For example, when explaining the nitrogen cycle, she used words and rough drawings of organisms to illustrate her points. She utilised opportunities to explain concepts to Min in one-on-one situations. She was welcoming and used Min's name often. However, Pam did not see it as her job to help to develop language skills. There was no evidence of a focus on literacy or extra effort to explain biological vocabulary. When it was pointed out that Min did not understand what an enzyme was, Pam's response was to say that Min had obviously not done her homework. Pam's classes did provide numerous opportunities for speaking, listening, reading and writing.

Raelee, the chemistry teacher, was also a committed and experienced teacher. Of the 16 science teachers observed, she was the only one who had some ESL experience. She had worked at a school for newly arrived immigrants for six months and at that time received some on the job training. Raelee did not appear overwhelmed by Min's problems like some of the other teachers. Her program followed the textbook closely and Min said that she always wrote the applicable page numbers on the board at the end of each lesson so Min could follow up at home. The chemistry class was small, well controlled and quiet and Min found it the easiest one in which to concentrate. By the end of her first semester, Min reported that she understood about eighty percent of what went on in chemistry. Raelee made extra efforts to include Min in the class. Group work was a regular occurrence. On one occasion the class was studying organic chemistry and Raelee asked them to form groups and make various molecules with the molymods. Min was placed in a group and left on her own would not have participated. Raelee circulated through the groups and ensured that Min made a model. She made it clear that Min was part of the class and expected to contribute in her own way even if she did not wish to speak. Towards the end of first semester, another ESL student joined the class. Raelee allowed them to use Chinese if they were working on problems but otherwise they were required to speak in English. She reported that she was just happy to see Min talking to someone.

The physics teacher, Dave was a younger man who stated that he had no idea what to do with Min. He said that she had never spoken to him, and so he had never spoken to her. He was strongly of the opinion that she should not do physics and was not interested in giving her extra help. He was certain that it was too hard for her and she was destined to fail. Gunstone (1978) reported that physics was the branch of science in which language notions rarely intruded into classrooms and this certainly seemed to be true in Dave's class. It was a large noisy class and Min appeared to hide down the back alone. The teaching took the form of Dave explaining a concept out the front on the board, demonstrating one problem and then allowing the students to work on their own.

For the first term the school was without an ESL specialist. In term 2 Lisa was appointed as the ESL teacher for all 25 ESL students although she had no formal

qualifications or experience in ESL. Her background was in English and Geography. Lisa was middle-aged, motherly (she had two teenaged children), friendly and happy. She confessed that she planned from week to week rather than from term to term. The school has no set curriculum but Lisa had a personal friend who was a very experienced ESL teacher and she gave her ideas, materials and advice. When Lisa decided what to teach she was not sure if it was relevant or aligned to what was going on in mainstream classes. There was little collaboration between Lisa and the mainstream teachers of other subjects. Often, teachers made inquires about a particular student but it what Lisa called *hallway communication* and was usually about pastoral matters rather than curriculum. The 25 students took ESL as one of their six subjects. This meant that they had five lessons of ESL per week. The remainder of their time was spent in normal lessons including English lessons with native speakers.

The biggest problem for Lisa was the range of students in the classroom. The students ranged from Year 8 through to Year 12 and were aged from 12 years to 19 years. They spoke Korean, Chinese, Japanese, French, Swedish, and German. Apart from age differences their language abilities varied greatly as well. According to Lisa there were 25 levels of language proficiency and 25 levels of need. Activities that suited some students were inappropriate for others. Often, especially at examination time the older students preferred to work on their other subjects and ask for Lisa's individual help. She decided to allow them one lesson per week for this kind of activity. It was also a method of her finding out what was happening in their mainstream classes. As she had no science background she said that when a student asked for help with a science practical report she was unable to assist them.

There was no one person overseeing the welfare of the ESL students. No teacher seemed to know how they were progressing in all their subjects or how they were fitting in socially. Luckily, Min related well to Lisa and had a friend, Lily, in the ESL class. She seemed happiest during the ESL sessions and said that as one of the older students, she did not feel as stupid as she did in mainstream classes. It was to Lisa with prompting from Lily that Min finally disclosed how unhappy she was living alone. Lisa was the one who set the wheels in motion to find her a homestay situation.

In many ways, despite her very obvious difficulties compared to other learners her age, Min was a model student. Her father had high expectations of her and she was quite determined to do well. She exhibited high levels of commitment to learning and was always task-orientated. Of necessity she initiated independent learning activities. However, by the end of her first semester of Year 11 and the end of the observation period comprising phase one of the study, Min was achieving a sound result in only chemistry. In both biology and physics her achievement level was low. This was not surprising given her overall level of communicative competence and the other difficulties she had experienced. Developing an understanding of science concepts in class was proving difficult but examinations caused her special problems and did not allow her to demonstrate all she knew. Min perceived that an examination question that took an English speaker five minutes might take her 30 minutes. She was allowed extra time in examinations and was also entitled to ask the meanings of questions if she wanted. However, according to her teachers although she used extra time she never asked extra questions. Her results for semester 1 are summarised in Table 4.1.

Table 4.1

Summary of Min's academic results in phase one

Subject	Knowledge	Scientific Process	Complex Reasoning	Overall
Chemistry	49%	48%	10%	SA2
Biology	43%	32.5%	8.75%	LA8
Physics	30%	27%	6%	LA4

By the end of semester 1 the fact that she understood about eighty percent in chemistry was reflected in her marks. She tended to listen carefully and then spent time at home consolidating and doing problems. However, this was not easy. She told the researcher that when she first started at the school she would start her homework at 3.30 pm and still be struggling with it at 1am. She was very worried that she would get into trouble if she did not have it all completed. After a few weeks she made a decision to rationalise this.

In biology although videos, overheads and other diagrams helped her understanding, she found the subject vocabulary rich. For this reason, there was a feeling at all three schools that biology was a very difficult choice for ESL students. However, Min was interested in perhaps pursuing a medical career when she finished school and so was keen to do well in the subject. She made an effort to learn special terms but, as Gardner (1975) found, it was often the everyday language which affected her understanding. When the class was doing an extended experimental investigation of their choice, Pam expressed that she was disappointed with Min for not bringing her materials from home. She had told her to buy *wheat germ* at a *health food shop*. Min told the researcher she had no idea what either of these things was and did not like to ask. On another occasion, she was working on a multiple choice problem about meiosis. A particular chromosome had been damaged in some way and she was asked to determine which alternative was the likely result of cell division. Because Min did not understand the meaning of *damaged* she as unable to complete the question. Generally, however, she liked biology examinations because there were often quite a number of multiple choice questions. These did not require any writing on her part and she found this much easier.

With regards to physics she said that she understood what was happening when the teacher used diagrams, tables and graphs. Min reported that although she found the theory of physics the easiest to understand physics examination questions were the most difficult because she did not know what to expect. During one observation session the following question was given to the class:

> *A rectangular room is 6m long. A mirror 0.35m wide is hung on the wall*
> *horizontally at one end of the room. A person standing 0.5m in front of the*
> *mirror can just see both ends of the back wall in the mirror. What is the*
> *length of the back wall?*

Min did not know the meanings of *rectangular, 0.35m wide, hung* and *horizontally*. Once the researcher explained the terms and drew a diagram, Min happily worked through the problem and explained how she had completed it correctly. Because there was absolutely no rapport with the physics teacher or any member of the class, normally she could not have finished the problem.

At the very beginning of the observation period, the main strategy employed in the classroom by the student herself to cope with the simultaneous acquisition of English language skills and academic content, was to use an electronic dictionary to translate most English words. It seemed to give her something to do in a class where she found participation difficult. During the final weeks of the observation period another Taiwanese student joined the Chemistry class. This student had slightly superior English language skills and although she too used an electronic translator she was able to make some meanings clearer for Min. When unsupervised, they conversed almost exclusively in Chinese. Over the holidays Min planned to get a tutor in Taiwan to help her in chemistry, physics and biology. She was using a physics book written in Chinese to try to improve her physics.

With respect to language, by the end of the first phase of the study Min had improved quite considerably. She had progressed from a frightened girl who barely exhibited basic survival skills to a student who could readily understand school routines and procedures. Her interaction and participation in science classes was still a cause for concern but was aided in some classes by caring and committed teachers. Academically she was passing chemistry and almost passing biology. She had been able with the help of a friend to express her unhappiness about her living arrangements and these had been altered.

Aya's story

Background information

At the beginning of the study, Aya was a 16-year-old Japanese student who had lived in Australia since she was three years old. She attended a prestigious all girls' school in the central city area and was about to start the second semester of Year 11. Her spoken English was very good but the student herself, her parents and her teachers were concerned with her current achievement in her three Year 11 science subjects, biology, chemistry and physics. Her English teacher also had concerns. The school saw she had some problems but no one was really clear what they were.

All of her schooling had been completed at Brisbane schools. However, her parents studiously guarded their Japanese culture at home. To this end only Japanese was spoken and Aya was encouraged to mix with Japanese friends outside of school. Apart from news programs, she was generally not permitted to watch television or see English movies. Holidays were all spent in Japan. Her father spoke what she termed "business English" and her mother spoke enough English to do the shopping. Aya explained that their limited language skills did not enable them to help her with her academic studies. Her perception was that most of her peers were able to access assistance at home. Because her mother taught Japanese typing, the computer keyboard that she used at home was a Japanese one.

Aya and her parents had very high expectations. Aya wanted to study science as a prelude to medicine when she finished school and so was determined to improve her achievement levels. The head of science at the school suggested that she might be an interesting student for this study and that she could benefit from assistance with developing some specific strategies. The student seemed unhappy, felt that she was different and was more than aware of her limitations. She was very articulate about her difficulties and longed to have someone to talk to about them.

The language and communicative competence

With regards to listening the student was an L3+. She could comprehend accurately in most personal, social and academic contexts. However, she reported that she was often baffled by slang. In speaking Aya was S4+. This meant that she was able to use language fluently and accurately on all levels normally pertinent to personal, social and academic needs. She had mastered some commonly occurring colloquial forms but some misuse of other items occurred. In her speech, errors of grammar were quite rare. Reading was assessed by her teachers to be at the R3+ level. She could read everyday material and class notes readily. Reading a novel or textbook required moderately frequent dictionary use. Writing was also thought to be at the 3+ level. Aya was able to write with sufficient accuracy in structures and spelling to meet all social needs and basic work needs. However, her academic writing revealed

a lack of well defined structure and contained a moderate number of grammatical errors.

Aya's own perception of her language difficulties was that she did not fully understand what was happening in the classroom because she did not understand idioms, jokes and colloquialisms. She cited an example of an incident in a physics lesson where her teacher was working a problem on the board and said and "*so Bob's your uncle*". She had no idea what this meant and felt she could not draw a proper conclusion because of her lack of understanding. Because her spoken English was so good, none of her teachers felt the difficulties she was encountering were really due to her language although her English teacher had told her vocabulary when writing was very limited and needed improving. Her only suggestion on how to do this was to read more.

Gardner (1974) pointed out that merely asserting that children might have a problem in learning because of language was unhelpful. He stressed the need to explore the specific nature of those language difficulties. Consequently, it was decided that Aya might find it helpful to record the words, phrases, idioms and colloquialisms which she did not understand during the following month so that strategies could be developed to address her lack of understanding. She undertook this task enthusiastically. The results were surprising and her full list of words and phrases appears in the Appendix C.

Predictably there were numerous technical science words which caused her difficulty during the month. These included:

> *albumin proteins; anaesthetise; aneurism; antibody; antigen; arterioles; bowels; budgerigar; coagulation; cumulus; cyst; diabetes; diastole; dry legumes; hormone; inorganic substances; insulin; interstitial fluid; ion; lymphatic tissue; lysosome; microbes; niche; organic substances; pancreas; pseudopodia; tonsils; vasoconstriction; venules.*

The researcher was present at many of the lessons when these terms were introduced and explained carefully. In some cases the terms had been used repeatedly for a number of years in junior science, biology and chemistry. *Organic* and *inorganic*

substances are examples of such terms. Despite this, the learner still did not recognise them as having meaning for her.

Gulland and Hinds-Howell (2001) define an idiom as a combination of words with a special meaning which cannot be inferred from its separate parts. Colloquialisms are informal words which are mainly used in conversation. Slang consists of words, expressions and meanings that are also informal and are used by people who know each other well and have the same interests (Campbell, 1995). Aya's perception that these were the major cause of her language difficulties was not really supported by the evidence collected. From her list of words and phrases the following were classified as belonging to the category of idioms, colloquialisms and slang:

> *already into the turps; ballistic; big yakka; bloke; Bob's your uncle; Bobbsey twins; bonza; cat-o'-nine-tails; charwoman; deadpan voice; discotheque décor; disc jockey patter; fair dinkum; Glenelg tram; golden glove; greasy wop; hold your horses; everybody's kicked a goal; maintenance dodgers; monsoon of beer; not cutting anyone's lunch; pisspot; schnozzer; sing-song voice; Southern Comfort; suffering your joke; tell him he's dreaming; Western Oriental; wog; yobbo; you ripper.*

Most of the above came from a book she was reading in English classes. She had also just watched the movie "The Castle" and could not understand why everyone else found it so funny. Although this made her feel different from the other students the idioms and colloquialisms above would not have affected her understanding of science to the extent Aya envisaged it did.

Of much more concern was the group of non-technical words which O'Toole (1996) points out teachers rarely explain because they assume knowledge. This results in a communication gap between student and teacher and in Aya's case between student and student and reduces comprehensible input. Words which were identified as being used in science classrooms and not understood by Aya included:

> *absurdly; agenda; autonomously; brood; bulge; carcass; complacency; contrary; convulse; copious; counteract shock; craters on the moon; crypt-like; deceitfully; degenerates; delusional; disgorging; dismally; distressed; diverged; domestic; ecstatic; elude; engrossed; episodically; eternal;*

excerpt; flippant; fossicked; gnarled; gravelly; hostile; hue; imminent; immobile; impervious; inept; instigate; intact skin; interminable; intervened; introverted; irony; jargon; menacing; misapprehension; mundane; obscene; opting; oversupply; paced; paradigm; precede; prevailed; profusion; prominent; quarantine station; rapture; reconcile; redundancy; reeling; reluctantly; remedy; replenished; reprieve; retaliating; reticulation systems; retort; scaffold; seething; shock; tentatively; thawed; too much sugar; traits; uninhabitable.

When the list was shown to the teachers involved they were amazed and could not understand how a student who had been educated completely in English and who had lived in the country for 13 years could not comprehend some very basic terms. It appeared that Aya's knowledge of the conversational aspects of language did not equate with her knowledge of academic language. Many of the teacher's questioned why Aya did not simply use a dictionary to help her with understanding. She explained that dictionary explanations were always complex and if she looked up every word she did not understand when reading a book she would never finish it.

Her difficulties with interpreting text impacted on Aya's assignment writing. The following is an example of an introductory paragraph for a biology assignment.

pGLO Transformation

Genetic transformation is a change brought by the introduction of exogenous DNA into a cell, which involves the insertion of a gene(s) into an organism in order to change the organism's distinguished and marked feature of their character. This technology is used in the areas of biotechnology, and this is one of the common methods of transferring DNA into bacteria.

In this example which is fairly typical of Aya's academic style she has made some grammatical errors, for example she has left out the *about* in the first sentence and a plural in the third line. She tries to use words which she thinks are suitable like *exogenous*. She is conscious that she must not copy a definition exactly so she paraphrases but her word choices are not always correct, for example, *distinguished and marked features* have a meaning close to want she wants but are not exactly correct. Aya also is not aware that the use of *technology* and *biotechnology* in the

same sentence is inappropriate. Finally, she introduces the concept of gene transfer into bacteria without explaining how this is related to what went before. When asked to explain what she means orally she can do so but she finds writing at the required level very complicated.

According to Pingree, Hawkin and Botta (2000), family communication appears to be of importance in developing the academic skills of the learner and the family's patterns can affect the development of a child's scientific literacy skills. Becoming literate in any particular domain involves learning a specific discourse, particular ways of thinking, acting and valuing. Gee (1991) refers to these discourses that are beyond the primary discourses of home as *secondary discourses*. He argues that students from non-mainstream backgrounds often do not get opportunities to acquire dominant secondary discourses including those associated with schools because their parents lack the resources to give them access to these discourses. It appeared that terms which would be used and reinforced in homes where English was spoken as a first language were not being encountered by Aya in her somewhat unique home life. The parental attitude to first language and culture maintenance was affecting development of academic English.

As well as difficulties with grammatical and discourse competences, Aya encountered problems with sociolinguistic competence and strategic competence. On one occasion she asked the researcher what she should say and do for her friend whose mother had just died. On another occasion, her physics teacher had forgotten to supply her with some articles which had been promised. She needed to be given encouragement and the correct form for approaching her and asking for these.

Participation and interaction in the teaching and learning environment

Adamson (1993) states that there are three reasons why ESL students are reluctant to speak in class: the student's cultural background; their fear of being laughed at because of their imperfect English; and their fear of divulging a lack of knowledge about the subject matter. It was the last reason which was most applicable to Aya. She told the researcher very early that her teachers and the other students all thought she was stupid. The only subject she was having what she perceived as success was

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Japanese where other students asked her for help. She had a lot of questions she wanted to ask but she was sure that everyone got tired of her asking. At the beginning of the observation period she would not ask any questions at all in chemistry or physics during class time. In biology she sat in the front row and asked questions occasionally in such a quiet voice that only those in the immediate vicinity could hear. This pattern of limited participation was troubling because Sutton (1996) refers to science learning as learning to talk in new ways. If a student does not enter into the dialogue then it is very difficult to learn it.

Aya had developed a rapport with some teachers and would question them after class or before school. This need to relate to her teachers was very important and she had manipulated changes of teachers a number of times. One of the chemistry teachers, Jeff, told the researcher that his teaching style had not suited her and so she had moved into another class. Aya said she could not talk to him and that he was unwilling to provide extra help. Jeff's perception was that Aya's difficulties were conceptual in nature and nothing to do with language. He maintained that she just did not have what it took to study chemistry and was

"still in Piaget's concrete phase".

Her new chemistry teacher, Carla, was a young inexperienced teacher who read a lot from the textbook. Although the atmosphere in the classroom seemed pleasant, Aya was a little scared of Carla. Carla explained that she tried to give Aya extra help when she could but that Aya seemed to blame her for not understanding chemistry.

"I feel that whatever I do is not enough".

There were some misunderstandings in the class and one day Aya was in tears because she had heard a rumour that Carla had said she was stupid. The root of this trouble was more likely a student being unpleasant than anything Carla had said but it did highlight some of the difficulties that Aya faced. Participation in group work provided the main avenue for use of spoken language in chemistry. Aya had a group of friends with whom she worked and was happy. She did not mind if the researcher observed practical work with the group but generally preferred to work alone in lessons.

Rachael, the physics teacher had a mathematics and chemistry background but had been asked to teach physics for the first time that year. She was a little unsure of the content and so did not seem to invite extra questions. The other students and Aya sensed this. Aya found physics the most difficult of the science subjects but still she did not speak or ask questions even though she did not really understand the concepts. Rachael's perception of Aya was

"She is at the point where she doesn't even know what she doesn't know".

Physics lessons appeared to have the least language demands of the three science subjects observed. An introductory lesson on fluids did contain some opportunities for language use but only for the vocal students of the group. Rachael did a good job of relating new information to past knowledge and general knowledge but in the end the whole concept was summed up in an equation the derivation of which was the point of the lesson. Aya did have a nice group of able friends in physics that she worked with during practical activities. These three other students had an excellent grasp of concepts and helped Aya to some extent but also tended to take over when performing experiments. Aya did feel she could ask them to explain things to her but not too frequently.

The biology teacher, Mary, was very strict and very experienced with excellent subject knowledge. Although the students were scared of her if they had not done their homework or were not in correct uniform they felt very comfortable asking questions about biology. Even though she claimed not to have any ideas about how to assist ESL students, Mary unconsciously used many strategies to assist Aya in her classes. Her lessons contained numerous opportunities for speaking, reading, writing and listening. She did not allow the students to write while she was explaining and so helped to develop listening skills. In a lesson on the *reflex arc,* Mary, who was very artistic, built up a marvellous diagram on the board, related the idea of potential difference to past knowledge, elicited information about real life experiences from students and presented the opportunity for practical experiences. Terms were introduced carefully and explained very clearly. For example, when Mary explained that neurotransmitters diffused, she reiterated the meaning of *diffusion.* A video was used to sum up, reinforce and present the information in another visual form. After class Aya told Mary she was confused about the difference between nerve fibres and

nerves. Mary explained by saying that the nerve was like the whole class while a fibre was an individual student. In biology, Aya sat and interacted with the same group of friends. They were attentive, high achievers who sat in the front row and were always on task.

Aya did not attend ESL classes offered by the school. These were not a separate subject like at Min's school but extra classes held outside normal school hours. Aya perceived that there was a stigma attached to attending these classes and had taken offence at something the ESL teacher said she first came to the school. According to Aya the teacher said

> "I've heard about you and your problems. It's compulsory for you to attend ESL classes".

Aya said that they had not been much help in primary school and that the teacher had her own agenda and would not help with assignments so her parents agreed that she did not have to take part. The manner in which she interacted with her teachers seemed to be all important to Aya. She talked about this much more than her friendships with students, perhaps because she had more difficulties in this area. She was quite articulate about the qualities of the teachers she preferred. She said she liked teachers who were approachable, explained things in a step-wise manner, checked for understanding and did not assume that she had prior knowledge.

In summary, Aya had many friends and interacted appropriately inside and outside the classroom. She had negotiated her classes so that in general she had approachable teachers who often helped her out of class hours. She was not participating in whole class discussions because she was worried about what others thought of her. This was affecting her understanding. Aya felt that there was no one person who realised the extent of her difficulties or really cared about her at school.

The student and academic competence

At the end of the phase one her academic results, presented in Table 4.2 showed that Aya was passing all subjects. However, the student and her parents were disappointed with these results. She felt that she worked much harder than many of her classmates, spent many hours doing her homework and studying and always

stayed on task in class. Furthermore she had tutors in both chemistry and physics. If she was to achieve her goal of doing science at university, Aya needed to improve her marks.

Table 4.2

Summary of Aya's academic results in phase one

Subject	Knowledge	Scientific Process	Complex Reasoning	Overall
Chemistry	69%	62%	26.3%	SA9
Biology	62%	55.6%	40%	SA10
Physics	66%	50%	30%	SA6

She was finding physics the most difficult. When her whole physics profile was examined, not surprisingly, her test results were better than her assignment and critical thinking portfolio items. Her difficulties with academic writing impacted on any extended writing and scientific reports. The following is an example from a research assignment.

> *For such a simple everyday phenomena there are two differing views on how the observed motion come about. Professor Keith Moffatt, whose theory is based on using an Euler's disc to discuss what affects the resulting motion and Professor Andy Ruina, who opposes this idea with a different theory, where air friction is not dominant component in which it showed no significance in a vacuum and that "viscous mechanisms can't be the primary damping for most disks most of the time."*

In this passage among other problems she made grammatical errors which she would not make if she was speaking. She knew that her written work had to be more complex than her speech but tended to make her sentences so convoluted that the meaning was lost. She also used contractions like *can't* which were not appropriate. Her writing skills did not allow her to display what she knew.

In chemistry, her first test revealed that she had experienced some difficulties with definitions. She defined an oxidising agent as:

> *"one that loses to give electrons to the other so it will reduce".*

This was surprising as she was usually quite good at rote learning when definitions had been supplied by the teacher. Other difficulties arose because of knowledge of some non-technical language was assumed although generally the language in chemistry examination papers was less demanding than biology.

In biology Aya tended to get lost in the technical language. In a lesson on *meiosis* the following terms were all introduced: *cytokinesis, interphase, prophase, metaphase, anaphase, telophase, chromosome, chromatid, chromatin, centromere, centriole, crossing over, equator, poles, aster, and spindle cage*. Although she had encountered many of them when studying mitosis, nevertheless she was confused by them. When asked she did not realise that the point of meiosis was reduction division. She often tended to focus on quite obscure details and lose sight of the main point and the big concepts. The students had a study guide which explained the important issues and contained questions and extra problem solving exercises. Mary tended to assume that the students had completed it and only went into detailed explanations if a student requested it. Aya said,

> *"She just asks if there are any problems. I have heaps of questions but when no one else asks I don't feel I can. They will all think I'm stupid."*

Her methods of expression made her views of concepts seem quite immature. She once asked if transfer RNA died after it has delivered amino acids to the ribosome. The language in biology caused her to miss important concepts and she tended not to relate what she learnt in one subject to another. She did not understand what *mineral ions* were in biology although the term *ion* was used in chemistry all the time and she know what it meant in that context.

Aya's was a unique case. Her spoken English was so sound that some of her teachers did not perceive that she had a language problem. Although her parents had high expectations they were not prepared to compromise their culture by allowing Aya access to English outside school hours. Consequently, her development of academic English had been affected. The student blamed her deficiencies on not understanding colloquialisms when in fact it was her failure to develop secondary discourses (Gee, 1991) that was affecting her understanding and impeding her academic writing. From the sociocultural perspective, Ogawa (1998) points out that in the past science education has gone to great lengths to eliminate cultural bias.

However, the influence of constructivism means that there needs to be a re-examination of the role that culture plays in developing scientific understanding. This was certainly true in Aya's case.

Claire's story

Background information

At the beginning of the study, Claire was a 16-year-old student who attended the same private coeducational school in suburban Brisbane as Min and Cliff. Claire had been in Australia for almost a year. Her family had moved to Brisbane from Taiwan although both her parents still spent time there. Her father was not often in Australia and her mother sometimes left Claire and her 14-year-old sister to be with her husband in Taiwan. At these times the girls looked after themselves. Claire spoke Mandarin at home but was also fairly fluent in Korean. Of the science subjects, she was studying chemistry and biology. She and Min knew each other but were in different classes. When she left school Claire hoped to become a nutritionist although her father wanted her to pursue a career in biotechnology. She was a shy, quiet, self-contained student who always tried hard with her school work. Although she was unfailingly polite, it took considerable time to build a rapport with Claire. Claire did not attend ESL classes. She believed that because she was a resident and not on a student visa she was ineligible for these. When questioned, all her teachers assumed she was attending these classes for the extra support she required.

The language and communicative competence

Her teachers agreed that Claire had minimal vocational proficiency (level 3) in the areas of listening and speaking. She was able to handle speaking in most social situations and could listen and take basic notes during lessons. Her writing and reading were considered to be at a 2+ level. She still made quite a few grammatical errors in her sentences when writing. Reading was difficult but she was very good at following clear sequential written instructions. Claire reported that she tried to improve her English by reading newspapers, watching the news and going to the

movies. Prior to coming to Australia, Claire had been learning English for five years.

During the initial observation period, as an important part of their assessment each individual member of Claire's chemistry class was required to research, design, carry out and report upon an extended experimental investigation (EEI). This posed quite a challenge for many students but especially for one with limited English skills. Additionally, Claire had to carry out a risk assessment and communicate her requirements to the laboratory assistant with a list of her requirements.

Claire had a number of strategies which she commonly used to help her to overcome difficulties with her study of science. With reference to her EEI she could not decide upon a question to investigate herself so she found a practical on the internet which involved determining the amount of Vitamin C in fruit and vegetables. Claire then prepared herself the list of instructions seen in Figure 4.1. She explained that she wrote procedural words in Chinese so that she would know how to conduct the experiment. Any word that she had learnt first in English like *ascorbic acid,* *volumetric flask* or *distilled water* only made sense to her in that language and it was no use translating them into Chinese. Even though she had employed a number of unique strategies in order to cope with the language difficulties of the task Claire still encountered some problems. She had no real understanding of the words *rinse,* *calculate* and *mix* which were important instructions in her procedure. She had looked them up but the explanations did not seem to be applicable to her work. If the researcher had not been observing she would not have asked the meanings.

The laboratory assistant provided her with an incorrect buffer solution and Claire did not feel that she could approach her to request the correct one. Consequently she wasted a whole lesson where her results were inconclusive. Canale and Swain's (1980) *sociolinguistic competence* and *strategic competence* involve knowing the sociocultural rules of language and the strategies that can be called into action to compensate for breakdowns in communication. Although the student had devised strategies to help develop grammatical and discourse competence, Claire required assistance with knowing the correct procedure to follow to solve her problem and the form to use in asking for the correct equipment. It took a whole lesson to persuade

her to overcome her shyness and to formulate the language she needed to explain her dilemma.

Vitamin C

Objective : To use oxidation/reduction titration methods to determine the amount of Vitamin C in various fruits /vegetable.

Equation : $C_6H_8O_6$ (colourless) + $C_{12}H_7O_2NCl_2$ (red) →
(pH3) $C_6H_6O_6$ (colourless) + $C_{12}H_9O_2NCl_2$ (colourless)

Procedure : ✳ Metaphosphoric 會腐食物.
要戴 Safety glass . ✳

① 用一才 analytical balance 去秤 40-60mg 既 ascorbic acid.
② 寫下它既 mass.
③ 把它掉入 一才 100mL 既 volumetric flask.
④ 加入 大約 50mL 既 distilled water (溶解酸性物質)
⑤ 再加入足夠既 distilled water 直到 100mL 喥止.
⑥ 徹底的攪拌. 放著.
⑦ 用一昃昃 (milliliters) 既 DCT 去洗 一才 50mL 既 滴定管 (buret)
⑧ 用一才 10mL 既 移液管 (volumetric pipet), 取 10mL 既
    ①号 solution 到 3才 250mL 既 窄頸瓶/燒杯.
⑨ 加大約 20mL 既 distilled water 和 10mL 既 pH3 buffer solution
    到 每一才 瓶子内.
⑩ "滴定" Titrate 直到 我見到第 1才反應 粉紅色 存留在
    裡面.
⑪ 用這才資料 去確定 concentration of DCP solution.
⑫ 用一才 秤子 去測量 一才 2-4g 既 solid food.
⑬ 把它放到一才 mortar, 加入 15mL 3% 既 metaphosphoric
    acid. 再把食物 搗碎到最小.
⑭ 慢²倒入 1才 250mL 既 量杯. (不可以有 子, 皮).
⑮ 用 30mL 既 distilled water 清洗 mortar. 再把這溶液
    加入 量杯 裡面.
⑯ Titrate (滴定) 這才溶液用 DCP solution. (倍的 DCP 吸取 10mL
    或吸取 50mL, 要重新調食物大小) Titration 需要 10mL > x > 40mL
⑰ 再用同樣的方式 再做又 2才 food sample. 且 calculate 那才有
    最多的 Vitamin C !

Figure 4.1 Claire's procedure for her Extended Experimental Investigation.

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Participation and interaction in the teaching and learning environment

Of all the students in the study Claire was the most organised in her class work. When conducting experiments she always constructed a list of directions to follow. Both in biology and chemistry she had a group of friends with whom she sat and worked. She appeared to feel safe in these environments. In her groups Claire ensured that the tasks were divided evenly and her group was usually the first to finish and clean up, largely due to Claire's initiative.

The chemistry class was a large, noisy one consisting of 30 students. The chemistry teacher, Narelle had been teaching for 15 years and had just completed a Masters degree in Learning Support. Although she was observed to use many strategies that assisted Claire's understanding of chemistry Narelle confessed to feeling inadequate when it came to instructing Claire. When teaching organic chemistry Narelle scaffolded the language well explaining how it was connected and made sense. She often provided concept maps for the students to show how ideas were linked. Claire never drew any attention to herself in chemistry and never asked questions in class. Although conducting the EEI posed many challenges for Claire, from an observer's point of view it was somewhat miraculous to note the change in classroom atmosphere during the sessions when students were investigating a problem of their own choosing. The class changed from one where there were always a number of students off task to one where they were all involved and keen to explain their ideas. However, the individual investigations involved a lot of help from the teacher and laboratory assistant and quiet students like Claire did not claim their fair share of attention.

During biology Claire's participation was also limited to small group interactions. She never took part in brainstorming sessions and any communication with her teacher was initiated by him. Phil was a kind teacher and he made time in most lessons to come to check Claire's understanding. Because he felt that she was embarrassed he did not ever ask her to speak out loud in class or ask her a question in a whole class situation.

Claire's results at the end of the first observation period are contained in Table 4.3. A sound achievement is considered to be a pass and a limited achievement is not. This means that Claire was passing biology and almost passing chemistry.

Table 4.3

Summary of Claire's academic results in phase one

Subject	Knowledge	Scientific Process	Complex Reasoning	Overall
Chemistry	45%	40%	40%	LA10
Biology	48%	41%	20%	SA1

Her teachers were pleased with her progress but felt that if her language improved her achievement would also improve. Like Min and Aya, Claire tried very hard, always completed her homework and was never off task in class. From the researcher's point of view there appeared to be several factors affecting her understanding of scientific concepts. Although Claire was very organised when collecting equipment and performing recipe type experiments when questioned about the purpose of practical exercises she usually had little idea. In one biology activity her group was investigating the effect of temperature on enzyme activity. A valid conclusion drawn from the results would have been:

As the temperature increases the activity of the enzyme decreases.

Claire had written:

As the temperature gets hotter starch breaks down more enzymes.

Claire seemed more concerned with completing tasks than trying to gain an understanding of the concepts.

Her reluctance to ask questions and her inadequate academic skills were having a large impact on Claire's understanding. The class had library research project on *biological control.* When asked to explain the concept it became obvious that she had no clear idea of what the word *control* meant let alone what its significance was to the topic under investigation. This was after it had been explained in class. Her strategy to determine the meaning was to type the words into a search engine.

However, this did not provide a very satisfactory answer. When it was suggested that she use her textbook, she seemed surprised by the idea. She explained that textbook definitions often had the effect of confusing her. On another occasion she provided the researcher with the following example from the textbook in which the words in italics were perplexing for her: *Gel electrophoresis* refers to the technique *in which* molecules are forced across a *span* of *gel motivated* by an *electrical current*.

There were other instances where problems with language had a direct effect on Claire's understanding of scientific concepts. Not surprisingly, Claire experienced problems with vocabulary, especially in Biology. She often confused the meanings of pairs of words. During observations the following caused her concern: *phagocytosis* and *pinocytosis; meiosis* and *mitosis; stroma* and *stomata; feminine* and *feminist.* Jarrett (1999) suggests that teachers of ESL students should limit the introduction of new vocabulary to fewer than twelve words per lesson. In one introductory lesson on Ecology all of the following terms were used, many for the first time;

> *population; intraspecies; interspecies; adaptation; pressure; competing for native resource; hierarchies; pecking order; natural selection;, breeding pair; territory; robust; pneumatophores; niche; tolerance limits; density; abundance; distribution; migration;* and *growth rate.*

Although Phil was careful to explain each one, there was little chance to practise the use of each in the lesson and so the meanings of most were lost on Claire.

In common with many English learners, preposition use was confusing for Claire and led to misunderstanding. On one occasion when the researcher was trying to explain the difference between *smooth* and *rough endoplasmic reticulum* Claire could not understand why rough endoplasmic reticulum was covered *in* ribosomes instead of *on* ribosomes.

Another area of difficulty for the student was determining the main concepts to learn. Concepts in both biology and chemistry were presented in various forms including: teachers' notes; videos; worksheets; set text books; and class sets of alternative textbooks. Although this provided variety, in neither subject were the students provided with a list of objectives and Claire seemed to get lost in all the information.

Like Aya, she found correcting worksheets and problems orally very difficult but never asked for clarification.

In summary, Claire's teachers felt that her academic competence would definitely improve as her communicative competence increased. Because she did not attend ESL classes, subjects like biology and chemistry were the sole means of providing access to academic skills and language. Although Claire interacted and participated appropriately within her small group setting, she never involved herself on a whole class level. Consequently, she needed to be encouraged to participate. She also required the opportunity to clarify her understanding in a one-on-one situation and to be given the chance to ask questions and explain difficulties. Clear objectives and written model answers to problem sheets would also be of help to Claire.

Simon's story

Background information

At the beginning of the study Simon was a 14-year-old student recently arrived from Taiwan. He had immigrated with his parents and little sister a few months before. He presented at the new private coeducational school in the outer suburbs where the author works part-time. The school has an affiliation with an international school although Simon had not attended this. His family spoke Mandarin at home. His parents did speak limited English. Simon's mother was trying to improve her English language skills in order to study in Australia. Simon is an extremely talented international sportsperson. He explained that in Taiwan he was doing well at school until Year 6. At this time his sporting prowess was recognised and he was removed from conventional schooling to concentrate exclusively on his sport. After two years his parents decided that they were not happy with this situation and made the decision to move to Australia so he could attend school and play sport simultaneously. He had not participated in any science lessons or formal English lessons for three years. Although he was keen to continue his schooling in mainstream subjects, his first priority remained his sport and his time outside school was primarily devoted to practice, training and gymnasium work. This left little time for homework or English tutoring.

His teachers agreed that Simon had social proficiency (level 2) in the areas of reading, writing and speaking and 2+ in listening. This meant that he was able to satisfy routine social demands and limited school requirements. Much of the language of the classroom was not understood by Simon. He and his family required assistance attending to matters such as paying school fees and obtaining uniform requirements. In one instance his school fee account contained a levy for art, a subject in which he did not participate. His father felt unable to deal with this difficulty, particularly by telephone. Simon was at a loss as to how to approach the problem himself and needed encouragement and to be accompanied to the office in order to deal with it for his father.

Simon did not use his prescribed textbooks in any of his subjects as the language levels were too difficult. With respect to the science text Simon experienced particular problems with referral terms like *they* and *them*. For example in the sentence: *Salt can be produced from salty water by allowing it to boil,* Simon did not know what *it* referred to and so the meaning of the sentence was lost on him. O'Toole (1992) and Gardner (1978) explain that writing in science is characterised by the use of such terms. Predictably, many non-technical words were not understood by him. For example, in the sentence *Electrons gain energy* he did not know the meaning of the word *gain*. When speaking he often omitted the first few words of his sentences which made him very difficult to understand. He also experienced particular problems with verb selection. Despite the numerous problems he encountered he had the ability to laugh at his difficulties and enjoyed trying to pronounce words like *parallel*. His parents' suggestion to improve his English was to send him to mix with native speakers who played his sport. This probably did improve his spoken language but limited his study time even further.

Participation and interaction in the teaching and learning environment

At the beginning of the year Simon appeared happy in the class. He had a well developed sense of humour and interacted with his peers as well as his language skills allowed. Although he spent many hours out of each day playing sport he did

try to concentrate in class, but often looked exhausted with the effort. He was taller and more mature than the other boys in the class and in an effort to fit in told them about his sporting achievements. Initially they were impressed but as the year progressed Simon experienced some problems in his dealings with them and spent lunch times with other Chinese students. The other Year 9 boys were not very tolerant of differences and they made fun of his speech and even the food he bought for lunch. The girls in the class were more understanding and welcomed him during group work but did not include him out of class time. Simon was accustomed to mixing with adults and interacted very well with most teachers. An ESL teacher visited the school and helped him for 30 minutes each week. This was not adequate and his language skills were slow to develop in the first six months. His English teacher gave him particular help when she had time by providing outlines for him to follow for essay writing.

The student and academic competence

Although Simon's language did improve slowly in the first six months, particular problems emerged during science. Like the other ESL students, he had difficulty deciding what was important and what to revise. Some concepts, for example *the atom* proved very abstract and difficult to appreciate with his limited use of scientific language. Instructions such as *distinguish between* or *compare* and *contrast* had no meaning for him and caused confusion when he did have some understanding of concepts.

In his first chemistry examination Simon managed 10 marks out of a possible 50. He had some success with a question involving a graph and another where he was required to follow a pattern to construct a diagram of a molecule. In the second term he did a little better in the ecology test obtaining 14 marks out of a possible 40. This was largely due to the inclusion of multiple choice questions for which he did not have to construct any language of his own. Some of these required interpreting food web diagrams where there was little language involved. He was able to substitute into a mathematical formula in order to calculate *abundance* and extract information from a table about endangered species. His attempt to explain key terms was interesting. The *environment* was defined as: *living thing web or like food chain.*

The definition of a *population* was: *see how many they have.* An adaptation was: *what kind animal or plant.*

Although the special needs teacher at the school suggested modifications should be made to the curriculum and to class materials for Simon and another student in the same class with learning difficulties, teachers were only allowed to make minor modifications to assessment. Consequently in his first semester report Simon received all D and E ratings. He and his parents had trouble distinguishing between his ability and language difficulties and so were very disappointed with these results. Simon needed considerable encouragement and to be congratulated on small gains. His parents required careful explanations of why he had *failed* all his subjects.

In summary, after six months Simon was quite unhappy at school. His communicative competence had not improved as much as expected. When at school he lacked energy and was experiencing difficulties with interaction and participation in the class setting. He was unable to make effective use of content area material or texts and consequently his results were disappointing to the student and his parents. His sporting commitments impacted considerably on time which could have been profitably spent improving his English and trying to develop his academic skills and understanding. From the science point of view, instruction needed to be reorganised in order to give Simon entry into the academic discipline. If communicative competence was to increase there was a need to firmly anchor instructional strategies in the subject matter of science.

Patricia's story

Background information

Patricia was a 16-year-old Year 11 student who had moved to Australia with her family from Germany two years before this study began. Although she missed her German friends and grandparents she had quickly assimilated and believed that her family would have a better life in Australia. Her mother had been born in Australia but left for Germany when very young. She had some Australian relatives but they lived in Victoria. Patricia had attended a state high school for Years 9 and 10. Her

parents were concerned about the discipline at this school and so had transferred her to the same private school in the outer suburbs which Simon attended. She enjoyed science and had elected to do chemistry and biology for Year 11. She hoped to pursue a career in medicine. She reported that since she was a little girl she had wanted to be a paediatrician. Patricia's parents were quite ambitious and her mother was considered *very pushy* by the teachers. Patricia herself was well-liked by staff and students.

The language and communicative competence

Patricia reported that she had learned minimal English in Germany and that what she had learnt had not proved very useful on arrival in Australia. She knew very basic survival phrases only. However, after two years her English was very good. Of all the students in the study she appeared to experience the least difficulties developing general skills in English. This may have been because she was what Cunningham and Terrill (2003) describe as Roman alphabet literate. She exhibited vocational proficiency in all skills, giving her a rating of 4 in listening, reading, writing and 4+ in speaking. She was able to use the language fluently and accurately on all levels normally pertinent to personal, social, academic or vocational needs. Although a slight accent was evident especially in intonation and stress patterns, Patricia could always be easily understood by native speakers. Like Aya, her excellent speech tended to mask the fact that she was an ESL student and many of her teachers did not regard her as such. When asked, Patricia agreed to record the terms she did not understand over the period of two weeks. She explained that there would be so many that she would have to carry pen and paper with her all the time. She became quite enthusiastic and recorded the following conscientiously. This was her list:

> *abolition, acquaintance, acquire, acquisition, adolescent, aerial, altered, analogy, appraise, arboreal, arced, assertion, assimilation, assumption at right angles, bachelor, bales, beggar, benign, bisect, brood, broth, broth, bulge, burrow, canopy, capacity, captivity, cargo, charred, combustion, companionway, composition, consecutive, constituent, convey, conviction, copious, corpse, correspondence, crevices, cyanophytes, dabbed, dally, depletion, deposited, destruction, diagonal, dinghy, dismal, distribution, diurnal, drained, dread, dusk, eccentric, ectothermic, eligible, encroachment,*

erosion, eutrophication, evaporate, endothermic, enterprise, exaggerate, exclusive, exerted, exploit, extract, feign, feral, fermentation, fiery, flinging, forfeit, gash, gauge, gaunt, gem, give rise to, grazing, horizontal, hull, hurling, hypocrite, ignite, illegible, immigration, impaled, indicate, inference, inflammable, intermittent, intone, intravenously, jutting, kelp, lapped, lee, legislation, literature, lone, loot, manoeuvre, merchant, mesmerised, milled, mischievous, modules, monarchy, mottled, nauseous, neglect, negligible, nosing, notion, nutrient, oar, oblige, obscured, omitted, opaque, optimal, pennants, phoney, planking, plausible, poised, precision, prejudice, preserve, prevail, principle, pry, pursue, quarrel, queue, raft, random, reluctantly, remnant, resolute, respectively, retain, rigging, roosting, salvage, scarcely, scene, scenery, scrabble, seared, sedentary, seizing, semaphore, sergeant, severely, sluggish, snarl, sodden, sovereigns, spars, stash, stashed, stony, stooped, stow, subsiding, summon, surge, sustain, swathe, tendrils, terrain, terrestrial, tether, thrive, tomahawk, topple, torpor, torso, transfixed, transparent, treacherously, trudged, unanimously, undulations, unfurling, vague, vengeance, venture, vertical, vessel, villain, what do they have in common.

Of her list only the following could be classed as scientific jargon:

benign, cyanophytes, distribution, diurnal, ectothermic, erosion, eutrophication, evaporate, endothermic, feral, fermentation, intravenously, nutrient, opaque, sedentary, terrain, terrestrial, torpor, torso and *transparent.*

Her list made it evident that the student experienced a particular problem with abstract nouns. For example not understanding words like *constituent, assumption* and *principle* could affect comprehension of important concepts and assessment items. The remainder of words on the list were all everyday terms which teachers assumed Patricia understood. Patricia herself was more than aware of her limitations. On one occasion she told the researcher that she would soon have a lot more words for her as she was reading a new book. None of her teachers or the other students had any idea that there were so many gaps in her language.

Participation and interaction in the teaching and learning environment

Like Aya, Patricia was a student who interacted very well socially in the classroom. She had a nice group of friends with whom she spent time in and out of school. She experienced no difficulties participating in classroom routines or group work. Patricia considered her biology teacher, Julia, catered for her language difficulties very well. The specific strategies used by this teacher will constitute a separate section of this chapter. Susan, her chemistry teacher was a woman of very decided views. She was of the opinion that because Patricia's spoken language was so good that she should not be considered an ESL student. When shown the list of words that Patricia did not understand, her reaction was,

"Well why doesn't she know these words? It's ridiculous."

She did not make herself available to help students outside class time. She held a position of added responsibility in the form of Head of Year and claimed this limited the time she could spend with students. Patricia's mother and Susan had a disagreement about this issue and a complaint had been made to the Headmaster about Susan's refusal to provide individual help. Patricia was upset by this ill feeling between her mother and Susan.

The student and academic competence

Patricia was studying chemistry, biology, mathematics B, German, English and physical education. In all subjects except chemistry Patricia was achieving at least a sound level of competence. Table 4.4. shows her results in the science subjects.

Table 4.4

Summary of Patricia's academic results in phase one

Subject	Knowledge	Scientific Process	Complex Reasoning	Overall
Chemistry	45%	40%	30%	LA10
Biology	68%	68%	44%	HA3

The student and her parents were disappointed with this and considered that if she could pass English she should be able to improve her results in a subject which she

would require in order to achieve her goal to study medicine at university. She was a model student, consistently on task in class time and always completing her homework. In chemistry there was a lot that Patricia did not understand. Its abstract nature appeared to cause her problems which should have been sorted out by talking about them. However, she did not feel comfortable asking questions despite the fact that there were only eight students in the class. In biology she was quiet but would put up her hand and ask Julia questions if the need arose. She preferred to have individual help. Like most of the ESL students in the study, Patricia worried about the other students thinking she was stupid. In examinations, not surprisingly, she often did not finish in the allotted time.

In summary, although generally happy at school and achieving well academically, Patricia was very discontented with her lack of success in chemistry. Her parents were quite ambitious and put a lot of pressure on her. She required help with strategies for understanding abstract concepts, asking for help and finishing tests in the allocated time. Although her basic interpersonal communication was very good, her English for academic purposes was still developing and Patricia required assistance with this. When new terms were introduced she still benefited from extra practice. However, her word list indicated that she needed to develop strategies to help her with the meanings of non-technical terms which are crucial to the understanding of scientific discourse.

Yan's story

Background information

Yan was a 16-year-old student who came from Shanghi. She had spent six months at the international school before coming to the same school as Patricia and Simon. She was a mature student who also hoped to study medicine when she finished school. As well as compulsory English, she had chosen to study two mathematics subjects, chemistry, physics and biology. Yan joined the school at the same time as three other Chinese students. Although the other international students all considered biology as too difficult because it was so language rich, Yan was determined to attempt it as it was the subject in which she had the most interest. Yan

was what McKay (1994) identifies as an *academically focused learner* or a *maverick learner*. She had very good background knowledge in the sciences and mathematics and had come to Australia in order to improve her English and perhaps to undertake tertiary studies eventually. She was determined to do extremely well at school. During her stay in Australia she was billeted with an Australian family.

The language and communicative competence

Yan had minimum vocational proficiency (rating 3) in all four macroskills. She was able to participate effectively in most formal and informal conversations with native speakers. She could comprehend readily topics relevant to her experiences. With respect to writing she could write with sufficient accuracy to meet social and educational needs and was able to read standard items without the use of a dictionary. Reading cursive writing still caused her difficulty.

Yan had several strategies that she could call into play when she did not understand input. Because of her motivation and determination to do well, she was not at all shy in class. She sat as close to the teacher as possible and was happy to ask as many questions as she thought necessary. She appeared not to worry about what her classmates thought. Like some of the other ESL students Yan was sometimes guilty of saying she understood a concept when she was not clear on the meaning. However, if she did this initially, she usually revisited the issue at a later time. When questioned about this she attributed it to what she called "Asian diplomacy". She was also very good at articulating what she needed. Her homestay brother had a sheet of prefixes and suffixes relevant to his nursing study. Yan could see that this would be helpful and asked the author if she had a similar list for biology. Like some of the other students she kept a list of the new words she encountered. When she was asked why she repeated words several times until she pronounced them clearly, Yan explained the importance of being able to pronounce words correctly.

"If I can't say the word then I can't remember the information."

Yan was also very good at reflecting on her language development and learning. She read articles which helped to develop skills and was not afraid to share her knowledge with her teachers. This was an email which she sent the author.

Hi!

When you ask us to read through the text book, I don't know what information I need to get. So after I read, it feels that I got nothing. Reading loudly can help effectively. I remember an article said that you, as an ESL student, can remember and use a word if it appears to you in seven different ways. I remember that you told me I just need to know the answer for the "Objective", but I think it would be better if you give me some question about the chapter on Thursday and I will finish it over the weekend. I think it's a good practice (scientific skills) for me to get the right information after I read some thing about biology (the chapter). Then I will show you the answer next week, so that you will know whether I can understand the chapter or not. Do you thing it's a good idea? Regard Yan

Like the other ESL students Yan had difficulty understanding the language in the textbook. However, she did try to use it. Like Simon, Yan experienced particular trouble with referentials like *"this."* She felt that these masked the true meaning of the sentences and even examination questions for her. In order for the author to understand how difficult reading the textbook was for her, she decided to record all the words in just one chapter of her Year 11 biology book that she did not understand. Her list follows:

Absorption, adequate, adipose, admiralty, adolescent, adulthood, amino acids, anaemia, anorexia nervosa, appendicitis, appendix, artery, artic, ascorbic acid, basal metabolism, beverage, bile, bind, binge, bleeding, bran, bulimia nervosa, carpenter, cater, cereal, cholesterol, cider, circulate, compensate, complexity, comprise, consistently, constipation, constituent, consume, coronary, crevasse, debilitate, deficiency, delirious, derive, designate, deteriorate, dietary, dipeptide, diverticulitis, domestication, dysentery, elasticity, eliminate, enzyme, Eskimo, excessive, exertion, faeces, foetus, follicle, fracture, galactoaemia, glycerol, gourmet, grain, gypsum, haemoglobin, haemorrhoid, hydroxylase, inactive, infant, inflammation, initially, insufficient, intake, integral, isoleucine, kwashiorkor, lactation, lactose, laxative, lecithin, legume, lentil, linoleic acid, log, lumen, macronutrient, malnourished, maple, marasmus, marrow, menopause, menstrual period, menstruation, metabolic, metabolise, micronutrient,

multiplication, myoglobin, nevertheless, nourishment, obesity, odour,
oestrogen, onset, osteoporosis, palatability, phenylalanine, phenylketonuria,
phospholipid, polysaccharide, pregnancy, primarily, profound, prosecution,
puberty, purge, radically, raisin, ration, reduction, regulator, replenish,
reserve, resorb, retarded, retinol, saccharide, saprophytic, saturated,
sawdust, scurvy, sedentary, sinewy, sledge, spaghetti, spice, sterilise,
susceptible, sustain, syrup, temperate, toughen, triglyceride, trim off, urine,
varicose, vein, vigorous, virtually, vital, vomit.

She explained that if she stopped to look up all the definitions in the glossary, she lost the meaning of the whole piece of writing. What she failed to realise was that many of the terms were non-technical ones and would not appear in the glossary.

Participation and interaction in the teaching and learning environment

Yan had three science teachers. Susan taught her chemistry, the author, biology and John took her for physics. Although Susan would not spend any extra time with her, Yan did not suffer like Patricia because she continued to ask questions until she understood. John was a very experienced physics teacher who the students liked and respected. Yan said that he explained everything very clearly and that his teaching style which was quite structured and very organised suited her. In biology she would monopolise the teacher's time if allowed. In her quest to understand she asked in class time, after class and out of school time via email. The ESL teacher at the school regarded her as very bright and consequently allotted her less time than some of the other ESL students. As some of the other students were really struggling, her attitude was that Yan was the least of her worries.

During class, because of her preference for the front row she usually ended up sitting alone. Despite her English being heavily accented, she often offered to read aloud in class and performed admirably when participating in an oral presentation during biology. The other students seemed to accept her and welcomed her into groups. However, even among the other international students she had not developed any special friendships. After a bout of illness she appeared quite unhappy and decided to confide her reasons. The following email highlights just how difficult it is to study away from home and parents when only 16 years of age.

Mrs Morris:

Hi! Thank you for your teaching so far. I will keep working hard. I have a special habit that I just can work hard at home. Actually, I don't really like being at school. You know, it is not strange that you feel lonely when you are alone. But what if you still feel lonely when many people are being around you? So I am trying to pay all my attention to my study. However, every time I see their un-nice face, I will feel sick. I will tell you one thing but I don't know whether you can understand me or not, that is, just few Chinese people like me. Maybe because most of them come from a different part of China, we have different culture which they don't know exist. It is different from that the people come here, because they know the cultures are different and they will try to understand. It is not very easy for a person go to an entirely different place on its own. Besides study, you will meet many difficulties and it makes you miss your mum and dad so much. Going abroad to further study is a meaningful but hard experience. Everything is coming up to you in a sudden and frighten you. I used to have a very carefree life in China. I don't need to worry too much for my parents will do it for me. However, they want me to understand what a life is. Anyway, I am glad to come here and I learned a lot so far.

Now, you can have a break. Have a nice holiday!

Yan

The student and academic competence

Yan was a very conscientious student in her science classes. She went through all the handouts, attempted every practice question, tried to read and summarise the textbook and attempted to understand every term presented in both written and spoken form. She did not realise until it was explained to her that most of the native speakers did not always understand every term in the textbook either. She looked for alternative explanations and diagrams on the internet and tried to sort out concepts by asking numerous questions. She experienced more success in chemistry and physics than in biology.

After a practice biology test in week six she became despondent. Yan explained that although she had learnt some of the same science content in China, the language made the most difference in biology. She told her biology teacher to assume she knew nothing as it was all quite different in English and like learning it all for the first time. Apparently physics and chemistry were more transferable from Chinese to English. In the practice test she had expected only content questions. She found that she could retrieve information quite well, but not surprisingly, experienced difficulty when trying to be creative with responses using her own language. Although quite competent at interpreting scientific data, evaluation of information and expressing opinions about biological issues caused problems. Yan's perception was that her teachers would not have been interested in her opinion in China.

Despite the differences in the ways that biology was taught in Australia and China, Yan grew to appreciate the approach taken here. After completing an extended experimental investigation she told her biology teacher,

> "I like your study design. You didn't just tell us what we need to learn but let us find what we need to learn from the experiments you have designed. It can help us try to think in a scientific way".

Yan was rewarded for all her hard work by excellent results at the end of her first semester. Her science results are shown in Table 4.5.

Table 4.5

Summary of Yan's academic results in phase one

Subject	Knowledge	Scientific Process	Complex Reasoning	Overall
Chemistry	84%	82%	65%	VHA2
Biology	77%	75%	52%	HA7
Physics	86%	85%	72%	VHA 4

Additionally she received a VHA- in Mathematics B, and a VHA in Mathematics C. Other than in English, biology was the only subject for which Yan did not receive a VHA. Consequently, she was disappointed and determined to do better.

In summary, Yan's communicative competence was developing well. Academically, she was very successful but disappointed with her achievement in biology. Although her maturity enabled her to interact well with her teachers, she was experiencing less success relating to her peers. This was a cause of unhappiness and loneliness.

Julia's story

Background information

At the beginning of the study Julia was a middle-aged woman who had been teaching Junior Science and Biology for 15 years. She had worked as a professional scientist for many years before obtaining a qualification in education. She became a teacher because it was a career to which she had always aspired and because she considered it more family friendly once she had children of her own. Julia was a committed, caring and conscientious teacher. She took every opportunity to pursue professional development opportunities and had obtained her Masters of Science Education. Her head of department said of Julia,

> *"Her concern for students as individuals and her plans to help them reach their potential can be described as inspirational to other members of staff."*

The language and communicative competence

Julia had always had an interest in the language involved in teaching and learning science and tried to be aware of how she used language and scaffolded new scientific terms. She had a well developed personal philosophy on the roles of language in science. For Julia the main purposes of language in science were description and communication. She said that scientific language is used to describe objects, processes and ideas and that it is better to use one word than a whole string of words to describe an object. She thought that language in science should aim for clarity and connections. Using correct terminology was a more precise and concise use of language.

In one lesson, Julia was observed to use language for the following purposes: give instructions, provide encouragement, express disappointment, transmit anxiety about

an imminent test, explain, clarify, question, develop a concept, check understanding, solve problems, relate theory to real life, give permission, read aloud the lesson objectives, reprimand, display disapproval, describe, give practical help, explain conventions, refer to previous knowledge, reiterate, demonstrate, model, and compare.

Julia outlined several language problems which she maintained affected students' understanding of science. She felt that many science teachers functioned at a level where they used scientific language unconsciously without explaining it clearly enough to students. She said:

> *"I recently had a student teacher who was a very bright girl. She was a vet who had decided to obtain a teaching qualification. We were doing physiology at the time and she was very knowledgeable and had a fantastic scientific vocabulary which she used without thinking. My first thought was that I was jealous of Rowena because I used to talk like that and sound intelligent too. More importantly her being here made me aware of just how carefully scientific terms need to be explained."*

Science textbooks can cause problems too. If the textbook has long sentences, does not give clear definitions, has catchy chapter titles in the index which give little indication as to the chapter content and no glossary, it can impede understanding. Julia also pointed out that it is very difficult to find a science dictionary with a language level suitable for high school students.

Julia was well aware that the technical language of science can be a barrier to learning but insisted that mastering it does help understanding. She explained that she enjoyed the rigors of science and that if students wanted to be particular about what they did then they had to strive to use terminology properly. She gave a personal example.

> *I read a lot of educational journals and when I first started I had to keep a dictionary beside me to look up words like " epistemology" and "metacognition" and I had to look them up several times. Now they aid my understanding.*

Julia insisted that students can learn technical terms. She gave the example of how 5-year-old boys can list off the quite involved names of numerous dinosaurs. In class she used a term, explained it carefully and then continued to use it. She maintained that it is the way language is explained and how it is put into context that matters. She did not really mind if students used their own words but encouraged them to strive for correct scientific terminology. She cited specific examples of exercises which she employed to target specific language needs. In Year 8 she spent considerable time helping the students to write correct scientific reports using past tense, passive voice and third person. She pointed out that this style of writing needs to be explained carefully and that the students required practice in order to master it. While in English they have all seen a play or a poem and so they understand the format, scientific reports are an unfamiliar genre.

Julia also made the point that students can sometimes use scientific discourse to disguise their lack of understanding in science. To this end, alternative formats like letter writing were used to follow up scientific investigations. Learning definitions off by heart did not mean that students really understood a concept. In biology she spent time helping the students to recognise and write good definitions. She supplied a formula which described a definition as having three main parts: the term, the class and the special features. In other units, Julia concentrated on skills such as summarising, comparing and contrasting, everyday uses of scientific terms, comprehension and dictionary use. While she could not say that every science lesson had language objectives, Julia was conscious of the language demands in science and often talked explicitly about them.

With regards to ESL students of science, despite using all of the above strategies, Julia felt that she had no idea what she should do for them to improve their language. Although opportunities for reading, writing, speaking and listening existed in many of her lessons, this was not a conscious decision. She assumed that basic language development was occurring in ESL classes. She had never been given any information about language levels or even who were the ESL students in her classes. Julia had noticed that there was a certain amount of resistance on the part of some students to attend ESL classes. In 15 years, *teaching science to ESL students* had

never been the subject of any professional development activities. She admitted to feeling underprepared to meet this growing challenge.

Participation and interaction in the teaching and learning environment

With respect to interaction and participation in science classes for ESL students, Julia felt more confident. She created a pleasant, calm environment where students seemed happy to express their opinions. She aimed to speak to every student in every lesson and she usually ensured that there was time for this to occur. Her student-centred classroom helped to make this possible. Additionally, overall the students at the school were well behaved and Julia said she rarely experienced any discipline problems. At the beginning of the year each class collaboratively developed class rules and one aspect that had been stressed was how everyone's opinion must be valued. Of course this was not always the case but students were reminded frequently about this. If she thought it was necessary, Julia made herself available for help outside class time and because students found her approachable many, including ESL students took advantage of this offer. She was aware of class dynamics and moved to ensure that students joined appropriate groups when necessary. Julia used all students' names often and listened and watched what was happening during group work. She created an atmosphere where every student felt that Julia was aware of what they were up to and that she was speaking directly to them during class.

The student and academic competence

When asked what strategies she used to assist ESL students' academic competence Julia was unaware of what she did. She felt inadequate in this area as well. However, when she was shown the checklist of possible strategies she recognised that her focus on the language of science was of great assistance to ESL students. She had been observed: introducing topics and sections with discussion ; rephrasing language for clarity; modelling logical expression of ideas; creating visual images to support understanding; practising scientific functions and language functions; ensuring that students understood language functions; paraphrasing or repeating difficult concepts; speaking slowly and enunciating clearly; using a controlled

vocabulary; providing practice for using keys, constructing tables, drawing scientific diagrams, constructing flow charts, using symbols, constructing graphs, and making summaries.

The environment that Julia created for her students was also structured to assist development of academic competence. Observations revealed Julia: demonstrating new concepts with hands on experiments and activities; sequencing ideas logically; using simplications; reviewing frequently; expanding ideas; checking for understanding; and integrating technology. Although Julia had never heard of comprehensible input she unintentionally provided this by using: props, graphs; visuals; transparencies and videos.

Regarding assessment, Julia reported that the science faculty members at her school had made a conscious effort to vary the types of assessment pieces used in junior science. They assessed using posters, concept maps, research assignments, laboratory reports and portfolios of work. They provided practice with assessment language and answering questions. They made conscious efforts to help students understand how a more experienced person connects ideas. To students with language problems they sometimes provided an aid to read the examination papers aloud and assisted with information gathering for assignments. When it came to senior subjects they felt that their hands were tied. Biology assessment involved written tests, a practical based assignment, a research assignment and a practical examination. The only concession to language problems was extra time for examinations. To obtain this, students had to formally apply for special consideration.

Although Julia felt underprepared to meet the growing challenges of ESL students, many of her classroom practices were already addressing their needs. Coming from a science background, she felt she would like to know more about language in general and the theory of second language acquisition. This might enable her to assist with development of communicative competence within the classroom.

Lenny's story

Background information

Lenny was a 28-year-old Columbian dentist who had been in Australia for four years. She had married an Australian two years previously and wanted to work at her chosen career of dentistry. She was employed as a dental assistant and Latin American dance instructor. To become registered as a dentist, Lenny was required by the Australian Dental Council to demonstrate her competence to practice dentistry in Australia. The assessment procedure consisted of three components. The first was an Occupational English test, which was designed to assess the candidate's understanding and use of English in the workplace. The second component was the preliminary examination, which consisted of two papers in multiple-choice question format and a paper of five short answer questions which aimed to assess the candidate's general dental knowledge. The final examination tested the candidate's practical clinical skills (Australian Dental Council Guidelines, 1999). Lenny approached the author for assistance with the first and second examinations, eight weeks prior to the first test. The costs of sitting for the examinations were considerable.

The language and communicative competence

Lenny's original motivation for learning English was to understand journal articles and the Internet for dental purposes. To that end she decided to come to an English speaking country. Once here, her minimal skills needed improving for survival purposes. When she married, she needed English to communicate with her husband and to function in the community in general and at her workplaces. Four years after arriving Lenny's everyday English was of a high standard (rating 4 in all areas) and so she decided to try to gain registration in her chosen profession. She had studied for five years in Columbia to become a dentist and enjoyed the work very much. Lenny reported that she experienced only minor difficulties with everyday English. These usually involved listening and included not understanding strange accents, and needing to ask for clarification when talking on the telephone. Her speech was very good and people had much less trouble understanding her than when she first arrived.

What was evident was that Lenny was able to clearly define the difficulties she encountered daily and had mechanisms in place for dealing with these problems. She was often aware when she had made an error herself and self-corrected. She received constant feedback from those around her in her workplace and her husband also corrected her speech.

In everyday life, Lenny basically used listening and speaking skills. She did try to read when she had time but this was not often. Her writing still posed difficulties, especially when she did not practise. She felt that studying the grammar was an essential part of learning a language but not enough emphasis had been placed on this when she was taught English. She envisaged that the skills developed for everyday purposes, particularly speaking and listening, were of a sufficient standard to enable her to pass her initial examination. However, for the next examination, the macroskills of reading and writing would become all important.

Participation and interaction in the teaching and learning environment

The learning environments for Lenny's everyday English have been rich in variety. She reported learning minimal English in two years at high school in Columbia. Her choice of Australia as a destination to learn the language forced her into an everyday situation where she was immersed in the language with her home stay family and the community surrounding her. She studied English formally for a year fulltime at a Language Studies International (LSI) school when first in Brisbane. She then married an Australian who spoke only English and she used the language in both of her workplaces.

Although, the above situations cannot be divorced from the English she required for her study, Lenny perceived that different types of learning experiences would be necessary to prepare her for her academic endeavours. The only help provided by the Dental Council was a suggested extensive reading list. She asked the dentists for whom she worked for assistance and approached the author for help with her preparation. The dentists helped her informally when they had the time. She purchased a book on academic writing.

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Although her basic interpersonal communication skills appeared more than adequate to pass the Occupational English Test, if she was to tackle the enormous academic task in front of her Lenny's cognitive/academic language proficiency needed to be developed. There were several difficulties involved with this process. With respect to reading, the level required to access university level textbooks was very high. Interpretation of examination questions was complicated. In one instance a practice question involved analysing the implications for using amalgam as a restorative material in children. It became obvious from her answer that Lenny had no clear idea of the meaning of "implications". Probing revealed that she had similar problems with terms like "indications, compare and contrast, advantages and disadvantages." Whereas in the everyday situation she often asked for clarification or repetition when she did not understand, she would not be able to do this during her examination.

Academic writing in English is a specialised skill and Lenny explained that she still thought in Spanish when she studied and prepared written answers. A frequent strategy, which Lenny reported employing when using English in everyday situations was concentration on meaning rather than form. She said that if she did not do this she became stressed and her performance suffered. Although it was necessary to employ this strategy when reading academic material the actual form was important when it came to written work. Lenny tried to work through her book on academic writing, however, not surprisingly the material was decontextualised and Lenny did not seem to be making the links between the exercises and what was expected of her in the examination. When she started to formulate answers to suggested sample questions in each of the specialist areas of dentistry it became that she had no idea of how to plan an answer or what form that answer should take.

Lenny had an enormous amount of content to cover as the examination was really testing her knowledge of five years of university study, but in a different sociocultural context. She had made copious notes from her reading but seemed to retain little of what she had read. Her note taking strategies were ineffective. Furthermore she had not developed strategies such as reading with a purpose and

looking for key words. She also did not possess a dictionary of dental terms. Although she must have encountered such questions during her university study, she had no policy for tackling multiple choice questions and found these very difficult. One of the dentists had given her a book on questions and answers on clinical dentistry. Instead of using this to test herself, she intended to read the book from cover to cover. She appeared overwhelmed by the task in front of her and it became evident that she would need to develop more specialised study skills if she was to be successful. She had made little effort to formulate possible questions and research answers. When presented with possible essay topics, she treated the material quite superficially and did not provide enough alternative responses to answer the question adequately. This indicated either a failure to access relevant information in her textbooks, an inability to relate what she was reading in the textbooks to everyday practice or an inadequate knowledge of the content in the first place.

In summary, Lenny had to first pass the Occupational English test. Practice was necessary in the form of writing and reading referral letters, everyday explanations of dental procedures, listening and replying to telephone conversations, and filling out dental record cards. It was also important to focus on academic writing and reading skills in context and developing better study habits.

Anna's story

Background information

In 1988, Anna arrived in Australia from Hong Kong at the age of 15 with her mother and sister. While her sister studied medicine at university, Anna started Year 11 at a private girls' school in Brisbane. Her parents had separated and her father to whom she is very close, remained in Hong Kong. Her first language was Cantonese although she could understand and read Mandarin. After school she studied pharmacy for four years and worked as a pharmacist for a year before deciding to undertake a Bachelor of Dental Science degree. This is a five year degree. After working for three years as a general dentist in Brisbane she began a Masters course in Dentistry which would make her an Orthodontist after three years. She lived with and cared for her mother but returned to Hong Kong to visit her father regularly. In

order that she might work as a dentist in Hong Kong at some time in the future, Anna had successfully passed a rigorous examination process.

The language and communicative competence

Anna's basic interpersonal communication skills were excellent. Her ISLPR ratings were as follows: 5 for listening, 4+ speaking, 4+ reading and 4+ writing. She reported that she no longer experienced any difficulty functioning in English in everyday contexts. When she first arrived in Australia Anna found *listening* the hardest but as her skills improved *reading* became and still was the most difficult. In order to gain entry into her Masters course she required very good results in her undergraduate degree and she had achieved first class honours. Obviously her examination results indicated that she exhibited excellent cognitive/academic language proficiency. Strategically, Anna said she was much better at asking when she required clarification and just kept asking if she did not understand.

Participation and interaction in the teaching and learning environment

Anna was very unhappy when she started school and experienced difficulty settling into Year 11 where friendships had already been formed. She perceived that she did not assimilate at all, had no friends and got laughed at. She still felt resentful that no-one took an interest in her or was concerned about her unhappiness. She found chemistry, physics and biology easy at school. She had covered most of the content at a higher level already in Hong Kong. Naturally she experienced difficulty studying English. The school's answer was to expect her to cover extra Shakespeare. Her comprehension of prose and poetry was limited and she found such activities as analysis and identification of themes in literature almost impossible. She did not enjoy Australian geography either. Overall she found that the study skills required in the science subjects much easier to master.

At the time of this study Anna was having difficulty with the writing of her final thesis. She had designed and carried out her research but was in despair as her Professor refused to assess her work. He said it was too full of grammatical errors for him even to consider. She had taken her work to an expert in scientific writing

but this was not successful as it was necessary to have an understanding of the specialist dental language and the relevant practical experience in order to ensure that the meaning was clear and that there was proper continuity in the writing. She felt she was in danger of not passing her course and had nowhere to turn. She felt there were many ESL students in the same position as her.

The student and academic competence

The student was in an unenviable position. Her practical work was excellent and she knew that she could function perfectly well as a practising orthodontist. She had never experienced any problems with language in undergraduate courses, although she did admit that in many of her previous assignments she had just copied bits and pieces from various sources and tied them together. The current piece of work was different in that it had to be unique and written to a publishable standard. She was perfectly happy with the research and her results. It was the communication of these that was the problem. Her Masters course had provided no unit or information on academic writing and Anna felt that all such courses should include such a unit.

In summary, Anna required specialised assistance with the writing of her thesis. Her professor was unwilling to help her. Together, the author and Anna embarked on a revision of her thesis which involved many hours of oral explanations, negotiation and rewriting.

Response to Research Question 1a

What are the difficulties for ESL students with respect to the language used in science classrooms?

The difficulties observed with the development of communicative competence ranged from general institutional problems to specific grammatical issues. On the interlanguage continuum, none of the students had obtained native speaker proficiency as evidenced in the summary in Table 4.6 and so all students needed assistance in increasing competence.

Table 4.6

Summary of ISLPR ratings in phase one

Student	ISLPR Rating			
	Listening	Speaking	Reading	Writing
Cliff	0+	0	0	0
Min	2	1	2	1
Claire	3	3	2+	2+
Aya	3+	4+	3+	3+
Patricia	4	4+	4	4
Simon	2+	2	2	2
Yan	3	3	3	3
Lenny	4	3+	3	3+
Anna	5	4+	4+	4+

In all three schools (and Anna's university) there was no planned or coordinated approach to developing the communicative competence of the ESL students. No attempt to integrate content and language instruction was evident. It might have been expected that Larsen-Freeman's (2000) model of sheltered-language instruction would have been adopted, particularly in the school affiliated with the international college. This model involves language instructors who through the use of instructional materials and techniques support ESL students and their teachers in mainstream classrooms. However, at best ESL support was unstructured and haphazard and at worst, non-existent. At various times Min, Cliff, Simon, Patricia, Claire and Yan were all merely submerged in mainstream classrooms and Larsen-Freeman (2000) claims that with no extra support this method of studying is very nearly an impossible undertaking.

Where there was ESL support little communication between ESL teachers and mainstream teachers occurred and none of the science teachers were aware of their students' past educational backgrounds or language levels. The problem was further complicated in Aya's case because of the perceived stigma attached to attending ESL classes and her certainty that they would be of no benefit to her.

It must be accepted that their mainstream classes such as science were the main vehicle for the development of language skills for the ESL students in this study. For

those who did not live with native speakers it was the only formal way in which they were addressing their language learning. However, there was not any recognition of this by the teachers and in most individual classrooms there was no identifiable attempt at development of communicative competence. None of the classrooms or curriculums made any effort to address the language proficiency problems of the ESL students. Teachers did not emphasise specific aspects of literacy to promote social or academic development in any consistent or systematic manner. It did not occur to the teachers to promote English language and literacy development as part of their subject area instruction. Considering that only one teacher had ESL experience and any background knowledge of second language development this was not surprising. All teachers felt that their subject content was their first priority and none of the teachers saw it as their role to develop language objectives alongside science objectives. Because of this lack of expertise and ESL specialist support, diagnosis of the students' individual problems was a further difficulty.

Anderson, Holland and Palincsar (1997) classified the language in the science classroom as being used for: interpersonal relationships or paying attention to each other; scientific activity or attention to systems the students are investigating; or task requirements of teacher, tasks and accountability systems. Each purpose requires different language skills. Interpersonal interactions require Cummins' (1983, 2000) basic interpersonal communication skills. At the beginning of the observation period, Cliff, Min and Simon were still developing these skills while all the other students could cope adequately when communication was embedded in interaction between members of the learning community.

Most scientific activity and the requirements for tasks demanded cognitive/academic language proficiency (Cummins, 1983, 2000). Academic language is described by Cummins (1981) as the specialised, cognitively demanding language functions and structures that are needed to understand, conceptualise, symbolise, discuss, read, and write about topics in academic subjects. It is fair to say that even Anna after years of tertiary study did not have the requisite skills to meet the academic requirements of writing her thesis. Aya, after 11 years in the Australian school system was still struggling with the development of this type of language. The results support Gee's (1991) argument that students from non-mainstream backgrounds do not get the

same opportunities to acquire dominant secondary discourses including those associated with schools because their parents lack the resources to give them access to these discourses. This was also true of Claire and to some extent, Patricia. Yan and Lenny were living in Australian families and so had more exposure than the other students who all spoke other languages at home.

Other factors such as motivation, background knowledge and study skills are also involved in the development of communicative competence. Motivation affects coping strategies, and so overall proficiency (Ellis, 1994). When Min was depressed and silent there was little improvement in her proficiency. Coleman (1995) argues that there is a link between motivation and proficiency even for advanced language learners. He suggests that the type of motivation language students have may influence their success as learners. A distinction is made between integrative and instrumental orientations. The former is a genuine interest in the L2 community, which amounts to a desire to integrate into it. The latter is a desire to advance in one's career. Integrative motivation is associated with above average success and instrumental, with below average success.

Predictably, the technical language of science caused all students difficulty. Words which were similar or pairs of words were confused by many of the students. Examples included: *phagocytosis* and *pinocytosis*; *mitosis* and *meiosis*; *chromosome, chromatid* and *chromatin*. It appears that teaching a term or concept requires contrasting the term with other terms within classes. Teachers did mediate with new language and did refer to students' prior knowledge. Jaipal (2001) points out that there is a danger that new labels in a second language may refer to a different set of features associated with a concept. Observations also revealed that when explaining new concepts and terms teachers use idioms and slang in order to make the science more accessible. Predictably, this caused difficulties for ESL students.

Biology was seen as the most language rich of the sciences and some ESL students were advised to avoid it for this reason. Interestingly, observations revealed more opportunities for using language in the biology classroom than in either physics or chemistry. In most of the biology lessons observed there were opportunities for reading, writing, listening and talking. So although it is considered the most difficult

science by many ESL students and teachers, findings support the idea that it is the best for development of English language skills.

The language in textbooks caused problems for all students, even Aya. Elaborated grammatical patterns and different reasoning patterns were a barrier to construction of meaning because they are not part of students' everyday experience. The students, especially Simon, confused everyday use of terms with scientific terms, for example *force, cleavage, slide, mass, mole* and *bond*. Referral words such as *it, they, this* and *them* proved particularly difficult for Simon, Yan, Min and Claire. Conjunctions such as *subsequently, consequently, although, however, since, unless* and *but* often masked meaning for Claire, Simon, Min and Yan. The language in questions, such as *deduce, appreciate, outline, describe the implications* and *analyse* was often not interpreted correctly. For Yan there were 159 terms in one chapter of the biology textbook which she did not understand. Many of these were non-technical or everyday terms for which teachers assume knowledge. Although observations revealed that science teachers are careful about explaining new terms, textbooks do not supply enough practice once they have been introduced.

The surprising finding with regards to the language used in science classrooms is just how much ESL students do not understand. Even students like Aya and Patricia whose everyday English was very good provided numerous examples of problems with understanding some very basic terms. When shown these lists of words, all teachers were amazed at just how much language is not comprehended. This problem is compounded by the fact that dictionary definitions are often so complex that they cannot be understood by the ESL student.

Finally, Lenny and Patricia who were Roman alphabet literate were quicker to develop reading and writing skills than the students whose first language was Mandarin or Cantonese. Both of these students found it easier to understand the teachers' handwriting as well. Min, particularly found cursive writing hard to understand and needed to watch the letters being formed on the white board in order to read what was being written.

How do science teachers assist ESL students to interact and participate in science learning environments in Australian schools?

Carrasquillo and Rodriquez (2002) explain that one of the aims of mainstreaming is to provide a full range of educational opportunities to all students, eliminating social and racial barriers. Another goal is to provide opportunities for English language learners to interact socially with English proficient peers. Unfortunately, in the three schools in this study, just as there were no organised attempts to improve communicative competence for ESL science learners, there were no formal mechanisms in place to ensure the interaction and participation of these students into the schools in general or into mainstream classrooms. It was disheartening to see large numbers of Asian students congregating together at break times with little integration into the general school population evident.

In each of the three schools there was no one person overseeing the students' welfare. The schools tended to react to difficult or even crisis situations like Min's depression or Simon being bullied, rather than preventing their occurrence. None of the science staff were aware of what was happening in other subjects except in Aya's case where there had been some discussion between teachers. No-one was monitoring the students' overall progress. Similarly at Anna's university, there was no process in place to help Anna with her academic writing. She felt she had nowhere to turn for help.

The individual classroom teacher exerted the main influence on interaction and participation. Large differences were evident in the ways that science teachers assisted ESL students. The least successful teacher, Dave, literally never spoke to Min and so in physics Min did not interact at all. Phil was very conscious of Claire's shyness and fear of being laughed at or thought stupid and so he dealt with this by never asking Claire a question in a whole class situation. Mary made extra time available outside class hours to answer Aya's questions. Julia encouraged Patricia to hand in drafts of assignments to check the grammar and structure.

Pam had several strategies for including Min and providing her with access into the academic discipline of biology. She was always welcoming and explained procedures for practicals by writing the steps on the white board and then asking a student to reinforce the steps by retelling what was required. She drew a lot of diagrams and utilised opportunities to explain concepts to Min in one-on-one situations. Raelee followed the chemistry textbook closely and Min said that she always wrote the applicable page numbers on the board so Min could check at home.

Teachers' beliefs and attitudes were very influential. Pam, Raelee and Julia were always positive, enthusiastic and encouraging. Where teachers believed in success and set realistic goals, small gains and successes were celebrated and so students progressed. These beliefs in the possibility of success for ESL students are important because if language instruction and content are separated the ESL students fall behind and do not have the opportunity to develop academic language (Cummins, 1994). Conversely, two of the teachers, Dave and Susan were not interested in improving the situation for their ESL students. They both expressed the belief that science subjects were too difficult for students with language difficulties and that consequently failure was inevitable. Interestingly, both Min and Patricia were not passing physics and chemistry respectively, although they were passing in other science subjects taught by other teachers. Rennie (1993) supports the idea that high expectations for language minority students in active learning environments that are academically challenging is an essential characteristic of effective programs for ESL students.

The teacher's approach to learning affected the frequency of student interaction. Inquiry-based learning proved to be a powerful instructional context for Claire in Narelle's noisy chemistry class. Obviously classrooms where collaborative learning techniques were employed provided more opportunities for interaction and participation. Furthermore mainstream students appeared to mirror the attitude of their teachers to the ESL learners. Pam, Raelee and Julia always ensured that students who were reluctant to join in were placed in a group with conscientious, friendly students who were likely to encourage interaction and participation. Carrasquillo and Rodriquez (2002) contend that mainstreaming should provide opportunities for groups to function effectively once successful instructional

strategies are employed. Raelee was very good at making it clear to Min that as part of the class she was expected to contribute. Where teachers made these efforts the native speakers were more accepting of the ESL students. When teachers used the students' names frequently the other students were more likely to do so. In physics Dave did not speak to Min and so no-one spoke to Min.

Clegg (1996) maintains that mainstream classrooms can be harsh places for ESL learners. Whether this was true or not largely depended on the individual teacher's personality, beliefs, attitudes, approaches to learning and classroom management. The expertise and experience of the teacher also affected the extent to which they welcomed questions and provided clear alternative explanations. It would appear that some teachers need to heed Levine's (1990) simple advice to be hospitable to ESL students.

Response to Research Question 1c

What difficulties do ESL students encounter when constructing an understanding of scientific concepts?

The most obvious difficulty for ESL students when trying to construct scientific concepts is the language. Cliff, Min, Claire and Simon all still experienced some difficulties with every day communication and so had not fully developed basic interpersonal communication skills. All of the students had some problems with cognitive/academic language proficiency. However, the situation is not that straight forward. The students' engagement with scientific information was mediated not only by their prior linguistic experience but by their cultural knowledge of scientific concepts as well. Duit and Treagust (1995) explain that the sources of students' conceptions are sensual experiences, cultural background, peer groups, mass media and science instructions as well as language experiences. Apart from sensual input, for many ESL students these other experiences differ significantly from those of their native speaking peers. Some assessment instruments designed to measure the understanding of scientific concepts were infused with specific cultural knowledge which was not equally accessible to some of the students. Yan, for example was very surprised to be asked her opinion on an ecological issue in a test. She

maintained that in China, she would never be asked to evaluate information in order to express an opinion. Aya's family limited her access to mass media and so her experiences were often different from her peers.

As well as language proficiency, there were many other factors that affected academic success. Lack of participation and interaction resulted in lost opportunities for clarifying understanding. Students did not ask questions of their peers or teachers for many reasons. Sociolinguistic competence which was not yet developed meant that sometimes they did not know the correct form for asking questions. Fear of being laughed at or thought stupid were concerns for all of the students. Anna maintained that she was often laughed in high school. In her biology classes Mary had a very comprehensive study guide which the students worked through. Instead of checking their answers, she asked if anyone had any problems. Aya always had lots of queries but because no-one else said anything, she felt she could not. Where a teacher provided an opportunity to ask questions in a small group or one-on-one situation, the students had time to formulate their language for questions and always utilised the time fully.

Lack of effective study skills often hampered academic progress for many of the students. Min found listening and taking notes at the same time impossible and had made a conscious decision just to listen. Many of the students experienced difficulty with research. When using the internet many did their searching in their own language and then translated the information. All of the high school students struggled to mark work in class when the answers were only supplied orally. This process involved listening, reading and writing at the same time. Distinguishing what were the important concepts was another common problem. If there were no clear objectives or learning outcomes for a particular unit, the students often went off on tangents and lost sight of the larger picture. Because most of the teachers did not rely solely on a textbook but had various methods of presenting concepts, the ESL students were often not clear on what was important and what was assessable.

Assessment items affected academic progress. All of the students preferred multiple choice questions because they were not required to formulate any of their own language but only had to interpret what was presented. In Years 11 and 12 there was

little attempt at any modifications of assessment items and no instances of using alternative assessment was observed. Obviously, the students' language skills affected their understanding of assessment items. Even Yan, whose skills were superior did not understand terms in a biology test like *conspicuous, distinctly* and *tolerance*. This lack of understanding affected her overall achievement. Even though the ESL students knew they were allowed to ask the meanings of non-technical terms, none did in examination situations.

For Lenny, it became evident that lack of background knowledge of the content was a reason for limited academic progress. It appears that the assumption that ESL students already have a general knowledge of words and concepts because they have heard them in their first language cannot be taken for granted. Even when she understood what was being asked in practice questions, Lenny's answers reflected superficial treatment of the information. It seemed probable that her dental course in Columbia had not covered the different disciplines of dentistry in the same depth as they would be covered in Australian universities.

Summary of the findings in phase one

Table 4.7

Summary of language difficulties

What are the difficulties for ESL students with respect to the language used in science classrooms?
Communicative competence which is still developing
Little ESL specialist support
No coordinated approach to integrating science and language
Culture shock, depression and issues of motivation
Technical language
Non-technical language used unconsciously by teachers
Failure to develop cognitive/academic language proficiency
Textbook language
Grammatical patterns of scientific language
Specific grammatical difficulties e.g. subject verb agreement, pronouns and prepositions

Table 4.8

Summary of teacher strategies

How do science teachers assist ESL students to interact and participate in science learning environments in Australian schools?

Being hospitable and welcoming

Building a rapport with students

Using the students' names often

Providing opportunities for interaction

Establishing workable cooperative groups

Employing collaborative learning activities

Providing opportunities for clarification

Presenting the same concepts in different ways

Setting realistic goals

Celebrating small gains and successes

Table 4.9

Summary of academic difficulties

What difficulties do ESL students encounter when constructing an understanding of scientific concepts?

Developing BICS and CALP

Different cultural background

Different past science instruction

Different background knowledge

Limited opportunity to clarify understanding

Ineffective study skills

Reading cursive writing

Pronunciation of new words

Reading, writing and listening simultaneously

Assessment instruments infused with specific linguistic or cultural knowledge

CHAPTER 5   RATIONALE FOR STRATEGY DEVELOPMENT

Chapter 4 sought to interpret the experiences of ESL science learners and their teachers in Queensland educational institutions with regard to the three areas of the language, the teaching and learning environment and the ESL student. This represented phase one of the study. Chapter 5 corresponds to phase two of the study and aims to provide a rationale for the specific strategies or interventions which were designed to promote proficiency in all three areas by answering the following research questions:

2a. What teaching and learning strategies are likely to assist the language development of ESL students in science classrooms?

2b. What teaching and learning strategies are likely to improve the interaction and participation of ESL students in science classroom?

2c. What learning strategies are likely to enhance ESL students' understanding of scientific concepts?

In this chapter the purposes of the study will be reiterated and the overarching goals for the strategies that were developed in phase two will be explained. The concept of a needs analysis (Oxford, 1994), which was introduced in Chapter 2, will then be elaborated upon and the main results of this analysis will be presented for each student. This will be followed by a detailed description of the interventions and the reasons behind their development. Because it is relevant to all three areas of the study, a separate section on materials development will be included. The processes involved in the development of a unit of work will be illustrated with reference to a specific unit, *Genetics*. Finally, at the conclusion of the chapter, a summary of the findings for phase two will be presented in the form of specific responses to the research questions.

Overarching goals for phase two

The first purpose of this thesis was to understand the experiences of ESL science learners and their teachers in Queensland educational institutions. The second

purpose was to bring about change by introducing specially designed strategies within the classroom setting and evaluating their effectiveness.

In the United States the TESOL organization's national standards (1997) provide teachers with clear guidelines with which to support ESL students. As discussed in Chapter 2 the TESOL ideals aim to encourage development of social language, academic language and sociocultural knowledge. The strategies which were developed for this phase of the study incorporate the TESOL goals. However, they have a slightly broader emphasis. As well as focusing on language development, the strategies were intended to increase interaction and participation in science classrooms and to progress understanding of scientific concepts.

More specifically, the goal of the first group of strategies was to help the students in the study to develop communicative competence. In so doing it was hoped that basic interpersonal competence (BICS) and cognitive academic language proficiency (CALP) would improve. Because students learn from their peers and other native speakers there was a need to develop supportive whole school structures and an inclusive and safe classroom environment which made students feel welcome and respected. The assumption was made that all students in a science class should be aware of the learning and social requirements of ESL students and the role that the whole class can play in making the ESL learning experience a success. Consequently, the second goal was to help improve the interaction and participation of ESL students in selected science classrooms in Australia. To achieve academic competence students must be able to acquire new skills, assimilate new information, and construct new concepts. These accomplishments can be very difficult in situations where English is still developing. The third goal was to assist the students' understanding of scientific concepts and so improve their academic proficiency.

Needs Analysis

In working towards these goals, one of the difficulties was choosing which of the numerous strategies suggested in the literature would be most appropriate for each student and teacher. It was also necessary to limit the number of strategies to be

utilised if they were to be evaluated comprehensibly. It was clear that the data collected on each student should be analysed and the most pressing needs elicited.

Brown (1995) defines a needs analysis as:

> the systematic collection and analysis of all the subjective and objective information necessary to define and validate defensible curriculum purposes that satisfy the language learning requirements of students within the context of particular institutions that influence the teaching and learning situations (p. 36).

Brindley (1984) reinforces that it is important to distinguish between the subjective and objective needs of the learner. Objective needs which are identified with content (linguistic input), are defined as "those, which can be diagnosed by the teacher on the basis of the analysis of personal data about the learners along with information about their language proficiency" (Brindley, 1984, p.31). Subjective needs are associated with the learning process and are more difficult to diagnose. They include the wants, desires and expectations of the students.

Another method of defining the needs of learners is outlined by Stufflebeam, McCormick, Brinkerhoff and Nelson (1985). Their four common approaches to needs definition include democracy, discrepancy, diagnosis and analysis. Needs derived from a democratic perspective are those which are articulated by the majority of the reference group. In this case the reference group could include the schools, the teachers, the science syllabus and the students. It is necessary to consult the different members of the reference group in order to define the needs that will be addressed. These democratic needs varied from school to school. Working within the discrepancy approach to needs assessment, the observed differences between actual performance and desired performance of the students is ascertained. This approach could be applied to the teacher's expectations regarding participation and interaction as well as the student's language and academic performances. Closely related to the discrepancy approach is the diagnostic view in which need definition results from reflection on some element of language that the student continually finds difficult. Referral words in scientific text or the use of prepositions would be applicable examples. Needs definition in this area can provide guidance for the development of language objectives within the science context. Similarly, diagnosis of problems

with particular assessment items in science could also prove useful. Analysis of specific errors can also provide important information on both the academic and linguistic needs of the students.

Specific needs of the students

Cliff

As the student with the lowest English language proficiency rating, Cliff had an urgent need to develop BICS. He was able to interact with the other students nonverbally in hands-on science activities, but required an entry into scientific discourse at his own level. This was necessary if he was to have an opportunity to use language in a meaningful way, improve participation, begin to develop academic language and continue his science education.

Min

In order to develop both BICS and CALP, Min had a need to address communicative competence within science. Participation and interaction were also a concern for this student, as was her emotional well-being. If her understanding of scientific concepts was to improve Min required some individual attention and some time to formulate and ask questions. Comprehensive input in the form of extra visual prompts, practice with assessment items and modifications to assessment items were also necessary. Academically, her father's high expectations impacted on her desire to achieve.

Aya

Aya's ability to function well in the everyday school environment suggested that her BICS was adequate. Although there were many words she encountered on a daily basis that she did not understand, these had more of an affect on her academic language than on her everyday functioning. The English she required for academic purposes lagged behind many of her peers and she needed assistance with developing this. With respect to CALP, she experienced reading, listening and writing

difficulties and she needed feedback, particularly on written work, if these skills were to improve.

Because her speech was so good few of her teachers considered that she needed assistance with language. However, her participation in class discussions was disappointing and stemmed from insecurity. Aya also required individual attention from a sympathetic adult to whom she could address the many questions she had about language and science that ordinarily went unasked and so unanswered.

Claire

For Claire, the development of both BICS and CALP were areas of need. She required more support than she was receiving within her mainstream classrooms. She needed encouragement to interact and participate, even to the point of being giving the form or specific vocabulary with which to ask important questions. Like Min and Aya, Claire required more comprehensive input and some individual attention from a science teacher if she was to improve her understanding of the concepts in biology and chemistry. Assignment work was a constant concern for her. She experienced difficulty with comprehension of topics, researching and writing.

Simon

Because of limited ESL support at Simon's school, there was an urgency to address his communicative competence in mainstream classes. Integration of language and literacy exercises within the science curriculum was essential. The complexity of the textbook language did not allow him to access information in this way. Consequently, there was a need to reorganise instruction so that student gained access to the academic discipline of science and so additional materials were provided. There was also a necessity to find ways to encourage interaction and participation within the class.

Patricia

For this student, vocabulary appeared to be the biggest stumbling block. There were many words she did not understand and she required exercises that enabled her to practise a new term once it had been introduced. She always tried to understand every word in the text and this was a time consuming exercise and actually impeded her understanding in the long term. Like Aya, Patricia was afraid of what others thought of her. She also was very shy and needed prompting to ask for help. Timing in examinations emerged as a problem and she needed to improve her study skills and time management. She was unhappy about the standard of her academic writing.

Yan

Yan was very proficient at stating her requirements and she desired extra help in the form of one-on-one tutorials. She felt this would give her time to ask questions, improve her pronunciation, check her understanding and help to develop her writing skills. Her other needs included provision of: typed copies of notes; copies of overhead transparencies so she could listen rather than write; examples of model answers; post-mortems after every test and examination; extra practice questions; materials in advance of a class so she could read before the class and prepare questions; and feedback on drafts of written work.

Julia

Julia felt that if she knew some of the theory behind second language acquisition she would have a better understanding of how to help the ESL students in her classes. She also required assistance with specific ways with which to integrate language, literacy and science. Some modifications to programs were necessary and Julia felt the development of special materials would be a practical method of integrating strategies, giving the students some autonomy and providing a structure with which to offer individual assistance.

Lenny

Lenny's immediate needs involved learning to write documents in English in order to pass her Occupational English Test. The aim of this test was to examine the skills which would be used in her workplace as a dentist like writing referral letters and patient's notes. In order to tackle the second part of the test which was her content examination she needed to develop study skills which would aid her development of general dental knowledge. She required practice in formulating answers in academic English and access to the content knowledge in English textbooks using the reading list supplied by the Dental Council. Her dental knowledge did not appear to be of the same standard as that expected in Australian universities even when she understood what was being asked. When presented with possible questions, she treated the material quite superficially and did not think of enough alternative answers to address the question adequately. This indicated a failure to relate what she was reading in the textbooks to everyday practice and she required help to do this.

Anna

Anna's problems were fairly specific and she was clear about her needs. She required support from someone who understood the content of her thesis and also had experience with academic writing. A major revision of her writing was needed in order to correct grammatical errors, to improve the flow of her ideas, to make her meaning clearer and bring her writing up to the standard required for publishing her work. She was not really interested in learning to improve her writing for the future as she regarded this exercise as a one off venture which she did not intend to repeat in the future.

Development of the interventions

After careful analysis of the literature on strategies (see strategy in Appendix B) it was decided that the following broad interventions would best meet the needs of the ESL students and their teachers. To address research question 2a, that is, to assist the language development of ESL students in science classrooms, methods of integrating language and literacy instruction with science education would be employed. In

order to encourage interaction and participation of the ESL students (research question 2b) each student would be provided with some individual assistance from the teachers and the researcher. In an effort to improve the academic proficiency of the students (research question 2c), modifications to their science courses would be made. These decisions along with the specific strategies which accompanied them are summarised in Table 5.1.

Table 5.1

Summary of the proposed interventions

Research question	Area of focus	Intervention	Individual strategies
2a	Language	Integration of language and literacy instruction with science education	Language objectives Worksheets Glossaries
2b	Teaching and Learning Environment	Individual assistance	Tutorials Co-operative groups Assignment drafts and email
2c	Student	Modifications to science courses	Content modifications Process modifications Product modifications

Fradd, Lee, Sutman and Saxton (2001) found that development of specialised instructional materials was one method which could integrate language education, encourage participation and interaction and allow for modification to the curriculum simultaneously. Consequently, although this was not the only way the interventions were implemented, the development of the specialised materials was a practical method of encompassing many needs at the same time.

Integration of language and literacy instruction with science education

Stoddart et al. (2002) state that effective science instruction enhances language development and that language instruction enhances the learning of science concepts. This view is supported by O'Toole (1996) who maintains that science activities are a fruitful context for language development for all students. DiMarco and Turner (1998) state that the specific language requirements of students including those

involving scientific discourse need to be ascertained and catered for by language-focused activities within the science curriculum. The need to overtly introduce the ESL learner to the genres characteristic of scientific discourse is emphasised by Rollnick (2000).

Unfortunately, Gutierrez (2001) found that science teachers' main concern was for their subject area and the findings in phase one of this study verify this. It appears that specialised ESL classes are often unavailable or provide unsatisfactory support for the students. Consequently, mainstream classes like science are where important language learning takes place because science classrooms can provide a meaningful and authentic use for second language. Opportunities for speaking, listening, reading and writing which exist in most science lessons provide comprehensive input, as do the use of visual cues like specimens, graphs, tables, videos and hands-on experience (Rosenthal, 1996). However, unless science teachers pay particular attention to the specific language needs of ESL students, the learners may not receive the assistance they require to help them to progress along the interlanguage continuum. Fradd et al. (2001) reinforce that literacy development is necessary if ESL students are to be included. With reference to the difficulties encountered because of special scientific discourse, O'Toole (1992) says those difficulties can be reduced either by simplification or by helping students to understand the specific demands of the language.

Language objectives

If integration of language and science education is to be achieved, there is a need for learning resources to be specifically developed with the ESL learners in mind (Fradd et al., 2001). Gutierrez (2002) suggests creating language objectives for lessons, either implicitly or explicitly. Objectives developed for a specially designed *Ecology* unit, are shown in Table 5.1. The entire unit is contained in Appendix N.

Ecology Unit Language Objectives

1. To improve reading, writing, speaking and listening by taking part in the activities of the classroom.

2. To understand the meaning of the following scientific terms and be able to spell them and use them correctly: *organism, producer, consumer, first order consumer, second order consumer, herbivores, carnivores, omnivores, food chain, food web, scavenger, decomposer, nitrogen-fixing bacteria, habitat, ecosystem, population, community, environment, adaptation, structural adaptation, functional adaptation, behavioural adaptation, natural selection, physical environment, abiotic factors, biotic factors.*

3. To have practice at using or reading the scientific writing style at the following levels: word, sentence, paragraph and passage.

4. To have practice at using the scientific style by: *describing, classifying, naming, defining, comparing, contrasting, distinguishing, observing, providing examples, inferring, and explaining.*

5. To determine the meanings of words using a glossary.

6. To analyse small chunks of text in order to make it comprehensible.

7. To translate text from one form to another.

8. To use a mind map to summarise information.

9. To have guided access to the textbook.

Figure 5.1 Language objectives for the Ecology Unit

Worksheets

There were few commercially available materials suitable for ESL students at the levels required. It was beyond the scope of the present study to develop a whole integrated course with emphasis on language skills as well as science concepts. Instead, it was decided to address the specific language needs of each student as determined by their needs analysis, within the units to be taught in phase three. Larsen-Freeman (2000) warned that the use of customised materials or value-added resources is usually necessary in order to mediate between the primary source material and the ESL student. Results of an investigation by O'Toole (1998)

indicated that conceptually coherent supplementary worksheets are an effective way of integrating specific language needs in science. The worksheets need to consider difficulties at the word and sentence level, paragraph and passage level, and give assistance with textbook structure. Consequently, language activities in the form of worksheets and exercises were developed and integrated into the biology and science units which were to be undertaken in phase three (see Appendices F-N). In some instances, depending on the level of need, it was deemed necessary to extensively scaffold the learning materials and the *Genetics, Geology, Electricity,* and *Short Ecology* units which are contained in Appendices F, G, H and I respectively are examples. This was particularly necessary for Cliff and Simon because their level of language proficiency demanded it. Although the *Ecology* unit in Appendix N was developed with ESL students in mind, it was used by the whole Year 10 science class.

There are a number of authors who have an interest in language integration and some of the activities which were developed were based on the ideas of the following: Cleland and Evans (1984); Greef and Bilali (2003); Morris and Stewart-Dore (1984); Norris (1998); O'Toole (1992); St Germaine (2000); Riley (2000); and Rosen (1983).

During phase two of the study many language activities were designed and these were informed by the strategies suggested in the literature (see Appendix B). Some specific examples based will be presented in Figures 5.2 – 5.13. Chamot and O'Malley (1994) suggest focusing activities explicitly on language forms and functions. Examples of such activities are contained in Figures 5.2 and 5.5. The strategy of providing linguistic scaffolding (Westby et al., 1999) is demonstrated in Figure 5.3. Carrasquillo and Rodriquez (2002) recommend decoding essential vocabulary and Gardner (1978) promotes paying attention to non-technical words. Figure 5.4 is an example of activity which utilises these strategies. Figure 5.6 illustrates providing exercises in word synthesis and analysis as recommended by Dalton and O'Toole (1984).

Correct form of a word
Choose the correct form of the word *erupt* from the list.

erupt, eruption, erupted, will erupt, had erupted, to erupt, may erupt, had not erupted, erupting.

Volcanoes can _____ at any time. In the United States Mount Saint Helens

_____ in 1980. Before that it _____

since 1857. People did not expect it _____ again. Why did it begin

_____ again? If it _____ in the holiday season,

many more people could have died. The local people wonder when it _____

again. It _____ at any time.

Figure 5.2 Exercise focusing on the correct form of the word *erupt*. Adapted from O'Toole, 1992, p.142)

Language focus   Affect and effect
Students often find it difficult to know whether to use "affect" or "effect" in a sentence. Generally *affect* is a verb which means *to influence or change* and *effect* is a noun which means *result*. It is helpful to remember the word *v a n e* where *v* stands for *verb* and *a* for *affect* and *n* stands for *noun* and *e* for *effect*.
Choose the correct word form of *affect* **or** *effect* **to complete the following sentences.**
1. Make a list of the biotic and abiotic factors that might _____rocky shore organisms and outline some of the methods they might use to overcome these problems.
2. Adrenaline has a number of _____on the body including increasing heart rate which would be helpful if you were required to run away.
3. Recently ecologists have shown the harmful _____of pollution and drawn attention to the limited nature of the Earth's resources.
4. Different materials on the bottom of a river _____the colour of flounder.

Figure 5.3 Linguistic scaffolding.

Writing complex sentences
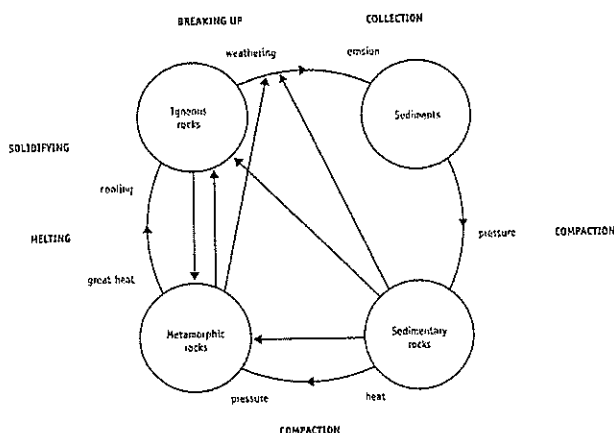
Complex sentences are made up of two clauses: an independent clause, which could be a sentence on its own, and a dependent which usually begins with a conjunction (joining word) and needs an independent clause to make sense.

Refer to the rock cycle diagram and the table below and write sentences about the rock cycle. Choose a dependent clause from the first table and match it with the correct independent clause from the second table. The first sentence has been done for you.

Dependent clause

Conjunction	Subject	Verb	Adverbial phrase
1. When	sediments	are	under pressure
2. As	liquid rock	is cooled	-
3. When	sedimentary, igneous and metamorphic rocks	are weathered	-
4. When	sedimentary rocks	are exposed	to heat and pressure
5. When	metamorphic rocks	are exposed	to great heat

Independent clause

Subject	Verb	Adverbial phrase
it	solidifies	into igneous rock.
they	are changed	into metamorphic rocks.
they	are compacted	into sedimentary rocks.
the rock material	solidifies	into igneous rock
the rock material	collects	as layers of sediment.

1. When sediments are under pressure they are compacted into sedimentary rocks.

Figure 5.4 Focusing on form: writing complex sentences (Adapted from Greef & Bilali, 2003, pp.5-6)

THE CELL THEORY

The invention of the microscope made it possible for us to see that living things are made up of units called **cells**. Biologists have **formulated** the cell **theory**.

The main principles or ideas of this theory are:

1. All living things are **composed of** cells and **cell products**.

2. New cells are formed from **pre-existing** ones.

3. The cell contains **inherited** information (genes) that are used as instructions for growth, **functioning** and **development**.

4. The cell is the functioning *unit* of life and the chemical reactions of life take place within the cell.

Some of the words above are in bold. Match those words with the meanings below.

1. *A hypothesis or a very good guess* _____

2. *Passed on from parents* _____

3. *Working* _____

4. *Basic units of living things* _____

5. *Made up of* _____

6. *Increase, expansion, or maturation* _____

7. *Ones that are already present* _____

8. *Put together* _____

9. *Materials made by cells* _____

10. *Small part* _____

Figure 5.5 Decoding vocabulary and paying attention to non-technical words.

Greek and Latin roots

Many words used in science are made up of parts of Greek and Latin words. If you know the roots sometimes it can help you guess the meanings of words.

Root	Meaning	Use the information to help you guess the meanings of the words.
astron	star	*Astronomy* - the study of stars.
omy	study of	*Hemisphere*
atmos	gas	*Equator*
aequator	equaliser	*Atmosphere*
hemi	half	*Lithosphere*
lithos	stone	*Longitude*
sphaira	ball	*Hydrosphere*
latitudo	breadth	*Latitude*
hydro	water	
logitudo	length	

Figure 5.6 Decoding vocabulary (Adapted from O'Toole, 1992, p.116).

The exercise in Figure 5.7 concentrates on non-technical vocabulary (Gardner, 1978). Figure 5.7 and 5.8 both pay attention to pronouns (O'Toole, 1992) and/or articles (Lee & Luykx, 2003)

Meanings of words

1. The slow but incessant action of weathering reduces even the hardest rocks to small fragments. 2. Such pieces of rock are carried by rivers, ground water, ice sheets, glaciers, or wind and transported to other places where they are deposited. 3. They usually accumulate in water, but sometimes they pile up on land. 4. When another load of sediment is deposited on top of them, layers begin to form. 5. These are compacted and cemented together by chemicals precipitated from the water. 6. There are other sedimentary rocks, however, which consist of layers of things which were once living. 7. These are called organic sedimentary rocks.

A. Find the words or phrases in the passage which mean the same as the words below. The number refers to the sentence.

a) never stopping (1)_____   b) breaks down (1) _____

c) carried (2) _____   d) put down (2) _____

e) pile up (3) _____   f) pressed (5) _____

g) stuck (5) _____

B. Find the following pointer words in the passage, put a ring around them and write the words they refer to in the space.

a) such pieces (2) _____   b) they (2) _____

c) them (4) _____   d) these (5)

e) these (7) _____

Figure 5.7 Decoding essential vocabulary and paying attention to pronouns. (From O'Toole, 1992, p.80)

USING ELECTRICITY

Complete the sentences by using the correct word from the list: *a, their, the, they, her*

To the people in the street, electricity is the form of energy that powers _____ television sets and washing machines. _____ know that electric trains also use electric power and are reminded of _____ dependence on electricity by the network of powerlines crisscrossing _____ countryside. During a power cut a student might have to do _____ homework by candlelight. But there are less well known, everyday processes which involve electricity. _____ beating of _____ heart, a running athlete, _____ dreaming baby, and a swimming fish all generate electricity just as surely as _____ power station does.

Figure 5.8 Paying attention to articles and pronouns (From O'Toole, 1992, p. 145)
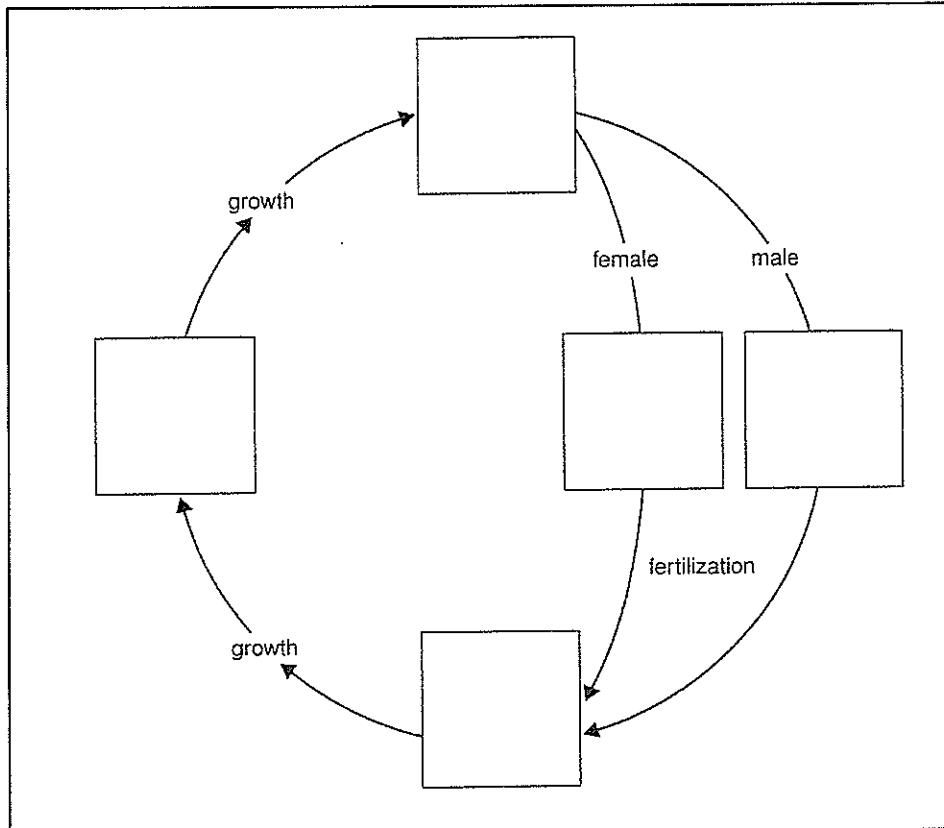
Cut out the squares and place them into the correct place on the diagram.
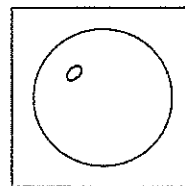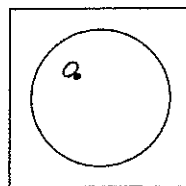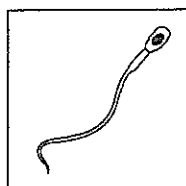
Use the terms below to label your completed diagram.

Male gamete or sperm, zygote, adult, baby, female gamete or ovum

Figure 5.9 Providing visual scaffolding (Adapted from Norris, 1998, p. 104)

Oxford (1990) recommends highlighting important terms and Carrasquillo and Rodriquez (2002) suggest identifying key vocabulary. Richard-Amato and Snow, (1992) when referring to creating activities for ESL students suggest the following: use simplications; build in redundancy; summarise and review frequently; increase

possibilities for success; clearly identify key terms; and avoid overly detailed explanations. The exercises in Figures 5.10 and 5.11 attempt to incorporate these strategies.

Check your understanding of the vocabulary by placing √ if you agree with the statement and a X if you disagree.

No.	Statement	√ or X
1	A chromosome is part of a gene.	
2.	In humans there are 22 matching pairs and the last pair determines the sex.	
3.	Autosomes are the sex chromosomes.	
4.	XX results in females and XY in males.	
5.	Chromosomes are made of DNA and protein.	
6.	Asexual reproduction results in two different cells.	
7.	In Down's syndrome there is one less chromosome.	
8.	Frogs reproduce internally.	
9.	From smallest to largest: gene, DNA, chromosome, nucleus, cell, and organism.	
10.	A karyotype is an arrangement of paired homologous chromosomes.	

Figure 5.10 Highlighting important terms, simplifying, summarising and reviewing.

WORD GROUPS

In each of the following groups there is one word which does not belong. Circle this word.

prevention	vaccine, balanced diet, immunity, surgery, disinfect, tooth brushing.
treatment	antibiotic, surgery, immunisation, chemotherapy, radiotherapy.
immunity	red blood cell, white blood cell, vaccine, antibody, immunise.
non-infectious	atherosclerosis, cholera, lung cancer, cystic fibrosis, asthma.
diagnosis	biopsy, chemotherapy, MRI, X rays, blood test, sphygmometer.

Figure 5.11 Increasing possibilities for success; clearly identifying key terms; and avoiding overly detailed explanations.

Simon had a particular problem with prepositions which Campbell (1995) reports as a common trouble spot for ESL students. Figure 5.12 is an exercise to assist him with this problem. All of the students found it difficult to write using the passive voice. The exercise in Figure 5.13 assists with this.

ACTIVITY 10 PREPOSITIONS

Look at the circuit and then choose the correct
preposition from the list to complete the following
sentences.

across, in, of, with, in, away from, around, of,

This circuit consists _____ a cell, a switch, a resistor,
an ammeter and a voltmeter. The ammeter is connected
_____ series _____ the resistor. Because the
voltmeter measures the potential difference _____ the resistor it must be
connected _____ parallel. When the switch is closed the electrons move
_____ the circuit. Electrons are pushed _____ the
negative terminal _____ the cell and pulled _____ the
positive terminal.
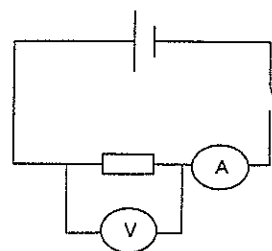
Figure 5.12   Focusing on the use of prepositions.

ACTIVITY 5.3 Language focus   *Passive voice*

In science an impersonal style of writing is often used because it is not important to
mention who does something. Using the passive voice is a more formal way of writing.
For example, instead of saying
1.   *Humans call plants producers.*
        We would say
        Plants are called producers.
2.   *Bacteria and fungi decompose dead remains.*
        becomes
        Dead remains are decomposed by bacteria and fungi.
Change the following active sentences into passive ones by beginning the sentence with
the word or words in **bold**.
1.   We know that **some consumers** are scavengers.
2.   We call **plants** producers because they make their own food.
3.   Bacteria and fungi convert **dead remains** back into carbon dioxide, water and
        minerals.
4.   We can divide **consumers** into carnivores, herbivores, and omnivores.
5.   Snakes feed on **many small animals.**

Figure 5.13 Focusing on writing in the passive voice.

The worksheets and units provided opportunities to incorporate many of the
strategies suggested in the literature. The following list provides further
representative examples along with a reference to the relevant appendix document.
The strategies included: providing practice for different forms of questions (Park,

1982; Appendix K); modelling logical ideas of argument (Gutierrez, 2002, Appendix L); presenting information in different formats (Rosenthal, 1996; Appendix G); introducing vocabulary in context (Oxford, 1990; Appendix J); practising scientific functions (O'Toole, 1992; Appendix N,), simplifying (Larsen-Freeman, 2000; Appendix G); organising information into tables (O'Toole, 1992; Appendix H,); retrieving information from tables (O'Toole, 1992; Appendix L) ; pointing out similarities and differences (Park, 1982; Appendix K); comparing and contrasting (Park, 1982, Appendix, K); constructing keys (O'Toole, 1992; Appendix L) ; practising study skills (Chamot & O'Malley, 1990; Appendix M); guiding the development of science related discourse skills (Lee & Luykx, 2003, Appendix M); directing to important terms (Oxford, 1990, Appendix F) ; providing clear diagrams (O'Toole, 1992; Appendix M); modelling correct language use (Gutierrez, 2002, Appendix I) including sequencing practice (Rosenthal, 1996, Appendix L); providing a structured review (Oxford, 1990, Appendix H); practising particular grammatical forms (O'Toole, 1992, Appendix G); and practising comprehension (Chamot & O'Malley, 1990, Appendix F)

Glossaries

Wellington and Osborne (2001) emphasise the importance of glossaries. They maintain that it is more important to explain rather than merely define. As well as making meanings clear, glossaries can be used to highlight the new words that will occur in teaching a topic. Wordbanks of new terms can be created and displayed on posters. Glossaries were included in most of the units that were developed for this study. For Aya and Patricia personalised glossaries were created as suggested by Abedi et al. (2000) (See Appendix D and E).

In summary, integration of language and literacy instruction with science education was attempted by analysing both the specific literacy needs of the students and the language skills involved in their individual units of study. Language objectives were developed alongside science objectives. Worksheets were developed which addressed difficulties at the word, sentence, paragraph and passage levels. Additionally, in some cases they provided assistance with textbook structure. General and personalised glossaries were constructed.

Providing individual assistance in the learning environment

McKay and Scarino (1992) state, as one of their principles of language teaching and learning, that ESL students learn best when they are treated as individuals with their own needs and interests. Similarly, Herrell and Jordan (2004) suggest that planning for more individualised instruction is essential for ESL learners. Heney (1996) says that when teachers have solid knowledge of their ESL students and respect individual needs, they are more likely to develop strategies that will support such students. The best way of determining individual needs, according to Gutierrez (2000), is by interacting with students. Furthermore, interested and hospitable teachers encourage the participation and interaction of ESL students which is necessary if they are going to acculturate (Levine, 1990). It comes as no surprise that all of the ESL students in the study were certain that they would benefit from some individual assistance. It must be acknowledged that this would probably be true of most science students, but for ESL students it is particularly important for many reasons.

All of the students in the study except Patricia and Lenny came from an Asian background. Kember and Gow (1991) warn that high academic expectations are placed upon Asian students and some teachers assume that these students do not require help. Lee (1997) suggests that their emotional needs such as perfectionism, stress and anxiety are often ignored by teachers and warns of the danger of stereotyping. Min and Yan were far from home. Although Simon, Cliff, Claire and Aya all resided at home, their parents' English was such that they were unable or reluctant to communicate with school authorities. Any problems that arose at school had to be dealt with by the students themselves. Only Patricia's parents were able to negotiate with the school on her behalf. At the beginning of the study, at none of the three schools, was there a person supervising their general welfare and to whom the ESL students could turn to for help. Even though some of the students had built up a good rapport with individual teachers, it was hoped that extra attention from their science teachers might provide them with a mediator should they require one.

Becoming literate in the science domain involves learning the specific discourse, as well as particular ways of thinking, acting and valuing. In short, students must develop Gee's (1991) *secondary discourses.* He argues that students from non-

mainstream backgrounds often do not get opportunities to acquire these because their parents lack the resources to provide access to them. Pingree et al. (2000) also reinforce the need for communication in developing the academic skills of the learner. For even the most proficient English speakers in the study, family patterns did not allow for the development of the child's academic literacy skills in English. It was therefore very important to provide these students with a chance to gain feedback on spoken and written language and to ask for clarification from a science teacher.

Many ESL students need encouragement to interact and participate in science classrooms. The reasons why students may not do this are many. Firstly, mainstream classrooms can be inhospitable (Clegg, 1996); this was certainly true of Min's physics classroom. Secondly, the student may be afraid of being laughed at, like Aya and Anna admitted they were. The student might not have adequate language skills or might need more time to formulate an answer than is allowed for in a busy classroom. The student could be going through a silent period (Ellis, 1994) where they choose to listen and not speak as Min did. The student's cultural background may dissuade them from speaking up or they may have a fear of divulging a lack of knowledge about the subject matter (Adamson, 1993).

The literature suggests numerous ways of providing individual assistance. The broad methods which were employed in this study included the following: individual or small group tutorials (Carrasquillo & Rodriguez, 2002; Jarrett, 1999); establishing workable cooperative groups (Gutierrez, 2002); academic language scaffolding (Herrell & Jordan, 2004) in the form of analysing assignment drafts (Carrasquillo & Rodriquez, 2002) and answering problems through email (Rollnick, 1994); and the development of customised materials (Fradd et al., 2001). Although it is relevant to this topic, in order to avoid repetition, materials development will be discussed in the next section on *modifications to the science program.*

Tutorials

Carrasquillo and Rodriguez (2002) and Jarrett (1999) found that both individual and small group tutorials provided valuable means of individualised instruction. The

literature presents numerous reasons why tutorials are considered successful methods of providing specialised attention and so promoting interaction and participation. Levine (1992) stresses the importance of building a rapport with ESL students and this takes time. Tutorials also allow for consideration of the student's prior knowledge and experience as recommended by Atwater (1994). Many ESL students are not comfortable speaking in whole class situations and there is a need to furnish them with opportunities to express needs and to speak in small group situations (Oxford, 1994). Second language learners need a great deal of input (Krashen, 1977), more than is supplied in a hectic science classroom where most of the other students have superior listening and speaking skills. Tutorials are opportunities of providing extra input and for checking for understanding as recommended by Oxford (1994).

Tutorial activities can be structured so students can participate at a level of comfort (Herrell & Jordan, 2004). Possibilities for the success of all students can be provided (Richard-Amato & Snow, 1992) as well as extra time for asking and answering questions (Stansfield & Rivera, 2001). It is possible to provide model written answers (Rosenthal, 1996) and to model logical expression of ideas, description and arguments (Gutierrez, 2002). A controlled vocabulary, with fewer pronouns and simple language structures (Jarrett 1999), can be employed, as well as other simplications which might not be appropriate to mainstream classes (Ur, 1996). Correction of oral errors is more easily achieved in a small group situation (Ur, 1996) and students are more likely to ask for correction themselves (Oxford, 1990).

For Simon, Patricia, Cliff, Yan, Aya, Anna and Lenny the researcher provided extra individual help on a weekly basis. The structure of the sessions was governed by individual need. Often the time was used to work through the supplementary worksheets and other class materials. For Min and Claire, their biology teachers, Pam and Phil, took turns in conducting regular tutorials. They used this time to reiterate what happened in class using more visual scaffolding than usual. The tutorials were used by the students to formulate and ask questions. They also were valuable in guiding library research and experimental activities, and practising problem solving.

In the first phase of the study, all of the ESL students experienced some difficulty interacting and participating in their science classrooms. Group work was difficult for Min, Simon, Claire, Aya and Yan to differing degrees. This is significant for a number of reasons. Schumann (1986) maintains that the learner will acquire the second language only to the degree that he or she acculturates. So it follows that if learners do not engage in group work, their communicative competence will be affected. Students who have not yet achieved communicative competence in English are disadvantaged when it comes to developing a deep understanding of science. Socially, as with most adolescents, the students wanted to fit in and be thought of as part of the class. Yan, Simon, Min, Claire, Patricia and Aya all had experienced social problems at various times which had led to feelings of alienation, sadness and frustration. Anna admitted that she still felt very angry about how she had been treated at school. In some cases it was difficult for the students to join in because of their limited English language skills. In other cases sociocultural differences hampered their efforts or the other students made little effort to include them.

The literature supports the importance of establishing workable cooperative groups. Buck (2000) argues that creating a classroom environment that is not dominated by teacher-student interaction is necessary if ESL students are to interact and participate appropriately. Gutierrez (2002) points out that cooperative learning situations are very important as they provide opportunities for students to develop both listening and speaking skills in English. Wellington and Osborne (2001) contend that student to student interaction is essential if oral skills are to progress. Rennie (1993) also recommends ensuring frequent student interaction through the use of collaborative learning techniques. Shoebottom (2003) warns that for effective interaction to be successful it is essential that the teacher treats ESL students as full members of the class community. Herrell and Jordan (2004) explain partner work is one way of ensuring verbal interaction and Heney (1996) recommends a buddy support system. For cooperative learning situations to be effective for ESL students, Jarrett (1999) explains that teachers must encourage positive attitudes in other students.

Cooperative groups can be very effective for ESL students because they provide peer guides and possible interpreters and encourage students who are hesitant to speak in large groups to do so. Furthermore, students' understanding and self-reliance may be fostered when they take part in problem-solving sessions. However, Gutierrez (2002) points out that group work, with its heavy emphasis on communication, can disadvantage ESL students when it is not planned with a clear understanding of language issues and power relations in the classroom. Buck and Mast (2003) found that although establishing workable cooperative groups seemed to be the most effective method for ESL student learning in science, it was much more difficult to achieve than at first suspected. Their initial findings revealed that the ESL students did little more than physically mimic other group members. As time progressed the ESL students became increasingly influenced by their learning groups. Sometimes this influence was positive but often it was negative. They recommended that care be taken to identify dominant personalities before placing students in groups.

During the initial observation period of the study, the researcher in conjunction with the classroom teacher identified the cooperative groups which they thought might be most appropriate for the ESL students. Extra efforts were made to monitor the groups in the classrooms and to ensure that they continued to work.

Marking assignment drafts and answering questions through email

In the classrooms observed in phase one, the majority of assessment items were in a written form. Rosenthal (1996) maintains that the kinds of written work required in science such as laboratory reports, short essays and assignments are some of the easiest forms of writing for ESL students. This is because there is usually a particular format required and the content is based on data, research findings and factual information. Nevertheless, many of the students experienced difficulties with writing and for Anna this was her greatest problem. Not only did she require assistance with grammar, vocabulary, punctuation, spelling, but more importantly at a Masters level with word selection and organization of ideas.

In order to cope with written assignment difficulties Rosenthal (1996) recommends the following: written instructions; models; sample assignments; individual

assistance with organization and revision of assignments; focusing on content; setting separate deadlines for selection and approval of topic, and submission of an outline, first draft and final product. Carrasquillo and Rodriguez (2002) also stress the importance of revising drafts for ESL learners. Although Rollnick (2000) acknowledges that repeated drafting and consulting is time consuming for instructors, nevertheless she emphasises its importance.

All of the students whose language skills enabled them to participate in writing in the classroom were keen to have assistance with this. In Lisa's ESL class, help with written assignment tasks was the most frequent request. Carrasquillo and Rodriquez (2002) explain that when helping ESL students with writing there is a need to reduce anxiety about the correctness of grammar and punctuation and focus on the purpose of the task. This makes it easier for the students to feel ownership.

Rollnick (1994) found that the use of email when communicating chemistry content motivated students to express their chemistry ideas in writing. She maintains that emailing, because it involves writing with a particular audience in mind, is a valuable experience for ESL students. As the researcher was not in attendance at any of the schools on a fulltime basis, it was decided that email might be an appropriate means of communication for answering questions between visits. The students were all supplied with the email address and encouraged to send questions and drafts of work.

Modifications to science courses

When referring to content based language situations in general, Cummins (1994) explains that adaptations to instructional programs may be required to teach content in a manner appropriate for ESL students. This is because traditional instruction of content calls upon students who are entering the learning environment to have necessary prior knowledge and reading and writing skills to access content material. Deficiencies in these skills can make it impossible for ESL learners to understand and learn the content and so they risk academic failure. To remove the barriers and to promote success, teachers may be called upon to modify instruction in order to reduce the emphasis and reliance on the reading skills necessary to understand the

content. Modifications may involve changes to the course work (Cummins, 19944), to the course materials (Ur, 1996) or to assessment (Abedi et al., 2000).

With reference to course work, Fradd et al. (2001) report that it often does not meet the needs of ESL students and Lynch (2000) maintains that research-based curricula focusing on science inquiry for diverse learners were yet to be developed. Modifications are thus necessary to many science courses in order to provide access to scientific discourse at the ESL student's own level. As already mentioned the production of customised instructional science materials is a method of both integrating literacy and science education and providing individual assistance to ESL students (Larsen-Freeman, 2000). It is also a very useful way of modifying science courses for learners of English and so promoting science literacy (Fradd et al., 2001). Because materials development is a means of meeting so many needs it will considered in a separate section of this chapter.

With respect to assessment, four possible assessment modifications for mathematics testing of ESL students were investigated by Abedi et al. (2000). These were: simplifying English language test items; supplying a glossary of nonmathematical words or phrases; providing extra twenty-five minutes of time; providing both a glossary and extra time. The authors found that ESL students test scores were higher in all types of accommodations except the glossary only example. However, accommodations also helped native speakers who were randomly assigned to groups. The only type that narrowed the achievement gap was the simplified English strategy. This involved modifying the word problems for difficult generic vocabulary without changing the mathematical vocabulary.

Furtado and Tavares (1996) provide a different method of categorising modifications to curricula. They classify them as content, process or product adaptations. Content modifications include: modifying the presentation of material; reducing the amount of material; rewording text or handout material using more appropriate vocabulary; and simplifying while allowing key points to remain. Process adaptations refer to adjustments in the delivery and pacing of the course. Furtado and Tavares (1996) suggest: presenting materials at a slower rate; using simplified vocabulary to improve comprehension; using various methods of review; allowing more time for learners to

understand the language and concepts; embedding the content within meaningful contexts by actively involving listening, speaking, reading and writing; identifying and teaching specific vocabulary that cannot be simplified; organising materials into small, easily attainable sequential steps so students can develop learning skills and master content; and teaching study skills. Product adaptations involve reducing the amount of material the learner is expected to produce. For example, assignments may need to be adapted so they are manageable by the ESL student.

The techniques suggested by Furtado and Tavares (1996) are intended to help ESL students develop everyday and academic language skills and to give them access to subject knowledge in their mainstream classes. Even though the adaptations outlined by these authors are general ones aimed at specifically preparing students for the senior years of schooling in all subjects, they can be used to form the basis for modifications to science curricula at all levels.

For the students in this study many modifications were made. The presentation of material was altered and simplified and the volume of material was reduced in many cases. Extra handout material was provided using more appropriate vocabulary. The tutorial situations allowed for a change in pace and method of delivery of some content. They also allowed more time for review and for identifying and teaching specific vocabulary. There were changes to the products that the ESL students were required to produce. For example, Yan was allowed to produce a brochure instead of a magazine article for one assessment piece. Simon and Cliff were permitted to work with a partner when writing a laboratory report. In essay questions, Min and Claire were permitted to express their ideas as dot points instead of whole sentences. The students were permitted to take electronic dictionaries into most test situations.

Materials development

Lee (1999) points out that most science materials do not consider the needs of culturally and linguistically diverse students. Lynch (2000) maintains that if instructors are able to select and assemble materials the shortcomings presented by many science textbooks can be avoided. According to Wellington and Osborne (2001) it is a good idea for teachers to write some of their own text as writing

readable material is still one of the central skills of a teacher. Studies by Fradd et al. (2001) and Sutman and Saxton (2002) also lend support to materials development as an appropriate way of supporting ESL students.

Second language teachers have long been aware of the need to produce their own materials and the ESL literature supplies many reasons for doing so. Krashen (1982) suggests that the main purpose of customised materials is the provision of comprehensive input for ESL students. Swain (1985) explains that there is a need to encourage language use or output and carefully designed exercises are important for this. Furthermore, materials can help to build particular skills and provide a link with the real world. They can be developed to provide the opportunity for language use at various levels of proficiency (Jones & Moar, 1985). Wenden (1986) says that especially designed materials, often lead to the development of various kinds of coping strategies and so encourage autonomy. Good materials should have an intrinsic interest for the learner and take the focus away from language and towards content (Mohan, 1986). Ur (1996) says that materials should provoke critical reflection. Because materials are produced for complex sociocultural purposes, they provide a rich source of critical reflection which may be either specific to the target culture or may raise issues which are universal. Additionally, materials are embedded in the culture for which they were produced and therefore carry cultural meaning. Students may be encouraged to seek out these meanings and so be provided with insights into the target culture.

Unit development

The units and worksheets which were developed for phase two are contained in Appendixes F to N. In order to illustrate the processes involved, the development of one unit, *Genetics* (Appendix F), will be explained in detail. Similar procedures were followed for the other units. This section of work was designed for Cliff and Simon whose language levels were such that they were unable to participate in normal class activities. It was also used by Min and Claire even though they were studying genetics at a higher level. Both the curriculum and the materials were developed taking into account the general principles of: content-based ESL learning;

science education; genetics education; and materials development. These considerations will be outlined in the following sections.

Principles of content-based ESL learning

As previously explained, content-based ESL teaching starts with meaningful use of language and through this medium the learner acquires the structures and forms of the language (Richards & Rodgers, 1986). Simon and Cliff's situation was a very difficult one in that they were being submerged in the language and expected to use English as a vehicle with which to study the science of Genetics and all their other academic subjects. With no extra support this was an impossible position. When using this approach, Larsen-Freeman (2000) stresses the need for the teacher to have clear language objectives as well as content learning objectives. Consideration must be given to development of communicative competence (Canal & Swain, 1980) and the four macroskills of speaking, listening, reading and writing. Widdowson (1983) argues that although the attention of the learner is focussed on the meaning rather than the language, it is vital to include contextualised analytical activities, which focus explicitly on language forms, functions and patterns.

The Unit Outline in Appendix F summarises the language objectives for the Genetics unit and divides them into skills and strategies. Opportunities for speaking, listening, reading and writing are included as are activities which encourage participation and interaction. In many instances the language is simplified and the responses required by the student are scaffolded. Important vocabulary is highlighted and clearly explained. If the students are to become independent, strategic competence needs to be developed. Consequently, they need to eventually access the textbook and so there are guided references which encourage them to do this.

Science and the ESL student

When teaching scientific concepts to all students the following are always areas for consideration: the broad kinds of knowledge and concepts involved; the areas which students traditionally find difficult; the ideas and misconceptions that students already have about a topic (Osborne & Freyberg, 1985; von Glassersfeld, 1995); and

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the conceptual changes necessary in achieving an understanding of specific concepts (Scott, Asoko & Driver, 1992). The difficulties that students have with science language are well explained by O'Toole (1982) and Dalton and O'Toole (1984). These authors suggest that science teachers should identify the specific language needed and then give students practice in manipulating it. Essential vocabulary and sentence structure should be decoded and exercises in word synthesis and analysis provided. Furthermore the learning should be continually evaluated. With respect to ESL science students, Stapp (2003) maintains that to facilitate the acquisition of science concepts the most effective strategies are presentation strategies and active learning.

The Genetics unit provides numerous opportunities to practise using the important terms once they have been introduced. A glossary is included and students are encouraged to use it. There are many visual cues accompanying the text and the material is continually summarised. Important concepts are highlighted and revision questions and problems are provided.

Principles of learning Genetics

Venville and Treagust (1998) report that when teaching Genetics, care must be taken to develop the larger ideas of *inheritance, genetic structure* and *genetic process*. They provide five broad areas which can be used to guide a unit of work. These are: the reason why most people look like their parents; the location of a gene; the relationship between a gene and a chromosome; how genes get passed from parent to offspring; and what a gene does and how. Lawson, Alkhoury, Bemford, Clark and Falconer (2000) classify all scientific concepts as: descriptive (i.e. concepts such as *predator* that can be directly observed); hypothetical (i.e. concepts such as *evolution* that cannot be observed due to limits of a time frame); and theoretical (concepts such as *atom* without directly observable exemplars). Theoretical concepts are the most difficult to develop and the *gene* is classed as one of these. To add to this complexity, Venville and Treagust (1998) state that successful genetics teaching results in a conceptual change from the idea that a gene is a passive particle passed from parent to offspring, to one of an active particle that controls characteristics.

With regards to solving genetics problems, Costello (1984) suggests that a weak understanding of the relationship between the processes of *meiosis* and the *monohybrid cross* interferes with the ability to develop meaningful solutions. Wandersee, Mintzes and Novak (1993) report that when asked about the transmission of hereditary traits children often ascribe certain traits such as eye and hair colour to the mother and others such as height and build to the father. They explain that many individuals of all ages subscribe to a type of pre-Mendelian blending of parental traits in offspring. Pearson and Hughes (1988) cite the technical vocabulary of genetics as a source of error and confusion to all students. This is a point of particular significance when considering ESL students.

The order of presentation of the main concepts in the Genetics unit which was developed was that suggested in the literature and this differed from the textbook. Because it was designed to be used at a Year 9 or 10 level, it was decided to concentrate on four out of the five major ideas recommended by Venville and Treagust (1998). Consequently the unit was based around the following ideas: the reason why most people look like their parents; the location of a gene; the relationship between a gene and a chromosome and how genes get passed from parent to offspring. Because of their language skills, the structure of DNA and the mechanisms involved in protein synthesis were deemed too difficult for the students at this stage. The science activities in the unit encouraged the students to: show relationships by utilising concept maps; make comparisons; extract information; construct a karyotype; and understand a life cycle. Problems involving manipulation of the language of genetics and monohybrid crosses also made up a large part of the content.

The need for materials

Many of the advantages of producing customised materials have already been described but within the context of unit development it is worth mentioning the most important. One of Larsen-Freeman's (2000) underlying principles of content-based learning is that when they work with authentic subject matter in the form of a textbook, students will need language support and so linguistic content must be scaffolded by the teacher. Value-added resources mediate between the primary

source material and the student. Allwright (1981) points out that supplementary materials are necessary where the textbook is deficient or where there is a need for different information and activities.

An evaluation of middle school science curricula reported by Fradd et al. (2001) found most materials covered too many subjects, included irrelevant classroom activities, and failed to develop important concepts. In contrast, materials which the authors designed for their studies provided ESL students with a sense of purpose about science, engaged them with relevant scientific phenomena, promoted the use of scientific ideas and terms, and encouraged students to examine their own understandings of science. In addition, they found that lessons progressed in a sequential manner and were used as building blocks to integrate and expand on concepts. Most importantly, the cycle of low academic performance of ESL students was broken and the support provided by the resources enabled the students to successfully engage in science. Fradd et al. (2001) concluded that the achievement gains of the students in their study reinforced the important role materials play in making science accessible to all students

Because neither Cliff nor Simon could access information in the textbook, they were unable to participate in many class or homework activities. The textbook posed several problems for the students. As well as the deficiencies already mentioned, the reading level was beyond their capabilities and there was insufficient visual scaffolding. There was not enough variety in the activities. New vocabulary was often not clearly explained and there was no glossary in the book. There were not enough opportunities for practice once a new term has been introduced. Genetics is rich in vocabulary and terms such as *homozygous, heterozygous, homologous chromosomes, alleles, codominance* and *incomplete dominance* all pose problems for native speakers until they have practised using them within the context of genetics problems.

Most of these problems were overcome by placing extra emphasis on understanding the scientific jargon. This was achieved by: the provision of the glossary; clearly defining terms and placing them in context; provision of numerous practice activities and examples; including comprehension checks; repetition of material; provision of

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comparison exercises; and simplifying the language. Other learner needs were met by varying the activities, providing questions of increasing complexity with less and less scaffolding, using concept and mind maps, the use of visuals and videos; and the inclusion of group and pair work.

Principles of materials development

The following points were of significance when planning this particular unit of work. A more logical approach to the major concepts was necessary if Simon and Cliff were to gain a clear understanding of the topics. Because the textbook was not providing comprehensive input (Krashen, 1977) it had to be supplemented with materials that could be understood, but with some effort. The learners' needs and proficiency governed the level of the materials. Opportunities for different kinds of interaction within the classroom were provided. Vocabulary and comprehension checks, methods of understanding the language involved in genetics problems and different approaches to the same concepts were inbuilt into the unit of work. Additionally, Ur (1996) recommends that if the text is too hard the following can help to overcome the problem: careful pre-teaching of vocabulary; introductory discussions of the topics and sections; providing interesting and challenging tasks; and omission of the difficult bits.

The following list of strategies for mainstream content-area teachers provided by Richard-Amato and Snow (1992) served as a useful checklist: use visuals; use simplications, expand ideas, provide direct definitions and comparisons to build in redundancy; reinforce key concepts over and over in a variety of situations and activities; avoid overly detailed explanations; summarise and review frequently; check understanding often; increase possibilities for success; be aware of linguistic demands; incorporate group work; and teach academic information processing skills such as concept mapping.

In summary, the materials developed for the genetics units and other units had their basis in sound theoretical principles. Classroom observations and reviewing the relevant literature enabled the researcher to understand both the problems confronting the mainstream ESL science learner, and some of the strategies that

should be used by teacher and learner to overcome these. The problems commonly encountered by all students when learning science and genetics were taken into account and used to inform the major concepts which were included. Although it was deemed necessary to supplement the textbook material extensively, the new materials still placed the onus for learning on the ESL student. They were required to be active participants in all learning activities.

Response to research question 2a

What teaching and learning strategies are likely to assist the language development of ESL students in science classrooms?

Analysis of the needs of the ESL students revealed that they all required assistance with English language development. For Simon, Cliff, Min and Claire language instruction was essential to enable them to function both inside and outside the classroom. For the other students their most pressing needs were of an academic nature. For all students important language learning needed to be addressed in mainstream classrooms like science because there was little formal effort language instruction occurring elsewhere. The literature (DiMarco & Turner, 1998; Fradd et al., 2001; Gutierrez, 2001; O'Toole, 1996; Rollnick, 2000; Stoddart et al., 2002) suggests that in order to assist the development of communicative competence within science there must be assimilation of language and literacy instruction with science education. It was decided to implement this integration by: constructing language objectives alongside the science objectives (Gutierrez, 2002); development of alternative supplementary units with guided access to the textbook (O'Toole, 1992); development of worksheets which addressed specific language needs (O'Toole, 1992); and creating both individual and personalised glossaries (Wellington & Osborne, 2001).

Response to research question 2b

What teaching and learning strategies are likely to improve the interaction and participation of ESL students in science classroom?

All of the students required help with interaction and participation. It was decided to address this need by providing each student with some individual attention (Herrell & Jordan, 2004). The literature suggests numerous ways of achieving this and the methods that were chosen included the following: individual or small group tutorials (Carrasquillo & Rodriguez, 2002; Jarrett, 1999); establishing workable cooperative groups (Gutierrez, 2002); marking assignment drafts (Carrasquillo & Rodriquez, 2002; Rosenthal, 1996); answering problems through email (Rollnick, 1994); and the development of customised materials (Fradd et al., 2001).

Response to research question 2c

What learning strategies are likely to enhance ESL students' understanding of scientific concepts?

Studying academic subjects in a language other than one's first language presents many challenges, but if ESL students wait until their language improves they are left behind (Stoddart et al., 2002). In order to give them access to scientific concepts modifications may involve changes to the course work (Cummins, 1994), to the course materials (Ur, 1996) or to assessment (Abedi et al., 2000). Furtado and Tavares (1996) suggest that content, process and product adaptations may be necessary. Based on their suggestions it was decided to attempt the following content modifications for the students in this study: modifying the presentation of material; reducing the amount of material; rewording text using more appropriate vocabulary; and simplifying while allowing key points to remain. Process adaptations which were chosen included: presenting materials at a slower rate; using simplified vocabulary to improve comprehension; using various methods of review; allowing more time for learners to understand the language and concepts; identifying and teaching specific vocabulary that cannot be simplified; organising materials into small, easily attainable sequential steps so students can develop learning skills and master content; and teaching study skills. It was decided that the product adaptations would involve reducing the amount of material the learner was expected to produce where necessary; and modifying assessment procedures. For example, in some instances it was decided to adapt assignments so that they might be manageable by the ESL students. Development of suitable materials was seen as a way of

integrating language and science education (DiMarco & Turner, 1998), providing individual assistance (Fradd et al., 2001) and modifying science courses for ESL students (Sutman & Saxton, 2002).

CHAPTER 6   IMPROVING THE SITUATION

The findings in chapter 4 highlighted the challenges faced by ESL science students in Queensland schools. Not only do these students have to deal with the normal problems of adolescence along with numerous sociocultural issues, but they must face the cognitive demands of science using English language skills which are still developing. The language skills of all of the students in the study were affecting their understanding of scientific concepts, their participation in class, their comprehension of assessment items and consequently their achievement levels in science. They all wished to improve their English language skills and were keen to improve their achievement in science. All of the teachers in the study felt that they were not properly prepared to deal with the many difficulties these students encountered. Only one science teacher in the study had some background in language education for ESL students. All but one of the teachers expressed concern about how to help the students in science classes more effectively. Most of the teachers were anxious about pastoral care issues and the general welfare of the ESL students.

The strategies which were designed in phase two of the study and described in chapter five attempted to ease some of these difficulties. The interventions were implemented in phase three. In an effort to address language concerns, an attempt was made to integrate language and literacy instruction with science education. In order to improve participation and interaction in the teaching and learning environment, individual assistance was provided for the students. Various modifications to science courses were made in an attempt to close the achievement gap between ESL students and the native speakers in their classes. These general interventions were achieved by utilising a number of specific strategies. The development of supplementary materials deserves special mention as it was a method which integrated language education, encouraged participation and interaction and allowed for modification to the curriculum, simultaneously.

Action research, according to Cohen et al. (2000) involves intervention and a close examination of the effects of such an intervention. Chapter 6 considers the

effectiveness of the interventions and strategies against a multidimensional interpretive framework which measures changes in communicative competence, participative and interactional competences, and academic competence. The specific questions for this phase were:

3a. What impact do strategies specifically designed to address language development in the science classroom have on ESL students' communicative competence?

3b. What impact do strategies specifically designed to improve the science teaching and learning environment have on ESL students' interactional and participative competencies?

3c. What impact do strategies specifically designed to assist ESL students' understanding of science have on academic competence?

In the first part of the chapter the interpretive framework is briefly outlined once again. Secondly, results for individual students are presented. The final section provides specific responses to the research questions.

The interpretive framework

In order to answer research question 3a, communicative competence in phase three needed to be compared with that in phase one. As outlined in chapter 3, communicative competence data were collected and analysed using classroom observation, case studies and the International Second Language Proficiency Rating (ISLPR) system. Details of the ISLPR levels are contained in Table 3.6.

Question 3b relates to interactive and participative competence. Data concerning how students responded to class tasks and demands were gathered by classroom observations, and teacher and student interviews. Participative competence involves responding appropriately to class tasks and demands, and interactional competence means that the learner can follow social rules and interact properly with peers and adults.

Question 3c was considered from the point of view of academic competence. As detailed in Chapter 3, academic competence was measured against the criteria set out by the various work programs applicable to the classrooms involved. In Years 10 to 12 this involved the three assessment categories of *Knowledge, Scientific Process and Complex Reasoning.* The results were expressed as: *Very High Achievement (VHA); High Achievement (HA); Sound Achievement (SA); Limited Achievement (LA) and Very Limited Achievement (VLA).* The nominal cut-offs for Years 11 and 12 are shown in the Table 3.7. Additionally, each level of achievement is subdivided into 10 levels. For example, a student may achieve an SA1 – SA10 in the sound achievement level. In Year 9, in one of the schools only *Knowledge* and *Scientific processes* were used for assessment purposes. At the other two schools all three criteria *(Knowledge, Scientific Process and Complex Reasoning)* were used. The cut-offs for Years 8, 9 and 10 are summarised in Table 3.8.

Individual student results

Cliff's story continued

Cliff was a 14-year-old boy who at the beginning of the study had only been in Australia for six weeks and consequently was unable to participate in most of his science lessons. As the school had no ESL teacher, his attendance in mainstream classes in his first term was his chief method of acquiring communicative competence in English. In the second term, the school appointed Lisa as the ESL teacher, although she had no experience in this role. Subsequently, Cliff began attending ESL classes as one of his subjects at school.

Language

When Cliff first arrived he was at a 0+ level in listening which meant that he could perform in a very limited capacity within the most immediate, predictable areas of need. However, in the areas of speaking, reading and writing he did not communicate at all. By the end of his first semester he had begun to read and write and his speaking and listening had advanced to level 2 which meant that Cliff was able to satisfy everyday transactional needs and limited social needs. Cliff had made

great improvements by the end of his first year of school in Australia. The change in his ISLPR levels from the end of phase one of the study to the end of phase three can be seen in Table 6.1. The numerous factors which contributed to this improvement in communicative competence will be discussed in Chapter 7.

Table 6.1

Cliff's ISLPR levels at the end of phases one and three.

Phase	Speaking	Listening	Reading	Writing
1	2	2	1	1
3	3	3	2	2

As well as involving him in group work, the major strategy used in science to develop Cliff's English was the design of a supplementary genetics unit (Appendix F). This took the form of specially constructed materials which were intended to give him access to some important scientific concepts. The unit contained language objectives, utilised simplified language and provided scaffolding for the students' responses. Important vocabulary was highlighted and clearly explained within the text and also in the glossary. There were numerous opportunities to practise using the important terms once they had been introduced. Because of the number of students attending the ESL class, Lisa was unable to give any specific assistance with regards to science materials, although ESL lessons were generally helpful in improving communicative competence.

The teaching and learning environment

Cliff's outgoing personality meant that he had fewer problems interacting in class activities than many of the other ESL students in the study. As his language skills improved, his participation in basic classrooms routines became much easier. Inquiry learning and group work became more meaningful. Some of the activities in the genetics unit were too difficult for Cliff to attempt alone and individual assistance in the form of lunchtime tutorials was necessary. For example, the comprehension activity in Appendix F was worthwhile when the passage and the questions were read to Cliff. He was then prepared to attempt oral answers in a one-on-one situation. Because most of the responses for this activity required brief one-word answers, with

considerable help, Cliff began to record written responses. His aunt, who was a teacher, was also willing to provide extra assistance using the science materials.

The student and academic competence

During the first phase of the study, Cliff's limited English meant that he was not assessed in science and other mainstream subjects. During the third phase, assignment work was still too difficult but word processed laboratory reports were meaningful if attempted with a willing native speaker as a partner. At the end of the genetics unit, it was decided to let Cliff attempt the examination paper. The paper consisted of 15 multiple choice questions and 20 marks of short answer responses including genetics problems. Although much of the paper was still too difficult, Cliff managed to answer 9 of the 15 multiple choice questions correctly. This was a very satisfying result for Cliff and his teacher. He volunteered that the special materials made a difference and that the tutorials provided the opportunity to have things explained slowly. The class was a large, noisy one and the quiet time made a big difference to Cliff. Many of the specially designed activities were used with the class in general and none of the students commented that they were too simplistic, but rather seemed to welcome the opportunity to reinforce the meaning of the new vocabulary.

By the end of the year, after using some of the other customised materials, Cliff received a sound achievement in knowledge and a limited achievement in both scientific process and complex reasoning. Although this meant that he received a D overall on his report card, nevertheless it was an impressive effort for a student who had extremely minimal skills at the beginning of the year. His success in the knowledge component of the course largely resulted from the number of multiple choice questions in examination papers which required only reading and no writing skills. Because he did not have to formulate any language of his own, this was much easier for Cliff.

At the onset of the study Min was a 16-year-old student beginning Year 11. She had been sent to Brisbane from Taiwan and was attending the same school as Cliff and Claire. She was living alone in a flat in the central city area of Brisbane close to Chinatown. She was shy, lonely and homesick. She had not obtained a sound achievement in Year 10 science despite having studied science in her homeland and already covering many of the topics in the syllabus. For Year 11 she had opted to study chemistry, physics and biology. By the end of the first phase of the study Min was coping much better with school life. She had progressed from a frightened girl who barely exhibited basic survival skills to a student who could readily understand school routines and procedures. However, her interaction and participation in science classes were still a cause for concern. Academically, Min was achieving a sound result in only chemistry. In both biology and physics her achievement level was limited. With the help of a friend, she had been able to express her unhappiness about her living arrangements and she was living quite happily with an Australian family.

Language

By the end of phase one, Min had started to speak and so had improved from S1+ level to S2. This meant that she was able to satisfy everyday transactional needs and limited social needs. Her reading, writing and listening were at level 2. By the end of phase three her speaking and listening were at level 3 which essentially meant that Min could perform effectively in most informal and formal situations and in educational settings which were not linguistically demanding. With respect to reading and writing, Min had progressed from basic social proficiency to social proficiency. Her improvement is summarised in Table 6.2

Table 6.2

Min's ISLPR levels at the end of phases one and three

Phase	Speaking	Listening	Reading	Writing
1	2	2	2	2
3	3	3	2+	2+

Supplementary biology worksheets were developed for Min on the topics of *Microscopes* and *Cells* (see Appendices K and L). These had a language focus as well as a biological focus and provided more visual support than the materials used in class. Although these exercises were intended to be used at weekly tutorials, Min preferred to work through them in her own time and have the material reviewed later. She was very conscientious about finishing them. She appreciated that they had been designed particularly for her and Claire and was pleased about this.

The teaching and learning environment

In the first part of the study, when Min was undergoing her silent phase where she did not speak at all, she became distressed if any overtures were made to her in class. She only interacted voluntarily with other ESL students, never English native speakers, and at every lesson had to be placed into a group for practical work. In order to overcome some of the awkwardness this caused, Pam, her biology teacher, quietly approached a group of kind, conscientious students and asked them if they would invite Min into their group for the term. They agreed somewhat reluctantly. They did not dislike Min. They just did not know her and she had never made any effort to speak to them. They allocated tasks to Min which she completed promptly and over time a rapport developed. In every lesson, Pam made an effort to include Min without embarrassing her. She treated her with respect and was always friendly and kind. She hoped that her behaviour would serve as a model to the other students. Pam was eager to report that one week, Min had playfully hit one of the boys in her group with a plastic spoon because he had said it was a woman's place to cook. She felt this was progress indeed. Slowly, Min was accepted by the class. When Min finally reached a sound level of achievement, Pam told the class about the big improvement she had made and they gave her a standing ovation.

Towards the end of phase three, her group was required to give an oral presentation and Min decided for the first time to participate. Pam said she spoke very quietly at first, but became more confident as time went on. Pam was delighted that Min was prepared to make this contribution as part of the group. About this time, Min volunteered that she felt much happier at school without stating specifically what had brought this change about. She may not have realised the subtle changes in classroom dynamics that occurred over the semester. While in the chemistry classroom similar progress was made under Raelee's guidance, no such advances were made in physics where Dave was not interested in promoting interaction.

Individual attention was provided by Pam during lessons when she had time, and in weekly tutorials which were shared by Phil, Pam and by the researcher. Pam used the tutorials to go over work she had covered in class using more visual cues than usual. Phil asked the Min and Claire to come with a prepared list of questions about the previous week's work. The researcher used the time to check understanding of assessment items such as assignments, to assist with research, to review drafts and to work through the extra materials. Although Min completed the extra materials alone, there was still a need to work through these so that she could have an oral explanation of the written material and an opportunity to clarify her ideas. It became evident that is was important to explore the main concepts in a number of different ways and at various levels in order to overcome the barrier that the language of Year 12 Biology presented.

The individual time was particularly valuable for Min because she never answered or asked questions during class time. She said that it took her about two minutes to formulate the language she needed to produce an oral answer to a question and asked that this time be provided during tutorials. In a classroom situation this would have been too long for the other students to wait, but it was reassuring that Min had the confidence to express her needs and request the extra time. By the end of phase three, Min was asking and answering quite complex questions during the tutorials which reflected an increased depth to her understanding. Although Min was encouraged to email questions and assignment drafts to the researcher, she did not take advantage of this offer.

Although Min's results stayed the same in physics, her achievement in both chemistry and biology improved. Her results for phases one and three for the three subjects are summarised in Tables 6.3, 6.4 and 6.5.

Table 6.3

Summary of Min's academic results in chemistry in phases one and three

Phase	Knowledge	Scientific Process	Complex Reasoning	Overall
1	49%	48%	10%	SA3
3	57.5%	52%	15.5%	SA5

Table 6.4

Summary of Min's academic results in physics in phases one and three

Phase	Knowledge	Scientific Process	Complex Reasoning	Overall
1	30%	27%	6%	LA4
3	32%	25%	7%	LA4

Table 6.5

Summary of Min's academic results in biology in phases one and three

Phase	Knowledge	Scientific Process	Complex Reasoning	Overall
1	43%	32.5%	8.75%	LA8
3	55%	48%	33%	SA5

The biggest advancement occurred in biology where the interventions were concentrated. No modifications were made to the volume of course work for Min. She was expected to cover all the same content as the other students in her class. The extra materials included detailed objectives so that she was clear on what was being assessed. Furthermore, the materials concentrated on the main concepts, gave her practice at using appropriate scientific language and at completing assessment

items. With regards to assessment, Pam explained to Min that she looked for meaning rather than expression when correcting her work. Min was allowed some extra time which she did not take. It was also permissible for her to ask the meaning of non-science words in examinations. However, her reticence did not allow her to take advantage of this assessment accommodation. Examinations were often supervised by teachers other than Pam and Phil. Min would have found it impossible to ask questions in a situation where she did not know the teacher.

By the end of phase three, Min's language proficiency, interaction and participation, and academic results had all improved significantly. Her ambition was to study science at an Australian or American university. Unfortunately, her final Year 12 results were not of a sufficient standard to allow her to achieve this goal immediately when she finished school. Min decided to undertake a bridging year at a private college in Brisbane in order to improve her tertiary entrance score.

Aya's story continued

At the beginning of the study, Aya was a 16-year-old Japanese student who had lived in Australia for 13 years. All of her schooling had been completed in Brisbane schools, but her parents were determined to preserve their Japanese culture at home. Aya attended an all girls' school in the central city area. Her spoken English was very good and she tried very hard at school, but there were concerns about her achievement levels in her three Year 11 science subjects, biology, chemistry and physics and also in English. Although she had obtained a sound achievement in all subjects (except Japanese for which she received a very high achievement), Aya and her parents had the expectation that she would study science at university as a prelude to medicine. Her academic results in phase one were not of the standard to allow her to do this.

Language

A comparison of Aya's ISLPR levels in phase one and phase three are contained in Table 6.6.

Table 6.6

Aya's ISLPR levels at the end of phases one and three

Phase	Speaking	Listening	Reading	Writing
1	4+	3+	3+	3+
3	4+	3+	4	4

In phase one Aya's basic interpersonal communication skills (BICS) enabled her to satisfy all social needs. Her academic needs were being met but not at a level which was acceptable to Aya and her family. She experienced reading, listening and writing difficulties and her English teacher viewed her vocabulary as a particular area of concern. The many words she encountered on a daily basis which she did not understand, affected her cognitive/academic language proficiency (CALP) and generally, the English language skills she required for academic purposes lagged behind many of her peers. Cummins (1994) states that it may take ESL learners up to five years to obtain CALP comparable to their native speaking peers. It seems that in Aya's case she had not acquired this level of proficiency in 13 years.

Although efforts to integrate language and literacy instruction with science education resulted in some improvements to Aya's reading and writing skills, her teachers agreed that there appeared to be no appreciable difference in her listening skills. She often missed important information. For example, Aya was confused by the terms *excretion* and *secretion*. She asked the researcher to clarify the difference. Mary, the biology teacher reported that Aya had asked her for the same explanation even though she felt she had supplied very clear definitions in the first instance. It was not only technical vocabulary which confused Aya. In one case, Mary had explained which objectives were applicable to the next test. Aya had not assimilated this essential information at all.

The intervention which proved most useful for improving Aya's literacy skills was the use of glossaries. In phase one of the study, Aya did not look up the meanings of words because dictionary definitions confused her and it took her too long to read text if she did. It was pointed out to her that good glossaries supplied explanations rather than definitions and she might find these more useful. Her biology textbook did not have a glossary so an alternative text was provided. To address the

difficulties Aya experienced with everyday words, a customised glossary was created by the researcher (Appendix D). Although the student found it very useful, the construction proved very time consuming. The problems associated with the glossary will be discussed more fully in Chapter 7.

The teaching and learning environment

Individual attention was provided for Aya by her teachers after class and by the researcher in weekly tutorials. Mary, for example, encouraged all students to hand in written responses to the problems in their study guides for correction and comment. Aya was one of the few students in the class to take advantage of this offer. The researcher's tutorials took the form of repeating explanations of difficult concepts such as *aerobic respiration* and answering the many questions which Aya accumulated during a week's study of biology. The time was also used to encourage the student to participate in question and answer sessions during class time. Aya needed reassurance that her questions were not too stupid or basic to be asked in front of other students. This endeavour was largely successful and her teachers reported that Aya was growing in confidence and extending her reasoning skills by taking part in classroom discussions. After one observation session, Mary asked the researcher,

"Did you tell her to ask questions out loud?"

Aya was also one of the students in the study who felt able to email drafts for revision. It appeared that, along with Patricia and Yan, she was confident enough in her language skills to be able to attempt this. Although Aya was aware that she made mistakes in her language, she was still willing to risk emailing. Orally, she was always exceedingly polite and her excellent manners extended to her writing. The following is a typical example of a text she sent the researcher.

Good evening Mrs Morris,

Hope you are well. Sorry I haven't been contacting you for a few days. I have bee really busy with work. Thank you for looking at my assignment. The information and ideas were really helpful. Its all bit complicating but Ill take my time and try and understand. I have some more random questions for you. Why do maple leaves change colour? Is it because the chloroplasts

die? When transpiration occur do they need energy? What are plant growth

regulators? What are xerophytes?

I hope to hear from you very soon! Regards (or is it sincerely..? sorry I am

not very good at these things ...!) Aya

 PS I have more words for the glossary but there's A LOT! Would you still

have interest in them? I find it VERY helpful. Sorry to keep you busy.

The student and academic competence

No content or product modifications were made for Aya. She studied the same course material as all the other students in her class and was assessed in exactly the same manner. However, the process of delivery of course material was altered by using simplified vocabulary to improve comprehension, using various methods of review; allowing extra time for her to understand the language and concepts; identifying important vocabulary; and helping her to organise her ideas when writing.

Aya's results in phases one and three in chemistry, physics and biology respectively are compared in Tables 6.7, 6.8 and 6.9. In physics there was a small improvement in Aya's results. Although her overall achievement level only moved up one level in chemistry, there were marked improvements in all areas of the course. Aya's failure to reach 40% in the complex reasoning criteria prevented her from moving to a higher achievement level in this subject. The largest improvement occurred in her biology where the interventions were concentrated.

Table 6.7

Summary of Aya's academic results in chemistry in phases one and three

Phase	Knowledge	Scientific Process	Complex Reasoning	Overall
1	69%	62%	26.3%	SA9
3	80.5%	72.5%	35.9%	SA10

Table 6.8

Summary of Aya's academic results in physics in phases one and three

Phase	Knowledge	Scientific Process	Complex Reasoning	Overall
1	66%	50%	30%	SA6
3	61%	63%	29%	SA7

Table 6.9

Summary of Aya's academic results in biology in phases one and three

Phase	Knowledge	Scientific Process	Complex Reasoning	Overall
1	62%	55.6%	40%	SA10
3	70.25%	67.83%	40.25%	HA2

Aya's realised her goal of studying science at university. In her first semester she achieved a distinction in her study of genetics and evolution.

Claire's story continued

At the beginning of the study, Claire was a 16-year-old student who had been Australia for about a year. She had moved from Taiwan with her family and she attended the same school as Min and Cliff. Like Min and Aya, in many ways Claire was a model student, always on task and completing all class work and homework to the best of her ability. Claire's teachers felt that her academic competence would definitely improve as her communicative competence increased.

Language

The changes in Claire's communicative competence are outlined in Table 6.10.

Table 6.10

Claire's ISLPR levels at the end of phases one and three

Phase	Speaking	Listening	Reading	Writing
1	3	3	2+	2+
3	3	3	3	3

Over the year of observations, there were small improvements in reading and writing, while her levels in speaking and listening remained about the same. Interviews in phase one revealed that Claire was not attending ESL classes, although her science teachers had made the assumption that she was. It was suggested to the student and her parents that this would be wise. However, ESL was timetabled as a separate subject and Claire did not want to give up any of her other subjects in order to attend ESL classes. Her science teachers saw this as a short sighted decision, but the family was adamant. Consequently, her mainstream subjects were the only formal instruction Claire had in English.

The supplementary biology materials which incorporated a literacy focus were the main interventions employed to assist Claire with communicative competence. She was enthusiastic about completing these worksheets. However, when she tackled the work alone she often missed important information. For example, one of the activities in Appendix L on *Cells* contained the following instruction:

> *Use the following information and your textbook to label the diagram on this page. The words in bold are the names you need to use.*

The word *label* did not stand out for Claire and so she missed the main point of what was an important learning experience with visual scaffolding. Some of the nontechnical language in the modified text caused her difficulties, even though it had been simplified for her purposes. Because the wording did not make sense to her it was important to clarify the information in the worksheets. For example, she found the following sentence impossible to understand.

> *No one cell contains all these features.*

Oral explanations were important to Claire's understanding.

Phil and Narelle, Claire's science teachers, worked hard at improving Claire's participation and interaction. Although she had always been organised during group work and practical exercises, they encouraged her to become more involved by offering her ideas to the group and asking questions of other students. It was necessary to suggest this, as like many of the ESL students, Claire was afraid that she would be laughed at or thought stupid and so was naturally reticent. Claire conscientiously prepared for practical exercises. She created flow charts of the procedures and recorded all results meticulously in her special combination of Chinese and English. On one occasion, her group was required to write their results on the whiteboard. One of the boys took Claire's book because he knew she would have a complete record of the experimental results and copied what she had written including his version of her Chinese results. When he was questioned about this, he said that he was catering to the multicultural needs of the classroom. All the students laughed including Claire.

Along with Min, Claire attended the weekly biology tutorials conducted by Pam, Phil and the researcher. Because she had a quieter nature than Min, she found it more difficult to initiate question and answer sessions. The researcher found it most productive to work through the extra materials with her or to check her understanding of assignment items rather than to wait for Claire to direct the sessions. Although she was encouraged to email drafts and questions she did not take advantage of this offer.

Because she lived with her family, Claire did not experience many of the difficulties and loneliness that plagued Min and Yan who were far from home. However, during the second part of the study, Claire acquired a boyfriend at school. She seemed much more cheerful and her general interactions with others in her classes improved as a result. Her parents were not happy about the situation. They saw Claire's primary role as that of a student and a social life was not part of their plans for her. Claire saw that the other students were permitted to have time off from studying for socialising. She was torn between wanting to be a dutiful daughter and behaving like everyone else around her. This conflict was very upsetting for her.

Claire's results for chemistry and biology are contained in tables 6.11 are 6.12. Although her results did improve over the year, her gains were not as great as some of the other students in the study.

Table 6.11

Summary of Claire's academic results in chemistry in phases one and three

Phase	Knowledge	Scientific Process	Complex Reasoning	Overall
1	45%	33.75%	21%	LA10
3	50.4%	41%	20%	SA2

Table 6.12

Summary of Claire's academic results in biology in phases one and three

Phase	Knowledge	Scientific Process	Complex Reasoning	Overall
1	48%	36%	16%	LA10
3	49%	40%	18%	SA1

Her naturally reserved nature prevented her from asking for clarification in class and even in a one-to-one situation. Whereas the other students quickly overcame shyness and took the researcher into their confidence, even at the end of phase three Claire was still reserved and self-contained. Ellis (1994) explains that there is some evidence to suggest that extroverted learners are advantaged when it comes to the development of language skills and are certainly more likely to participate actively in oral communication. Brown (2000) says that this difference in success in learning a second language is related to the learner's preferred learning strategies. Certainly, Claire's natural reticence often prevented her from seeking explanations about language issues and science concepts.

Like Min, Claire's academic results were not high enough to allow her entry into university. Her preferred university also had a requirement that student's should

have an ISLPR of 4 in each of the four macroskills. She too, enrolled into a bridging course after leaving school.

Simon's story continued

At the beginning of the study, Simon was a 14-year-old student recently arrived with his family from Taiwan. He attended the new private coeducational school in the outer suburbs where the author works part-time. His family had moved to Australia in order to give Simon, who is a talented international sportsperson, a more balanced education than he was receiving in Taiwan. He had not participated in any science lessons or formal English lessons for three years. Although he was keen to continue his schooling in mainstream subjects, his first priority remained his sport.

Language

During the year of observations, Simon's ISLPR levels improved as shown in Table 6.13. After quite slow progress in phase one, he made steadfast improvement during phase three. Many factors were involved in this improvement.

Table 6.13

Simon's ISLPR levels at the end of phases one and three

Phase	Speaking	Listening	Reading	Writing
1	2+	2+	2+	2+
3	3+	3+	3	3

The limited ESL support at Simon's school, meant there was an urgency to address his communicative competence in mainstream classes. Because the complexity of the textbook language did not allow him access to information from this source, integration of language and literacy exercises within the science curriculum was essential. In phase two, special units on *Genetics, Geology* and *Electricity* were developed for him. Although these were used with other students as well, many of the specific language problems which Simon experienced were addressed in these worksheets. Simon and one other student in the class with special needs worked from these modified texts during class time.

Simon's parents decided to petition the principal for increased ESL support. Over the year the school had been accepting more ESL students from its affiliated international college and eventually Cheryl was appointed to the school on a two day per week basis. She had an English background and was still studying to acquire her ESL qualification. However, she was very knowledgeable and enthusiastic. She was also genuinely kind and caring and the students related very well to her. Cheryl was happy to use the science materials as a basis with which to help Simon. This co-ordinated approach between mainstream teacher and ESL teacher proved invaluable. Cheryl's insight into Simon's language development helped the student and his teachers enormously.

The teaching and learning environment

At the end of phase, one Simon was not interacting very well with the other students in his class and it was necessary to find ways to encourage interaction and participation. When studying *earthquakes* Simon had mentioned to the researcher that he had lived through one in Taiwan and so he was invited to tell the class about this experience. The other students were fascinated by this and asked him many questions. At about the same time, Simon's photograph appeared in the local newspaper along with an article outlining his sporting achievements. Classroom opinion swung back in his favour again. Additionally, another international student joined the class during the term and Charles and Simon worked well together. Simon's language skills were slightly superior and so he enjoyed explaining things to Charles. In many educational institutions which cater for ESL students, the rules are very strict and students must speak English at all times. Simon maintained that it was extremely tiring speaking English continuously and that he wanted to speak Chinese sometimes, especially at lunch break. A compromise was reached and it was decided that during lessons he should try to speak English and only if Charles did not understand his English explanation could he switch to Mandarin.

Simon was very conscientious about attending weekly tutorials at lunch time to check his worksheets and utilise the opportunity to ask questions. This was in contrast to the other student in the class with special needs, who often forgot his supplementary materials and refused to spend any of his break time on school work.

Although Simon did not reach the point of emailing questions or drafts of assignments, he was organised enough to have a draft ready a few days before the due date for proofing.

During the term, Simon also acquired a girlfriend. She was a Chinese student who was two years older than him. Although he seemed happier in general and attended the school social with Yin, his parents saw it as a waste of his time to socialise. Like Claire, he was torn between obeying his parents and having a social life which his friends considered normal.

The student and academic competence

Simon's academic results reflected his improved communicative competence. Although class materials were modified for him, assessment items were the same as the other students. By the end of phase three his improved comprehension had made a big difference to his science results. His results appear in Table 6.14.

Table 6.14

Summary of Simon's academic results in year 9 science in phases one and three

Phase	Knowledge	Scientific Process	Overall
1	35%	31%	LA
3	54%	58%	SA

In his geology test Simon answered eight out of ten multiple choice questions correctly. His short answers showed increased comprehension. One question which required him to outline the difference between *weathering* and *erosion* was explained as follows:

> *Weathering is of two type – chemical and physical and is the breakdown of rock. The erotion is the rock carry away by water and then the rock get smaller and smaller.*

Although there were still many grammatical errors, Simon's expression of ideas was much better than in phase one and he understood what kind of information was required to adequately address the question. The simplified materials which concentrated upon the main concepts and provided practice with the use of

vocabulary and assessment items seemed to make a difference to his understanding of scientific concepts and assessment items. The co-ordinated approach between classroom science teacher and the ESL teacher allowed for reinforcement of both important ideas and the language involved in the discipline of science.

Patricia's story continued

Patricia was a 16-year-old Year 11 student who had moved to Australia with her family from Germany two years before this study began. She had quickly assimilated and was not viewed as an ESL student by the other students and many of her teachers because of her excellent spoken English language skills. This put her at a disadvantage in some ways as it was assumed that her comprehension was better than it was. Her parents were very ambitious for their daughter and although she worked very hard at her studies, they were disappointed with her efforts, particularly in chemistry.

Language

Although Patricia's basic interpersonal communication was very good, the English required for academic purposes was still developing and Patricia needed assistance with this. Vocabulary was her biggest stumbling block and the list of words that she did not understand indicated that she needed to develop strategies to help her with the meanings of the non-technical terms which were crucial to her comprehension of scientific discourse. The personalised glossary which was constructed for her is contained in Appendix E. Although she reported that this was very helpful, the construction of the glossary was too time consuming to be a permanent solution. Although Patricia did not routinely attend ESL lessons, Cheryl, the ESL teacher introduced her to a Learner's Dictionary which explained a term and then illustrated its use in a sentence. Patricia found this very useful and with Cheryl's help became proficient at looking up the meanings of important words.

With respect to technical vocabulary, the biology worksheets on *Microscopes, Cells and Reproduction* (Appendices K, L and M) contained exercises that enabled Patricia to practise a new term once it had been introduced. These were completed by

Patricia and then used in weekly tutorials which were conducted by Julia and the researcher. By the end of phase three there was a noticeable difference in Patricia's ISLPR levels as outlined in Table 6.15. The corresponding improvement in academic language proficiency had a very positive effect on her academic competence.

Table 6.15

Patricia's ISLPR levels at the end of phases one and three

Phase	Speaking	Listening	Reading	Writing
1	4+	4	4	4
3	4+	4+	4+	4+

The teaching and learning environment

Like Aya, the fact that Patricia was afraid of what others thought of her, impeded her willingness to ask for help during lessons. Julia's biology class was small and the students all knew each other quite well. With the Patricia's permission Julia explained to the other biology pupils how difficult it was for Patricia to understand the meaning of many words which they all knew instinctively. One of the other members of the class, Irena, volunteered that, although she had been in Australia for many years, her family all spoke Croatian at home and so she could relate to what Patricia was experiencing. Most of the students were amazed at Irena's disclosure as she spoke without the hint of an accent. Julia encouraged Patricia to call out when she did not understand what was being said. This became a regular occurrence in the class and was well tolerated by the other students. In fact, the students all became involved and they would often be the ones to explain the meaning of a term to Patricia. Quite regularly, Patricia was not the only member of the class who did not understand the meaning of a particular word.

The student and academic competence

As well as the language problems which have already been mentioned, timing in examinations had emerged as a problem for Patricia. She rarely finished written tests in the allotted timeframe and as a consequence often missed out on important

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complex reasoning marks which were at the end of the paper. Julia worked on this problem with her and Patricia spent some of her perusal time at the beginning of every test compiling a plan with which to manage her time more effectively. Patricia had also experienced difficulty understanding abstract concepts. This problem was dealt with in the weekly tutorials. Patricia grew in confidence and by the end of phase three her cognitive/academic language proficiency had improved alongside her basic interpersonal communication skills. A comparison of her results in phases one and three in chemistry and biology are contained in Tables 6.16.and 6.17 respectively.

Table 6.16

Summary of Patricia's academic results in chemistry in phases one and three

Phase	Knowledge	Scientific Process	Complex Reasoning	Overall
1	45%	40%	30%	LA10
3	61%	61%	32%	SA9

Table 6.17

Summary of Patricia's academic results in biology in phases one and three

Phase	Knowledge	Scientific Process	Complex Reasoning	Overall
1	68%	68%	44%	HA3
3	82%	74%	56%	HA8

The progress made in Patricia's academic competence was quite remarkable. Although Julia concentrated on strategies for biology, Patricia's chemistry results underwent the biggest improvement. Towards the end of phase three the improvement in her academic language skills seemed to suddenly make a difference to her overall performance. She was able to comprehend scientific text and to interpret examination questions more clearly and accurately. During this time, her results in maths B also jumped from a HA3 to a HA6. Because the school was relatively new and quite small, Patricia had been studying German by distance education without any active supervision by a member of staff. Her performance in her study of German improved around the same time as her other subjects and she

achieved the best results possible, a VHA10. For this effort Patricia received a prize from the University of Queensland for her German language skills.

Although Patricia was a hard working and conscientious student, it is doubtful that she would have progressed so well without the interest and enthusiasm of her teacher, Julia and without Cheryl's assistance. The teachers' encouragement and advice served to take a shy, sensitive student and give her the confidence and skills which ultimately resulted in significant improvements in both her academic language proficiency and her academic proficiency. Patricia achieved her goal of studying science at university in the following year.

Yan's story continued

Yan was a 16-year-old student who came from Shanghi. She had spent six months at the international school before coming to the same school as Patricia and Simon. She was a mature student who also hoped to study medicine when she finished school. As well as compulsory English, she had chosen to study two mathematics subjects, chemistry, physics and biology.

Language

During the year of the observations, Yan worked extremely conscientiously at improving her communicative competence. She lived with an Australian family. At school, while the other international students often spoke Chinese, Yan always used English. She completed all extra worksheets carefully and always asked if she did not understand a term. She studied very hard indeed and by the end of phase three her ISLPR levels had improved considerably as outlined in Table 6.18. She was still a little hard to understand orally, but her written skills were better than some of the native speakers in the class.

Her understanding of assessment items and scientific text indicated that Yan's academic language proficiency had improved also. Her increased comprehension meant that she no longer needed to record the new terms or words that she did not

Table 6.18

Yan's ISLPR Levels at the end of phases one and three

Phase	Speaking	Listening	Reading	Writing
1	3	3	3	3
3	3+	4	4	4

understand. Although the strategies designed to improve Yan's communicative competence may have assisted her, because of her determination and single-mindedness, it is likely that she would have progressed regardless of these. What did make a difference, according to Yan, were exercises which addressed specific language skills needed in particular biology units. Exercises such as those found in the *Disease* unit (Appendix J) which reinforced vocabulary, addressed the proper prefix to use to construct opposites, helped with derivation of the different forms of the words and differentiated between singular and plural forms were all very helpful. These kinds of skills would not have been taught to Yan if they had not been addressed alongside her biological content.

The teaching and learning environment

Generally, Yan was much happier at school. Although she had to be encouraged to socialise at break time instead of studying in the library, she had made more friends. The biology class liked her and respected the extraordinary effort that she made with her study. The class in general was very academically able and competitive and so she fitted in quite well. There was never any question of her not being included during group work and she was so efficient that she was an asset to any group that she joined. Yan conscientiously attended tutorials but did not limit herself to once per week. She often tried to disturb a teacher's lunchtime for extra explanations and was also very good at emailing questions and drafts.

Yan was so focussed on study and making the most of the opportunity her parents had given her, that she found it difficult to enjoy herself. She attended a two day field trip to the very picturesque North Stradbroke Island with her biology class. All of the students worked well and had a lot of fun. On the ferry trip home Yan was asked if she had liked the camp. She replied:

Mrs Morris, in China my teacher would ask if I had studied hard, not if I had had a good time.

During phase three it became obvious that something was troubling Yan, but she was loath to talk about her problem. The ESL teacher, Cheryl broached the subject and Yan tearfully told her that she had become very unhappy in her homestay situation. Yan said that she had limited internet access, not enough to eat, and that the food she received was sometimes stale. It was typical of Yan to mention the problem of the internet access first. With Cheryl's encouragement, Yan requested an appointment with homestay supervisor whose office was at the international school and was not easy to access. Furthermore she was required to pay for any time spent with this supervisor. Yan's perception was that the supervisor tended to represent the homestay parents' interest rather than that of the students. There was probably some truth in this as homestay families were not easy to find. With the support of her teachers, her problems were backed up and a new homestay situation was found. After this experience, the teachers who taught Yan petitioned the administration to provide an international student co-coordinator who was situated on the campus and so more accessible. Such a person was appointed the following year.

On the Year 11 leadership camp at the end of the year, Yan impressed the staff and her classmates with her leadership skills and was nominated as the School Vice-Captain. The nomination in itself was very pleasing and demonstrated how far she had come with respect to integrating into the school and her class. However, it was decided that because she found public speaking difficult, she would be given a lesser role of House Captain instead. Yan returned happily to China for her long summer holidays.

The student and academic competence

During phase three Yan was provided with: typed copies of notes; copies of overhead transparencies so she could listen rather than write; examples of model answers; post-mortems after every test and examination; extra practice questions; materials in advance of a class so she could read before the class and prepare questions; and feedback on drafts of written work. Her academic results were very good and are

outlined in Tables 6.19, 6.20 and 6.21. Her chemistry results stayed the same over the year and her physics results went down one rung. In biology she improved but was still disappointed that she was not achieving a VHA.

Table 6.19

Summary of Yan's academic results chemistry in phases one and three

Phase	Knowledge	Scientific Process	Complex Reasoning	Overall
1	84%	82%	65%	VHA2
3	86%	80%	64%	VHA2

Table 6.20

Summary of Yan's academic results physics in phases one and three

Phase	Knowledge	Scientific Process	Complex Reasoning	Overall
1	86%	85%	72%	VHA 4
3	86%	82%	68%	VHA 3

Table 6.21

Summary of Yan's academic results biology in phases one and three

Phase	Knowledge	Scientific Process	Complex Reasoning	Overall
1	77%	75%	52%	HA7
3	82%	79%	58%	HA9

Although Yan's knowledge and ability to interpret data were of a very high standard, she continued to have difficulty evaluating biological issues. Lee (2003) explains that Western science promotes a critical and questioning stance which requires the student to criticise other's viewpoints and be sceptical of information. This independent way of thinking can be discontinuous with the norms of cultures that favour co-operation, social and emotional support, and acceptance of the authority of teachers and elders. The following question which appeared on one of her tests, illustrates the difficulties Yan experienced. The question read:

Question 1 Gerald Joyce of the Scripps Research Institute in La Jolla, California describes life as *a self-sustaining chemical system capable of evolving through Darwinian natural selection.*

     a)   Explain what this definition means.

     b)   What is your opinion of this definition?

Although Yan gave one of the better answers in the class to part a, she found it extremely difficult to constructively criticise the definition. As this ability to evaluate biological information and issues is an important part of the new biology syllabus, unless Yan improves her aptitude in this area she will be unable to achieve her much desired VHA. Because she is such a determined student, this will be the area on which she concentrates in her final year of schooling.

Julia's story continued

Julia was a committed, conscientious and caring teacher who like many teachers in Queensland, was encountering more ESL students in science classes every year and was concerned that she was not addressing their needs adequately. She was keen to discover what strategies she could use to improve these students' learning in science. In the first part of the study, the school that she taught at had inconsistent and unsatisfactory ESL support and so Julia had come to realise that in addition to facilitating learning in science, the responsibility of improving the student's English language skills fell to her and the other mainstream teachers.

Language

Although Julia had a well developed philosophy on addressing the language of science in her teaching, she had not paid particular attention to any other language objectives. She felt she had a lot to learn as, unlike her colleagues with language backgrounds, she had never even considered the fact that the four macroskills of writing, reading, speaking and listening should be an essential part of every lesson. Observations revealed that in most of her junior science and biology lessons she unconsciously included practice in these four areas. In fact, all of the biology classes

that were observed as part of this study routinely provided more opportunities for all four skills than did chemistry and physics classes.

Julia gained a better understanding of the theory behind second language acquisition by reading the literature on communicative competence (Canale & Swain, 1980) and the ideas put forward by Chomsky (1965; 1972), Cummins (1983, 1994, 1996)), Kaplan (1966) and Krashen (1985; 1997). In addition, she found the TESOL standards (1997) and the ESL bandscales (McKay, 1994) helpful resources which could be used to guide the planning of science units for her ESL students.

Julia required assistance with specific ways with which to integrate literacy and science. Contrary to what had occurred in the past, she began to consciously gather as much information about her ESL students as she could. Determining their ISLPR levels was a useful starting point. She realised, because of past experience, that adjustments would be necessary to her science units if she was to address the issue of communicative competence properly and for the students to experience some success. She noted the specific difficulties that the students were having with their writing and designed activities which would address these. The development of special materials was a practical method of integrating science and language objectives, giving the students some autonomy and providing a structure with which to offer individual assistance. She collaborated with the author to develop several worksheets and units and provided constructive feedback on their effectiveness. She included in her teaching, exercises which encouraged the use of glossaries, but did not have time to prepare personalised glossaries like those constructed by the author for Aya and Patricia.

The teaching and learning environment

Like Pam, Julia expected her ESL students to contribute as fully as possible in class activities and discussions. She modelled the behaviour she expected and the students were largely accepted by the class and included in group work. In most lessons, Julia consciously checked the understanding of individual students. She routinely made time for individual sessions with the ESL students and any other students who required extra assistance. Weekly tutorials were used to answer questions, review

difficult concepts, work through supplementary worksheets or just listen to any difficulties which the students were experiencing. The students related well to Julia and used the sessions productively. She set dates for reviewing drafts and was happy to receive questions in email form from any of her students. Along with Pam and Phil, teachers like Julia demonstrated the importance of respecting individual identities. Her beliefs in the students were found to have a profound influence on their overall success. It appears that in classrooms where participation and interaction of ESL students is actively encouraged, acculturation is positively assisted.

The student and academic competence

When she first started teaching, Julia assumed that skills like creating tables, graphing, summarising, note making and taking, assignment writing and word processing would be taught in other areas and that her students would arrive at science armed with these abilities at their disposal. She quickly learnt that if she wanted students to perform to her standards, she must address the skills she required in an integrated fashion herself. Consequently, Julia spent a lot of time developing research and study skills, and integrating technology, mathematical skills, and consideration of the ethical issues associated with science into her programs. In other words, Julia did not view science education as the individual topics of the curriculum but as a unified whole. By taking part in this study, Julia hoped to enlarge this view to include integration of strategies which would increase her ESL students' understanding and academic achievement in science. The strategy checklist which was developed in the first stage of the study from review of the ESL literature provided numerous suggestions on ideas of how to achieve this and Julia found this useful, but extensive. When interviewed at the end of the study, she offered the opinion that there were no prescriptive solutions for helping ESL students. Their needs were quite individual and it was important not to stereotype. What she did become committed to, was concentrating a lot more on academic writing skills which she was convinced helped all the students in the class. She expressed the opinion that all university degrees should incorporate a subject on academic writing. Neither her undergraduate or postgraduate study had provided this.

Lenny's story continued

At the beginning of the study Lenny was a 28 year dentist from Columbia who had made Queensland her home four years previously. Her aim was to obtain registration to practise dentistry in Australia. In order to achieve this, Lenny was required by the Australian Dental Council to pass through a three part assessment program. The first section involved demonstrating her understanding and use of English in the workplace. The second examination was one where Lenny would provide written evidence of her general dental knowledge. The final examination tested the candidate's practical clinical skills (Australian Dental Council Guidelines, 1999). Lenny approached the author for assistance with the first and second examinations, eight weeks prior to the first test.

Language

Lenny's ISLPR levels did not progress appreciably during the relatively short observation period. However, the student herself reported that in the four years since she had arrived in Australia, she had improved from very low proficiency to vocational proficiency. She was therefore assessed to have an ISLPR level of four in all of the macro skills.

It is important to understand that in everyday life, Lenny used mainly listening and speaking skills. However, for her examinations, the macroskills of writing and reading were much more important. In order to assist her in her preparation for the first examination, practice was provided in the form of writing and reading referral letters, everyday explanations of dental procedures, listening and replying to telephone conversations, and filling out dental record cards. A useful strategy which aided this practice was the formulation of an error summary at the end of each exercise. This enabled the student and the author to check if Lenny was making the same mistake over and over and to determine the cause, if this was the case. Lenny was delighted when she heard that she had passed her occupational English test and so had overcome her first hurdle to registration as a dentist in Australia.

The teaching and learning environment

Lenny has been successful in acquiring everyday competence in English. The next obstacle was an academic one which required different skills. It was necessary for her to demonstrate knowledge that she had acquired over a period of five years in another language. General dental information involves knowledge of several different disciplines which include: orthodontics; periodontics; operative dentistry; preventative dentistry; prosthodontics; paedodontics; endodontics; and oral pathology. Studying for an examination such as this would be a daunting task for a person who had obtained a degree in an Australian university. There was little assistance available to Lenny. The Dental Council's only suggestion was an extensive booklist in English. This meant that the majority of Lenny's input for her academic learning was coming from textbooks and Brown (2000) points out the importance of feedback when negotiating meaning. The local university provided courses which helped Australian dentists who had been out of the workplace, update their skills, but did not provide help for people in Lenny's position. Lenny asked the dentists she worked with for help as well as the author. The task was overwhelming and the student had no clear plan about how to tackle it. It was difficult to know how best to help her. Past papers were not available. It was decided to spend the little time she had before the test, writing answers to practice questions in each of the above areas of dentistry. The author posed some of the questions and the other dentists in her practice also helped with suggested topics.

The student and academic competence

It became obvious that when answering questions, Lenny was experiencing several difficulties. Firstly, the sheer volume of material was affecting her learning. Adamson (1993) suggests that to complete academic tasks successfully, good study strategies in the areas of reading, dictionary use, note taking, use of research tools, and organization are essential. Lenny's study skills were such that they are not enhancing any basic understanding that she obtained. One of the dentists had given her book on questions and answers on clinical dentistry. Instead of using this to test herself, she intended to read the book from cover to cover. She had bought herself a

book on academic writing and was working through it, but the material it contained was completely unrelated to her topic of dentistry and only served to confuse her.

Lenny's second problem involved the academic language required for her reading which affected her interpretation of examination questions. Cummins (1983) stresses that academic competence differs from everyday competence in that it is cognitively demanding and context reduced. Corson (1997) explains that most of the words in everyday English are of an Anglo-Saxon derivation and are simple, while academic language tends to be of Greek or Latin origin and so is unfamiliar. Lenny explained that scientific terminology is so specific and that there is little opportunity to guess meaning. The following example illuminates some of the difficulties experienced by the student.

A practice clinical question which was used was:

> *What are the implications for using dental amalgam as a restorative material in children?*

It was obvious from her answer that Lenny had no clear understanding of the meaning of the word *implications* and so her answer to the question did not provide the necessary information. Investigations revealed that she had similar problems with terms such as *indications, compare, contrast, advantages and disadvantages,* all of which abound in dental examination questions.

Two weeks before the test Lenny prepared an answer to a question of basic clinical significance:

> *What aids are generally used to assist the dentist with diagnosis?"*

On the whole, although there were ten different grammatical errors and five lexical errors, the meaning of her writing was quite clear. The plan of the essay was quite good and an improvement on her earlier attempts. Of greatest concern however, was the shallow nature of her answer. She had used textbooks when preparing her answer and yet missed several important points. Reflection on her own clinical practice should have suggested a more detailed description than the one she provided. Even when she understood the questions, her superficial treatment of the content material suggested something more than a language problem. It suggested

that the depth of knowledge required of her in Columbia to become a dentist was not the same as what was expected in Australia.

Sadly, Lenny did not pass her examination and her results were such that she decided she would require a lot more assistance if she was to become a registered dentist in Australia. She and her husband moved to Melbourne where there was a full time year long bridging course available for dentists in her position at considerable expense. After the first year, Lenny still did not pass and repeated the course. Her second attempt was finally successful. After all the time that had passed, her practical skills needed updating and she was obliged to return to Columbia where she intends to work for six months in order to regain her practical competence before sitting the final part of the examination process.

Anna's story continued

Anna moved to Australia from Hong Kong in 1988. She is a very dutiful daughter who, in 2003 still lived with and cared for her elderly mother. Cantonese was the language spoken in the home. Anna had obtained undergraduate degrees in pharmacy and dentistry at a Queensland university and had experienced few problems with language in these courses. She modestly revealed during an interview that she had obtained first class honours and won a university medal for her results in her undergraduate dental degree. As with most science based undergraduate courses, most of her assessment had been in the form of examinations, practical activities and oral vivas. She admitted that her technique in previous written assignments had been to copy sections from various sources and tie them together. At the time of this study Anna was at the end of a three year Masters course in Orthodontics. In addition to meeting the majority of the course requirements, she had designed and carried out the compulsory research component for her course, but was experiencing difficulty communicating her findings in her final thesis. Her professor said that he assumed his students had adequate language skills and he did not see it as part of his job to give assistance with written communication. Anna's problems were quite specific. She required support from someone who understood the content of her thesis and also had experience with academic writing. Together, the author and Anna

embarked on a revision of her thesis which involved many hours of oral explanations, negotiation and rewriting.

Cummins (1983) explains that academic language involves cognitively demanding language functions and structures which are necessary to understand, conceptualise, symbolise, discuss, read, and write about topics in academic subjects. According to Rosenthal (1996) scientific writing in English must also be linear and inductive. Like Cummins (1983, 2000), Corson (1997) differentiates between the language needed for every day interactions and that required for academic purposes. He maintains that because academic vocabulary is primarily of Graeco-Latin origin, some learners are not favourably placed to acquire these academic meaning systems. Learners are positioned differently by their linguistic and sociocultural relations and so have different lexico-semantic ranges. To be successful at academic writing, learners need to be aware of the appropriate meaning systems and be able to manipulate the rules for their use.

An initial reading of Anna's thesis revealed several difficulties with her academic writing. The academic language required to communicate her results was extremely exacting in nature because many of the terms were very specialised and specific. For numerous reasons Anna's constructed text did not clearly convey her intended meaning. Even for someone with dental knowledge, it was difficult to understand the finer implications of what was being described. The flow of her ideas needed improvement in order to communicate her findings concisely and bring her writing up to the standard required for publishing her work.

It became obvious when talking to Anna that she was a very capable and intelligent young woman whose oral and written communication was such that she functioned very effectively in the workplace as a general dentist. However, the extent of the difficulty she was experiencing with her academic writing is exemplified by her endeavours to express the aim of her research in appropriate language. Even though she was very clear in her mind about the purpose of her study, she found the language required to express her aim quite elusive. Anna's original aim read:

> *To investigate the suitability of occlusograms in recording the occlusal view of upper and lower study models.*

When she was asked what this meant, she explained that the purpose of the research was to devise an easier, more portable method of comparing the relationships between upper and lower jaws. She had taken 152 sets of three dimensional plaster of Paris models of teeth and made photocopies of them. The photocopied models were termed *occlusograms*. She chose anatomically significant points and marked them on both the models and the photocopies. Measurements between the chosen points were made on both the models and the photocopies. The measurements were then compared for each of the 152 cases and the degree of accuracy between the two sets of data was determined.

Her first effort to communicate her aim did not address the fact that she was assessing the accuracy of the method. Not many dentists would be familiar with the term *occlusograms* and so further explanation was needed. It seemed a small point to Anna, but it was the use of the method rather than the occlusogram which was being investigated. This needed to be made clear, as did the fact that the fundamental difference between the two methods was that one was a three dimensional representation of the mouth and other two dimensional. After explanations and negotiation the aim was altered to:

> *To investigate the accuracy and suitability of the use of two dimensional photocopied occlusograms in recording the occlusal view of upper and lower study models.*

Despite having taken her work to an expert in academic writing, the bulk of the thesis contained many errors. There were still several grammatical mistakes, punctuation errors and incomplete sentences. Construction of paragraphs caused particular problems. Anna did not really understand when to start a new paragraph. She had never heard that each paragraph should contain a theme and a topic sentence. Coherence within paragraphs was also a problem. The following paragraph which was part of her *methodology* section illustrates some of the above problems.

> *Defined points were identified and marked with a sharp soft lead pencil. An occlusal photocopy of each of the one hundred and fifty-two sets of models were obtained. By placing the occlusal contacts of the teeth over the geometric middle section of the platen of the photocopier. Measurements*

were made on the study models and the particular photocopies and the
accuracy of the measurements was calculated.

This was altered collaboratively to:

By means of a sharp, soft lead pencil, previously determined anatomical
points were identified on each of the one hundred and fifty-two sets of teeth
models. An occlusal photocopy of each of the model sets was obtained by
placing the occlusal contacts of the teeth over the geometric middle section of
the platen of the photocopier. Measurements between equivalent points were
made on both the study models and the corresponding photocopies. The
measurements were compared in order to ascertain the degree of accuracy of
the proposed method.

The process of oral explanation, negotiation of meaning and the language needed to express that meaning was continued throughout the whole piece of work. Even by the end of the process, it was evident that Anna had little confidence in her own ability to write appropriate academic English. The rewriting of the thesis involved working meticulously with the researcher to scaffold the whole piece of writing. Coherence was improved by: repetition of key nouns; the use of consistent pronouns which referred back to nouns; and employing transition signals such as *consequently, firstly, secondly, finally, next* and *subsequently*. In order to make the writing more interesting, sentence lengths were varied and it was suggested that Anna use the thesaurus to avoid repetition of the same terms. These techniques had never occurred to Anna, but she was in agreement that they improved the readability of her work. Finally after many hours, Anna felt she could take it back to her professor. Two further revision sessions were necessary but the thesis was finally submitted for publication. Anna is now working as an orthodontist. It is interesting to note that after she finished her study of orthodontics, Anna embarked upon a Master of Business Administration. As part of this course, a unit on academic writing was included. Anna found the structured approach in this subject to be most helpful. It was at this juncture that she felt her academic writing started to improve and that she was able to produce texts herself.

Responses to the research questions

As with chapters 4 and 5, the summary of the findings from chapter 6 will take the form of responses to research questions 3a, 3b and 3c. The interventions and strategies which were introduced into each focal area are summarised in Table 6.22.

Table 6.22

Summary of interventions

Area of focus	Intervention	Individual strategies
Language	Integration of literacy instruction with science education	Objectives, worksheets, glossaries
Teaching and learning environment	Individual assistance	Tutorials, co-operative groups, assignment drafts and email
Student	Modifications to science courses	Content, process, product modifications

Response to research question 3a

What impact do strategies specifically designed to address language development in the science classroom have on ESL students' communicative competence?

Of the three focal areas, assessing the impact of the strategies designed to improve language skills was the most difficult. Because communicative competence encompasses the four separate strands of grammatical competence, discourse competence, sociolinguistic competence and strategic competence, it is quite a complex phenomenon. Consequently many factors affected improvements in outcomes for individual students. It was therefore difficult to attribute their progress to the specific strategies designed to integrate literacy instruction with science education.

There were improvements in the language skills of all the students. The high school students all made steps forward in at least two of their ISLPR levels as seen in Table 6.23.

Table 6.23

Summary of ISLPR levels at the end of phases one and three for the high school students

Student	Speaking Level		Listening Level		Reading Level		Writing Level	
	Phase		Phase		Phase		Phase	
	1	3	1	3	1	3	1	3
Cliff	2	3	2	3	1	2	1	2
Min	2	3	2	3	2	2+	2	2+
Aya	4+	4+	3+	3+	3+	4	3+	4
Claire	3	3	3	3	2+	3	2+	3
Simon	2+	3+	2+	3+	2+	3	2+	3
Patricia	4+	4+	4	4+	4	4+	4	4+
Yan	3	3+	3	4	3	4	3	4

Of the two postgraduate students, Lenny's skills improved enough for her to write effective case notes and referral letters and so pass her occupational English test. Anna's writing skills reached a standard which allowed for her thesis to be published and for her to pass her course.

Language objectives

It is difficult to ascertain the impact that this strategy had on individual students' language skills. If it is accepted that communicative competence needs to be addressed in science lessons, the development of language objectives is an effective way of attempting this. Fatham and Crowther (2006) support this assumption by maintaining that effective lessons for ESL learners must include language objectives which work harmoniously with the science content. To a science teacher with little knowledge of the second language teaching and learning, this task can seem overwhelming. However, there were a few methods employed which made this undertaking more straightforward than it first appeared to be and enhanced its impact.

To assist basic interpersonal communication skills, the inclusion of reading, writing, speaking and listening in each lesson, proved a realistic goal. As already mentioned,

opportunities for the development of the four macroskills were observed to occur more often in biology than in chemistry and physics. In order to assist the development of academic language, more specific objectives needed to be considered. The language involved in a particular unit of work was analysed and specific skills were identified. O'Toole's (1992) suggestions of considering word, sentence and paragraph objectives worked well. The inclusion of objectives which dealt with the characteristics of scientific style in texts, laboratory reports and essays was another way of meeting students' needs.

Analysing the specific language difficulties for individual students also provided ideas for objectives. For example, Simon's problems with prepositions and referral words were common to a number of the students. One of the most surprising findings of the study was the gaps in vocabulary of the students with better language skills and this problem needed to be addressed if their academic language was to improve. Lenny and some of the other students had problems with functions such as comparing, describing, hypothesising and classifying. This area was also identified in the literature (Chamot & O'Malley, 1994) as one that should be explicitly addressed in mainstream lessons.

The strategy checklist (Appendix B) which was compiled from the literature review proved to be an effective method of informing the development of objectives. Founding the learning objectives on research-based evidence was a sound way of ensuring that they would have the desired impact. The list proved particularly useful for compiling objectives which addressed the more difficult concepts of strategic competence and sociolinguistic competence. Suggestions in the literature to assist strategic competence which were utilised included: providing the form for asking questions (Ellis, 1994); using synonyms (Oxford, 1990); overviewing (Oxford, 1990); and providing structured reviews (Oxford, 1990). Sociolinguistic objectives which were included involved finding ways to: value home cultures (Herrell & Jordan, 2004); develop cultural understanding (Oxford, 1990); and develop student awareness of differences (Walqui, 2000).

Worksheets

The students in the study believed that the worksheets provided valuable assistance. As a method of implementing the language objectives, they were also very effective. Furthermore, they provided structure for individual tutorials, were a means of collaboration between the science teacher and the ESL specialist and were tailored to meet specific needs. For the other science teachers involved in the study they saved preparation time and provided ideas with which to cater for these students. However, they worked most effectively when the teachers had some input, felt some ownership and provided feedback on their use.

Practically, the worksheets were designed to: take the place of whole units when the level of language in the text book was too difficult; be slotted into a unit when further explanation or development of language skills was deemed necessary; or to address a specific language objective or identified need. The most successful application was the development of whole units. Initially, when Cliff's and Simon's English language skills did not give them access to the class text, the alternative units allowed them to participate in a meaningful way. However, all of the students appreciated the extra assistance that the materials provided and were conscientious in completing them. Additionally, many of the exercises proved useful to the mainstream native speakers, especially those which provided practice in using a scientific term once it had been introduced.

Glossaries

Saville-Troike (1984) reported that vocabulary knowledge is the most important aspect of oral proficiency for academic achievement. For Patricia, Aya and Anna development of the terms they had at their disposal for use seemed to have plateaued and so they required assistance to improve their vocabularies. For Anna, this was achieved by oral explanation of her meanings and negotiation with a more experienced language user. For Patricia and Aya, the personalised glossaries which are contained in Appendixes D and E were developed.

The students reported that they found these personal glossaries extremely useful. The researcher found them an invaluable tool for understanding the problems encountered by these students in their search for the meanings of words. For example, it soon became apparent that in order for an explanation of a term to be effective, the meaning had first to be explained and then an example of its use provided in a sentence. Because terms can be used in several situations, this was more difficult than it first appeared. Specific examples of the problems associated with the development of these glossaries will be discussed in chapter 7. However, it is important to note that although personalised glossaries proved to be a very effective way of addressing the vocabulary needs of ESL students, the sheer number of terms which are not understood by students with comparatively good language skills makes the construction of such glossaries so time consuming as to be impractical.

Encouraging students to use glossaries and science dictionaries proved to be an effective method of promoting strategic competence. However, this endeavour was hampered by the number of science texts which have no glossaries. The students did not experience success when using normal dictionaries and tended to avoid their use. Finding a science dictionary which was of the appropriate level was difficult. Where a unit was designed which included a glossary, exercises were included to guide student use initially. By the end of these units the students became proficient in the independent use of the glossaries. Cheryl, one of the ESL teachers, expressed the opinion that there was a need to develop a comprehensive glossary of scientific terms for ESL students as she has been unable to find a commercially available one that is suitable.

Response to research question 3b

What impact do strategies specifically designed to improve the science teaching and learning environment have on ESL students' interactional and participative competencies?

The students and teachers in the study agreed that the teaching and learning environments were where the biggest changes and improvements occurred as a result

of the interventions. It became very apparent that the teachers, who had positive attitudes, were hospitable and prepared to provide extra assistance had more success encouraging interaction and participation. At the end of phase three all of the ESL students were much happier and involved in their science classrooms and the teachers felt more confident that they were catering to the students' individual needs.

Tutorials

Matta, Dobb and Ostlund (2006) contend that the affective domain is often overlooked when considering the quality of science teaching for ESL learners. Adamson (1990) says that ESL students must have the opportunity to discuss content material in an environment that is protected from native speakers. It was found that in these protected sessions the ESL students learnt academic skills and reviewed vocabulary and background knowledge more effectively.

In order to maximise learning it was necessary to make positive connections with the learners. Individual or small group tutorials successfully provided opportunities to learn who students were, in terms of their language and cultural background and for teachers to develop a rapport with the students. Furthermore, teachers were able to convey the message that they did have an interest in the students' success. Instructions were able to be repeated or reworded and the embarrassment of asking and answering in whole class situations was reduced. The extra time required to ask, understand and answer questions was appreciated and utilised by the students.

All of the ESL students were conscientious in attending tutorials and were appreciative that the teachers were willing to give up their own time to help them. For Yan, who tried to monopolise the teacher's time during class, the tutorial provided a more appropriate opportunity to have all of her minute inquires attended to without disadvantaging the other students. Because teachers were so busy and had so many calls on their time, the system worked best where the tutorials could be shared between teachers and the researcher. This also had the advantage of the students being exposed to different teaching styles which sometimes enhanced understanding.

For both Anna and Lenny, individual assistance was essential. Because Anna's requirements involved a particular piece of writing, the strategies involved in helping her were of necessity, specific. Anna's academic language was more than adequate to cope with most demands of postgraduate study. With regards to her research, she could easily explain her first hand experience orally, but needed to move to the register of expressing academic knowledge in writing. The improvements that occurred illustrated that there is a difference between what a person can do on their own in a second language and what they can do with the help of a more experienced language user working closely with them. This was also true in Lenny's case. Her experience as a dentist in her own country meant that she knew what the content of a referral letter should be and the requirements for dental case notes. She needed assistance with grammatical and discourse structures in order to express that knowledge in the appropriate way in her second language. Tutorial time with these postgraduate learners was spent working towards these aims.

Co-operative groups

The success experienced by the ESL learners was found to be influenced by both the provision of individual assistance and by establishment of workable cooperative groups. The ESL students benefited most from working in small groups when they were encouraged to participate and their contributions were valued. Group work allowed them to use English in a meaningful way, clarify their understandings with their peers and to develop better relationships with them. However, the findings in phase one revealed that this did not happen automatically. Clegg (1996) found that mainstream classrooms were often inhospitable places for ESL learners and in this study the native speakers did not routinely welcome or include the ESL learners and they were often left alone after working groups had formed. Simon was bullied at one stage and Yan's predisposition for the front seat sometimes set her apart from the other students. Min's anxiety during her silent period made overtures of friendship difficult. In the two schools with the larger numbers of ESL learners, these students tended to congregate together at lunch time, speaking their first language. There was little evidence of any real integration.

Because co-operative learning was an important opportunity to use language and interact with peers, the establishment of workable groups was essential. However, teachers needed to monitor how effectively the relationships were working, and to provide guidance on how to work cooperatively. When arranging ESL students into groups, the needs of the individual students and the demands of the task needed to be taken into consideration. The teachers who had a positive and friendly attitude to ESL students conveyed this to the other students in the class. Pam's approach to a nice group of students to include Min worked well. Mary was always firm with Aya and she made it clear that she was expected to participate as a full group member and contribute to group activities and discussions. The author took advantage of Yan's absence from school one day to talk to the class about the loneliness she was feeling and the importance of working as a group to make all students feel welcome. Once the other students had worked with the ESL learners, they often realised how conscientious and efficient they were. Yan, Min, Aya, Patricia and Claire had always prepared experiments meticulously and so the groups which they joined soon realised their value. It was noted that in some situations ESL students benefited from working together as they could support each other through their first language.

Assignment drafts and email

Emailing proved a very successful strategy, but only for the students with the more advanced English language skills. It appears that students only feel comfortable contacting teachers in writing if their expression is of a certain standard. Once again they have a fear of being thought stupid or being embarrassed. Min, Claire, Cliff and Simon did not feel able to take advantage of this strategy. Even Patricia, with her very good English did not send questions or drafts by email until towards the end of phase three. When asked about this, she confessed that her shyness played a role in her reluctance to utilise this type of assistance and furthermore she did not really know the form an email to a teacher should take. Once the greeting and the type of language needed to ask for help had been explained to her, she felt happier about emailing. One student ended an email with the salutation, *Love*. It had to be pointed out that while emailing did not have to contain formal language, this was not an appropriate way to end correspondence to a teacher.

Yan and Aya embraced the idea of emailing enthusiastically. It provided them with time to formulate the language for questions which might not be available in a busy classroom and helped to build up the rapport with teachers. As a form of communication, it forced them to express their queries concisely in writing and so clarified their thinking. As well as requesting help with their science and clarifying requirements for assessments tasks, they also mentioned sociocultural problems they were experiencing. Yan even emailed on holidays from China with photographs of her city and parents. The students often asked if particular aspects of the grammar in their emails were correct.

The majority of assessment which was analysed was in a written form. Even when the assessment was a practical test or exercise the results had to be communicated in written form. Mastering academic writing was a priority for all of the students. When they were given a choice of activities in ESL classes, help with written assignments was what they always requested. Carrasquillo and Rodriguez (2002) stress the importance of revising drafts for ESL learners. Rosenthal (1996) recommends submission of an outline, first draft and final product if help for ESL learners is to be effective. For most students this level of assistance would be a considerable organizational challenge. As Rollnick (2000) acknowledges; repeated drafting and consulting is time consuming for instructors, nevertheless she emphasises its importance.

As a method of reviewing drafts, emailing proved invaluable to many students and their teachers. It enabled the teachers to allocate the time they could spare to reviewing work instead of trying to fit it into busy classroom schedules. Mostly, the students were organised enough to hand in drafts in time for help to be effective. On one occasion when Aya had several assignments and examinations in the same week, she emailed a piece of work late on the night before it was due. This was an ineffective strategy as there was no time to discuss the ideas. Reviewing drafts worked best when negotiation between the teacher and the student took place.

What impact do strategies specifically designed to assist ESL students'
understanding of science have on academic competence?

At the end of phase one the following were identified as the most pressing problems
affecting the students' understanding of science: developing BICS and CALP;
limited opportunity to clarify understanding; ineffective study skills; having to read,
write and listen simultaneously; and assessment instruments infused with specific
linguistic or cultural knowledge. According to Maatta, Dobb and Ostlund (2006) the
key to working with ESL students is to adapt presentations, activities and materials
so that they can participate fully in the science classroom. Based on the suggestions
of Furtado and Tavares (1996) content, process and product adaptations were made
in order to assist the development of academic competence. Many different
modifications were trialled in order to address the problems above.

All of the students made improvements to their achievement levels, some quite
dramatic. Changes in academic competence for the students in Years 11 and 12 are
summarised in Table 6.24. Cliff's proficiency improved from phase one to phase
three enough to allow him to attempt assessment. Simon's results improved from a
limited achievement to sound achievement.

Table 6.24

Summary of academic achievement at the end of phases one and three for the
students in Years 11 and 12

Student	Chemistry		Physics		Biology	
	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
Min	SA3	SA5	LA4	LA4	LA8	SA5
Aya	SA9	SA10	SA6	SA7	SA10	HA2
Claire	LA10	SA2	-	-	LA10	SA1
Patricia	LA10	SA9	-	-	HA3	HA8
Yan	VH2	VH2	VH4	VH3	HA7	HA9

As with the language focus, numerous factors were involved in the above improvements in academic competence. Better academic language must be directly influenced by the improvements already noted in communicative competence. However, it is unlikely the achievement gains outlined above would have been realised without the introduction of the specific strategies designed to address academic competence. The success of individual and small group tutorials has already been related. The other strategies which proved most successful were: providing more visual support; modifying the presentation of material; supplying copies of class notes and overhead transparencies; rewording text using more appropriate vocabulary; simplifying content while allowing key points to remain; using various methods of review including supplying outlines which highlighted key points; allowing more time for learners to understand the language and concepts; identifying and teaching specific vocabulary; organising materials into small, easily attainable steps; teaching study skills; supplying model written answers to practice questions; and checking answers to study guides.

Many of the above strategies were integrated into special units and worksheets. The use of these materials proved to be successful for a number of reasons. For learners with low English proficiency they provided a purpose to their science lessons and permitted engagement with important scientific content. For Simon and Cliff the materials were necessary to allow them to access scientific information at all. The materials provided practice in the use of scientific terms and ideas and exposed the students to various types of questions. The lesson sequences were based on ideas from the literature and so often the progression through a unit was easier for the students to follow than that suggested in the textbook.

Because assessment tasks directly influenced academic competence, it was important to ensure that the students understood the background information required for a task. For example, if Australian examples were given in biology it was necessary to check that the ESL learners were familiar with the context. Many assessment tasks needed to be broken down into small steps and it was essential to be explicit about the requirements of assignments and to check the learners' understanding. It also proved useful to model the way the task was to be presented. During examinations, even though students were encouraged to ask if they did not understand non-

scientific terms, they rarely did this. In some instances they were permitted extra time. In many cases, meaning rather than expression was assessed.

Summary

The impetus for this study was to find ways of helping ESL students develop a better understanding of scientific concepts. Along the way it became apparent that science teachers were also responsible for helping to develop language skills. Observations revealed that many ESL learners were experiencing difficulties participating and interacting appropriately within science classrooms and for numerous reasons this was also affecting their academic performance. Many strategies were trialed to address these needs.

The interpretive framework used to assess the impact of the strategies, examined improvements in the three focal areas of language, the teaching and learning environment and the student's academic performance. Improvements were noted in all three areas for every student. Teachers also reported that they felt more confident that they were addressing the needs of the ESL learners in their classes. The interventions which had the greatest impact proved to be those that met several needs at once. These included: providing individual assistance in the form of tutorials; forming workable cooperative groups for students in the classroom; and developing special materials which addressed both literacy and science objectives.

Despite the effort to view the changes that occurred during the study from three different perspectives, the cumulative effect of the interventions cannot be ignored. Obviously there is overlap. Improvements in communicative competence affected understanding and achievement in science. Increased confidence in language ability or opportunities to ask questions in a non-threatening environment also affected academic competence. Group work with native speakers provided a meaningful use of English which helped to improve communicative competence and actively encouraged acculturation and so on.

CHAPTER 7   DISCUSSION OF FINDINGS

This chapter, which is divided into four main sections, is devoted to discussing the design and findings of the study, and the factors which influenced the findings. The first section examines the goals, the appropriateness of the research questions and the adequacy of the methodology, including the interpretive framework. The next section discusses: the factors which affected the impact of the interventions in each of the three focal areas of the language, the teaching and learning environment and the ESL students; and the advantages and disadvantages of the individual strategies. The third section discusses the outcomes of the study and the final section outlines where the findings of this study support evidence from previous studies and make some suggestions for further research.

The design of the study

Goals

The first purpose of this thesis was to report upon the current situation of ESL science learners and their teachers in Queensland educational institutions. The complex nature of interaction between learners and their peers, and learners and their teachers meant that there was a need to interpret happenings from different perspectives and so the three foci of the language, the teaching and learning environment, and the ESL student were chosen.

Because a study of only nine students was undertaken, it was difficult to generalise about their circumstances. However, it took considerable time to build a rapport with the students and teachers and to analyse the events in busy classrooms and so this relatively small number proved both practical and manageable. Furthermore, describing the participants' experiences was a complicated process which involved ascertaining their goals, endeavouring to understand the behaviours they exhibited and interpreting their associated beliefs. Because the situation surrounding each student was so unique, it seemed more appropriate to undertake cases studies than to try to make generalizations about student experiences. This proved to be an effective

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means of describing the current situation of ESL learners and their teachers and so the primary goal of the thesis was achieved.

It is possible that the fact that all the students in the study were attending private schools might have some influence on the effect of the interventions. It must be acknowledged that the students from these schools are more likely to have had education in their home countries which was of a high standard when compared to those attending government schools. However, it would be incorrect to assume that teachers in government schools would be less willing to introduce the interventions. Additionally, had the students been attending government schools in Queensland, specialist ESL support would have automatically been provided. In Queensland, the ESL Program in government schools operates according to quite strict Commonwealth Guidelines for Schools, under an agreement between Education Queensland and the Department of Education, Science and Training (Department of Education, Training and the Arts, 2006). There are no such guidelines governing what happens in private schools.

The second purpose of the study was to bring about change by the introduction of classroom strategies. In Chapter 3, Stringer (1996) was cited as describing the processes involved in action research as reflective and interpretive and engaging those who are interested as active participants in the research process. It also should result in a practical outcome for the participants. Using these ideas as a guide, modified action research proved to be a useful research design for working towards the goal of classroom change.

The educational research which was applicable to this study came from three major areas and these formed the theoretical framework of the study. Review of the theories on language and language acquisition, content-based language learning in mainstream classrooms and ESL learners of science yielded huge numbers of strategies which could be used to bring about the desired changes in classrooms. In order to make sense of these, a classification scheme based on the three foci of the language, the teaching and learning environment and the student was developed in the form of a checklist (Appendix B). From this extensive list, general interventions which were applicable to each of the three areas were chosen by analysing the needs

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of the students and teachers. The data collected indicated that changes did occur as a result of these interventions and so the second goal of the study was achieved.

Research Questions

The general goals of investigating the current situation and bringing about change, needed to be translated into more specific research questions. Because the study was conducted in three phases, it was decided to develop research questions for each of the three foci within each phase, making nine research questions in all. This meant that although the resulting questions sounded a little repetitive, they genuinely reflected the significant factors to be investigated. The research questions also served several other purposes. They aided the organization of the study and gave it direction and coherence. They delineated the project by making its boundaries clear and in so doing, kept it focused. They helped to identify the type of data to be collected, what was observed in the field and what questions to ask at interview. Finally, they contributed to the framework which was used to write up the study (Merriam, 1998; Punch, 1998).

Data sources and the interpretive framework

In order to analyse the students' language, data had to include samples of speaking, listening, reading and writing. This was attended to by the use of observation, interviews and by the collection of samples of student work. Data on experiences of teachers and students and instructional practices in the learning environment were obtained using observation, the strategy checklist and interviews. The ESL students' wider experiences and history were compiled as case studies. The students' academic progress was followed by interview, observation and examination of their work.

In order to give the collection of data a more specific focus, the interpretive framework was developed. It served many purposes. It proved to be a valuable means of triangulation and a useful guide for choosing relevant strategies. It helped to create a holistic picture of what was happening in the classrooms. Most importantly, the framework was a method of analysing the data by comparing the

situation before the interventions with that afterwards. In this capacity it provided a means of assessing the effectiveness of the associated strategies.

Changes in communicative competence were assessed using the International Second Language Proficiency Ratings (ISLPR). These were easy and effective to apply for teachers with limited second language teaching experience. Because normal classroom activities and written work could be used, student rating levels were ascertained without the stress of extra assessment. However, this method had limitations. Communicative competence consists of the four strands: grammatical competence; discourse competence; sociolinguistic competence; and strategic competence. These were described in detail in Chapter 1 and are defined in the glossary in Appendix A. Although the introduced strategies addressed all four areas, the ISLPR which concentrate on the four macroskills of speaking, listening, reading and writing can only be said to assess the grammatical and discourse competencies directly. This was thought to be a reasonable compromise as the nature of sociolinguistic competence is such it is almost impossible to assess improvement in this area using a rating. Strategic competence was improved by the use of glossaries and dictionaries. Improvements in this area were indirectly reflected in the ISLPR and also in any progress made in academic competence.

While the use of the ISLPR proved to be the most effective way of assessing improvements in language, the ratings did not give a direct indication of changes in academic language proficiency. For some of the students this was the most pressing need. Once again, this was indirectly evaluated in any improvements in academic achievement.

The use of the students' regular assessment procedures and associated achievement levels in science also provided an accurate picture of academic achievement without subjecting the students to extra examinations. Classroom observations and interviews with staff and students conducted over a period of 12 months provided accurate data on the way students were interacting and participating.

As well as those already mentioned, there were several other limitations of the interpretive framework. Improvements in communicative competence were related

to many factors and not just the result of the interventions. For example, in general students who lived in homestay situations progressed faster than the others whose parents spoke other languages at home. For all of the students, general social interaction at school assisted communicative competence. It would have been surprising if Cliff had not progressed along the interlanguage continuum on being immersed in English at school even though he used Chinese at home. Many of the students reported that they learnt a lot about English language and western culture by watching television. So although it is hoped that the interventions did assist communicative competence they were certainly not the only influence on the students' English language development.

The other major drawback of the interpretive framework was related to the innate interconnections of the three areas of focus. It was impossible to separate the improvements in all three areas or to allocate success to separate interventions. The three areas of the language, the learning environment and the student were all interdependent. Improvements in communicative competence made it easier to interact and participate. Interaction and participation in science activities led to better achievement in science. Better spoken language enabled students to interact and ask for clarification. Improved reading skills meant better comprehension of assessment items. Developing written communication made answers to examination questions clearer and so contributed to improvements in academic competence.

Trustworthiness and ethical issues

Where a single researcher is involved in a study, there is always a danger that the data might not be distinguishable from the researcher's interpretation. To insure against this, the techniques of triangulation, prolonged engagement, persistent engagement, provision of thick description, member checks and peer debriefing were built into the methodology. The subject matter and the methods of investigation were closely scrutinised. It was intended that all of these measures contributed to the results being reported truthfully and objectively.

Research impacts on the people involved and it is the responsibility of the researcher to ensure the participants suffer no harm because of it (Burns, 1997). A concern at

the onset of the study was that students would feel singled out or embarrassed by the extra attention they received, particularly during class time. This proved to be unfounded. Once a rapport was established, the researcher's presence was well accepted in the classrooms and any help was welcomed by the students. The regularity of the observation sessions meant that the other students in the class accepted the researcher's presence and often asked for assistance as well. Some of the teachers admitted to feeling a little intimidated by having an observer in their classrooms initially. But like the students, they soon realised that researcher's aim was to observe and help rather than offer any criticism. By making sure that the aims of the research remained clear throughout the study, a good working relationship was established with all the participating teachers. The use of pseudonyms protected the identity of the participants.

The factors affecting the impact of the interventions

The strategies suggested in the literature were numerous and varied from broad sweeping policy statements to very specific classroom techniques. Because of this, it was decided to concentrate on broad interventions rather than the assessment of the specific strategies which was initially considered. Details of the interventions and associated strategies are contained in Table 5.1.

The language

Whether science teachers are aware of it or not, mainstream classrooms are where important development of English language skills is taking place for their ESL learners. In the three schools in this study, ESL specialist instruction was inconsistent and in most cases lacked organization and direction. Another factor which became evident during the study was that teachers needed to be more aware of the differences between everyday English and academic English. Because many of the students had very good speaking skills it was often assumed that they their academic language skills were at a higher level than was actually the case. What became evident was that on a daily basis, ESL learners encountered many new terms whose meaning were novel, unusual and changeable across contexts and systems.

Not only did they come across them, but they were expected to master the rules of use for them. Obviously the students needed opportunities to practice the new language. In order to provide them with the help they needed, it was necessary for teachers to shift their view of language from an instrument of teaching for teachers to an instrument of learning for pupils. It was decided that to address communicative competence in science adequately, there should be an attempt at integration of language and literacy instruction with science education. The creation of language objectives was the first way this was attempted.

Language objectives

Although ideas for objectives were obtained from the literature, by assessing the students' individual needs and by dissecting the specific language requirements of particular units of work, it was felt that this approach was a little haphazard. To be truly effective there is a need to develop a comprehensive science course where language skills are introduced in context. Skills could be built on from unit to unit and year to year. If such a course was guided by ideas set out in documents such as the TESOL standards (1997) or ESL bandscales (McKay, 1994), it could have a proper structure and be in keeping with the ideals of communicative language learning.

Another limitation of this intervention was that many of the science teachers felt they did not have the expertise to teach language skills effectively. In most cases they were overwhelmed by the idea that they were partly responsible for developing the students' language skills. The teachers in the study were mostly unaware of how English was taught in schools as a first language and many admitted they had never considered that the skills of speaking, listening, reading and writing should be included in each science lesson if language skills were to be attended to properly. Although they manipulated language effectively themselves, they often did not remember the grammatical rules that governed their unconscious use of English. They knew when something was incorrect but were not sure how to explain this. The best outcome for the students occurred when Cheryl, the ESL teacher cooperated with the science teachers and used the science materials to guide ESL sessions. An even better approach would be an integrated one where teachers of all mainstream

subjects and ESL specialists collaborated to determine what the student language needs were and designed language objectives to address these across the curriculum.

Despite the obvious problems, paying attention to the language needs of students was considered to be a good start. The objectives which directly focussed on the students' specific needs certainly did have an impact. Science teachers felt more comfortable discussing the language of specific science units and scientific language. Perhaps to concentrate on academic language is a more realistic short term goal than trying to address everyday competence in science. The language objectives were translated into exercises in the worksheets and units of work which were developed.

Worksheets

The worksheets, exercises and units served several general purposes. As well as a means of integrating science and language, they made interaction between teacher and student easier and were a method of modifying science courses to allow ESL students access to scientific concepts. Language-wise, they addressed student needs and provided opportunities for practice with new language. They also allowed and encouraged students to communicate their understanding in a variety of formats, for example in writing, orally, drawing, and creating tables and graphs. It became apparent that it was necessary to provide students with examples of model answers and detailed written feedback as well as correcting their efforts orally.

Generally the units of work were more successful than isolated worksheets. This was because the ideal order for presenting concepts could be determined and a proper balance in the type of activities could be reached. Concepts were presented in clear, concise language and then the students were given a chance to reinforce what had been presented and to practise the associated language. Where the students had lower language proficiency, simplifying the language which they needed to produce, gave them the confidence to tackle the content. True and false and multiple choices questions and circling the correct answers were all successful means of checking for understanding when written skills were very underdeveloped. The advantages and disadvantages of these materials are discussed in more detail in later sections.

Glossaries

Many of the textbooks used by students did not contain glossaries. Even where they did, exercises had to be built into units to encourage the students to use them. A science dictionary at an appropriate level could not be found and so glossaries of scientific words were constructed for each of the extra units.

One of the most revealing pieces of data collected in this study was just how much students with near native speaker proficiency in English do not understand in their everyday interactions. When the word lists compiled by Aya and Patricia were shown to their teachers they were greeted with disbelief. The fact that Yan did not understand 158 words in a single chapter of her biology book came as a huge surprise to her teacher. Aya perceived that her difficulties with comprehension stemmed from problems with colloquialisms or idioms. However, examination of her word list supported Gardner's (1975) ideas. He maintained that science students do not only encounter problems with technical scientific jargon, but also with non-technical terms. These include certain words in ordinary English, which are crucial to the understanding of science. This fact was bought home to the researcher on one occasion when talking about this very problem with Aya. The discussion had been underway for some time when Aya asked the meaning of the word *jargon*.

According to the students, the personalised glossaries which were constructed for Aya and Patricia (Appendixes D and E) were very helpful. Unfortunately, they proved to be too time consuming to be a practical, long term solution to their vocabulary problems. However, creating the glossary provided an invaluable insight into the problems faced by these students when trying to understand the meaning of terms. Normal dictionary definitions with their emphasis on covering all the possible connotations of a word are usually too complex to be of use to an ESL student. For example, one of the words on Patricia's list was *prejudice*. If a dictionary is used, the explanation of the meaning is as follows: *any preconceived opinion or feeling, favourable or unfavourable.* Of course Patricia did not understand the meaning of *preconceived* and so this definition was of no use to her. Looking up the second term was very time consuming and caused her to forget what she was originally looking

for. It seemed that when a concept was unfamiliar, the student's semantic confusion was rarely resolved by dictionary definitions.

When the glossaries were started for Aya and Patricia, it was decided that the use of synonyms might be more effective. For example, for *prejudice* the thesaurus suggested *chauvinism, narrow-mindedness, discrimination, bigotry, intolerance, injustice or unfairness*. Because it was thought likely that some of these would not be understood or might cause further confusion, the terms *discrimination, intolerance and injustice* were chosen. The provision of alternatives was necessary in order to increase the likelihood that at least one might be familiar or understood. Additionally, because the word list did not supply the original context, different possibilities were supplied in the hope that one would make sense to the learner.

The first glossary was constructed for Aya and she returned it with questions written all over it. Her feedback was as enlightening as the original list itself. Often the synonyms provided were not understood. For example, *conniving* had been explained using *scheming, devious* and *shrewd*. None of these terms meant anything to her. What should have been obvious from the beginning and soon became very clear was that a context needed to be supplied in order to assist comprehension. Learner's dictionaries were useful for this, as, every term was explained and then used in a sentence. Even then, the context given often did not have meaning to school students. The learner's dictionary provided a context for *prejudice* as: *There was deep-rooted racial prejudice in the community*. Patricia did not understand what this meant. Both students preferred the context to be directly related to their personal experiences. For example, when *opts* was explained as *chooses* or *decides,* Aya had written, *Aya opts to eat cheesecake?*

Another difficulty with the glossaries was caused by the fact that so many words have several meanings and unless the original context is known the explanation given can cause further confusion. Sitting with the students after they had read the glossary was often the only way to discover what the original context of the word had been. For example, one of Patricia's words was *capacity*. In this case *capacity* was being used in an ecological sense and so was explained as *an ability*. The sentence supplied in the glossary was: *The area of land had the capacity to support*

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10 head of cattle. If the context had been unknown, a completely different explanation might have been supplied. Often if the discussion of the context took place more than a week after the word list had been compiled, the students could not remember the original context. When it came to explaining the meanings of idioms and colloquialisms it soon became evident that even though a native speaker might have an innate knowledge of their meanings, it is seldom easy to put the explanation into words.

When reading the word lists it was often difficult to understand how the students managed as well as they did. There were several words on Aya's list which she must have encountered numerous times in her education. Yet because she did not get to practise them and they were not being reinforced at home she did not recognise them when she encountered them in a new context. Throughout the process of constructing and reconstructing the glossaries, the students had to be continually reassured that they were not stupid for not understanding the terms. The problem lay with the language and not within them.

The teaching and learning environment

Carrasquillo and Rodriquez (2002) suggest four guiding principles for mainstream classrooms. They maintain that mainstreaming should provide: opportunities for all teachers to consider the language demands of all the students in the classroom; opportunities for English language learners to interact socially with English proficient peers; opportunities for groups to function effectively once successful instructional strategies are employed; and a full range of educational opportunities to all students, eliminating social and racial barriers.

The strategies employed by the teachers in this study contributed significantly to the provision of the opportunities described above. The teachers were convinced that the teaching and learning environment was the area where the interventions made the greatest difference. Providing individual assistance produced noticeable improvement in participation and interaction. The students felt that the tutorials, assistance with assignments and the special materials produced for them were the most important interventions.

Tutorials

There were several advantages to lunchtime tutorials. They provided opportunities to discuss content material in an environment that was protected from native speakers. Teachers were able to find out who the students were, in terms of their language and cultural background and to develop a rapport with them. Spending time with their students enabled the teachers to demonstrate that they were interested in their success. The extra time provided the students with time to clarify ideas, understand concepts and answer questions. The disadvantages were few. Busy teachers had to give their free time to accommodate the students and so the tutorials worked best when the load could be spread between a few. Some of the other high achieving students in the class saw it was unfair that the ESL students were having extra tuition.

Co-operative groups

Schumann (1986) proposes that the learner will acquire the second language only to the degree that he or she acculturates. The implications of this model for the science classroom are that in order for language to improve there is a need for the learner to participate and interact in class activities and discussions. Collaborative activities are essential if the ESL student is to have the opportunity to use language in ways that are meaningful, purposeful and fun.

Socially, teenagers do not like to feel different and in phase one of the study the ESL students were often not included when groups were formed for practical work or discussions. In order to form workable cooperative groups, the needs of all the students in the class and the demands of the tasks needed to be taken into consideration. Work had to be done by the teachers to ensure that groups worked effectively. This effort was extremely worthwhile and over the period of the study, it was rewarding to see the difference in the way the students were accepted into the class. Many of the native speakers came to a very good understanding of the difficulties the ESL students faced and as a consequence, became quite helpful.

Assignment drafts and email

All of the students wanted help with assignments. When they were given a choice of activities in ESL classes, help with written assignments was what they always requested. It was important to ensure that they understood what the assessment piece was asking before they started. Yan spent hours determining what the requirements of assignments were before beginning work. She would often visit her teacher three or four times to make sure she was on the right track. Emailing proved a very successful strategy, but only for the students with the more advanced English language skills. As well as requesting help with their science and clarifying requirements for assessments tasks, this form of individual assistance provided the opportunity to mention any sociocultural problems they were experiencing.

Helping with drafts was also time-consuming for teachers. Another problem was determining how much assistance to provide. While the drafts presented an opportunity to give individual feedback on grammatical errors, it was how the concepts were addressed that was more important in assessing scientific understanding. Often compromises had to be reached. Correcting all errors could be soul destroying for the student and usually only those grammatical errors which clouded the meaning or were extremely repetitive were addressed. Big gaps in concept development were pointed out. To do more would have disadvantaged many of the native speakers whose writing skills also required improvement.

Attributes of successful teachers

The teachers in this study made a large contribution to the improvements enjoyed by the students and so it seems fitting to end this section with a description of the attributes of successful teachers. Successful teachers of ESL students: were positive and hospitable; created a positive environment for cultural diversity; planned for success; modelled appropriate attitudes and behaviour to students; believed the student could achieve; appropriately selected and sequenced learning activities; paid attention to the language needs of their students; selected and implemented teaching and assessment practices appropriate for the learners; were sensitive to students' culture; were informed by social and educational trends; identified issues or concerns

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and worked collaboratively to address them; paid attention to grouping; encouraged participation and ensured that ESL students contributions were valued; celebrated gains; made it obvious that they were willing to help; provided extra assistance and gave up their own time willingly.

The students

Instruction in science calls upon students who are entering the learning environment to have necessary prior knowledge and reading and writing skills to access content material. Deficiencies in these skills can make it impossible for ESL learners to understand and learn the content and so they risk academic failure.

When Simon first sat in his science class in Australia, most of what was happening around him had no meaning. He could not understand much of the spoken language. His text book and class notes were largely incomprehensible and his writing skills did not allow him to participate in the class activities with his peers. For most lessons, there was little that he could attempt and he just sat unhappily in silence. In order to give him access to the scientific content and provide him with the same educational opportunities as the others in the class, modifications to his science course were necessary.

Modifications to science courses

The modifications which were attempted in this study were classified as content, process or product adaptations (Furtado & Tavares, 1996). Content modifications included: modifying the presentation of material by paying particular attention to making the language input more comprehensible; reducing the amount of material; rewording text or handout material using simpler vocabulary; and simplifying the material while allowing key points to remain. Process adaptations meant adjustments in the delivery and pacing of the course. Product adaptations involved reducing the amount of material the learner was expected to produce.

The modifications were governed by a number of factors. The individual needs and language proficiency of the students were the first considerations. The language

involved in a particular unit of work influenced the type of support required as did the branch of science being studied. Biology was more language rich than chemistry or physics, but was easier to illustrate with visual images. The extent to which the students could access their textbooks affected the amount of scaffolding which was necessary. For the older students, some of the assessment modifications were regulated by school and state policies. The amount of assistance that individual teachers were willing to provide also affected the modifications.

Content, process and product modifications

The most successful content modifications involved the development of whole units of work. These allowed the language objectives to be implemented comprehensibly. An ideal sequence of learning activities could be developed and this was informed by educational literature. The materials which were produced provided students with a sense of purpose, allowed them to engage in worthwhile activity, promoted the correct use of technical terms and gave them practice at manipulating the scientific concepts and the language. The units worked best when the class teachers were involved in the development or were invited to provide feedback about them.

Another factor which enhanced effective use of the materials was when some of the activities were included in general class work. This enabled the ESL students to perceive the usefulness of the exercises for other students too. It soon became apparent that there was a need to explain the information orally as well as presenting it in written form. Most of the students preferred to have the materials before the lesson in question so that they could be prepared. It was also necessary to give feedback on the students' work both orally and in a written form. There was need to assess and modify the units after they had been completed by the students. Even though care was taken with the language the first time they were used, there were always terms or questions which were not understood by the students. The students were pleased that their feedback was valued.

Once the ideal learning sequence had been addressed, the provision of tutorials was the best method of changing the delivery and pace of the courses. These provided the opportunity to ask the students questions and gave them the time to formulate the

language needed for a reply. Pam and Mary used the time to provide extra visual support in the form of diagrams and pictures which often replaced the spoken language they used in their classrooms. Most importantly, after a rapport with the students had been established, the tutorials provided the opportunity for students to clarify their understanding. The normal pace in mainstream classes did not allow for this.

With respect to assessment, most of the students preferred to attempt the same items as the other students in the class. If the task was an assignment, it was therefore essential to check their understanding of the task before they started and to keep on checking throughout the duration of the assessment piece. Even though the students were encouraged to ask the meaning of non-scientific terms during examinations, they rarely did this. They were usually rushed for time and felt that asking differentiated them. In some cases they were permitted to take their electronic translators into examinations. In situations where the language proficiency levels were low, most of the teachers marked for meaning rather than considering the expression.

Simon was delighted when he was presented with his first alternative unit. He showed it to his other teachers and completed assigned activities conscientiously. It provided him with work he could attempt and something worthwhile to do during the lesson. It gave him access to simplified scientific concepts. It was important to him that something was being done to address his needs. It is unlikely that he and the other students would have progressed as quickly academically if the materials had not been provided.

Attributes of successful students

From the constructivist point of view, language is the chief means used by children to build knowledge (Bruner, 1966). Vygotsky (1978) explains that social interaction through language is a prerequisite to cognitive development. Although teachers can promote understanding by engaging students in interactive tasks, the students themselves are ultimately responsible for improving their own English language skills and constructing their own development of scientific concepts.

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Just as there were some teachers who were more successful at helping ESL students, there were some students who were better at helping themselves. Successful ESL learners: asked questions in class; actively sought support; always completed all set tasks; had high expectations; were internally motivated; clarified understanding with teachers and peers; presented drafts and emailed questions; took notes; were good listeners; were out-going and friendly; and developed strategies which assisted them when they encountered difficulties.

The outcomes of study

The goal of action research is to find solutions to real problems and so employing this type of methodology gave the study a definite direction and focus. The interpretive framework which was used assisted in making the general outcomes clear. The first phase of the study outlined the problems of ESL students and their science teachers in Queensland educational institutions. The second phase aimed to find solutions to some of these needs by employing interventions in the three areas of focus. The three headings which have been employed throughout the study will be used to outline the general outcomes.

Language

Although it cannot be claimed that the language interventions were solely responsible for the improvements noticed in all the students' communicative competence, there was evidence that they did contribute to language development in a number of ways.

The specific language needed in a particular unit was determined and suitable language objectives were developed to be used alongside the content objectives. The language objectives were translated into exercises within worksheets and units. This ensured that specific language skills were addressed and there was subsequent improvement in manipulating the language in these special ways. Improving strategic skills helped with the major difficulties of understanding new vocabulary which all the students experienced. This was largely accomplished by encouraging the use of glossaries and learners' dictionaries. For the teachers, who, in the

beginning had little confidence in their ability to promote communicative competence, learning about some of the principles associated with second language learning helped to demystify this area of education for them. Where the problem of language instruction had seemed insurmountable, they were now aware of the things that they already did that assisted their ESL students. They also developed some new strategies with which to promote communicative competence and make input more comprehensible.

Teaching and learning environment

Some of the most positive outcomes in the study were attitudinal ones. Lee (2004) explains that teacher change is necessary if teachers are successfully to integrate language and literacy into content areas such as science. Not only were there modifications to teacher's beliefs about academic content and ESL students' abilities to learn it, but the change was continuous and reflective as evidenced by the monitoring of working of co-operative groups.

By the end of the study, the working relationships between the ESL students and the native speakers had improved, as well as that between the teachers and students. The rapport which had been developed between the members of the class went a long way to addressing the affective needs of the ESL students. At the beginning of the study most have felt isolated and did not interact because of the fear of ridicule. By the end of the study the patterns of participation and interaction changed dramatically, largely due to the effort of the teachers.

The student

The academic outcomes for the students were positive with all students improving their science results over the period of the study. Once they were provided with opportunities where they felt comfortable asking questions, they were able to clarify their understanding of vocabulary, scientific concepts and assessment tasks. This removed some of the frustration they reported feeling with their study of science. Once a rapport had been developed with a particular teacher, they often used these

times to discuss peer problems and any sociocultural problems they were experiencing.

The materials which were developed to assist academic competence also affected the outcomes for students. The enhanced conceptual development which resulted from modifying the course content was reflected in their achievement levels. It became evident that students were able to build on successful tasks. Another benefit is that it will be possible to use the exercises and materials again with other ESL students and also with native speakers experiencing problems with literacy.

Other research

Support for previous findings

The initial findings of phase one along with the findings of phase three support a number of issues addressed in the literature and will be considered under the appropriate headings.

The language

Carrasquillo and Rodriquez (2000) explain that traditionally it was assumed that English language proficiency was a prerequisite for subject matter learning. However, Stoddart et al. (2002) suggest that if language instruction and content are separated ESL students fall behind and do not have the opportunity to develop the cognitive/ academic language described by Cummins (1983). Lenny and Yan were the only students in this study to have attended intensive language courses before entering mainstream classrooms. Aya had the offer of ESL support outside the science classroom, but perceived that it was of no assistance and that there was a stigma attached to this type of instruction. At the beginning of the study the other students were merely submerged in their classes and expected to use English as a vehicle with which to study the science and other academic subjects. Although Larsen-Freeman (2000) claims that with no extra support this method of studying is very nearly an impossible undertaking, this was the situation that most of the

students found themselves in at the onset of the study and they were all unhappy with their results in science at this stage.

O'Toole (1982) explained that scientific language causes difficulties for a wide range of students, with second language learners experiencing particular difficulties. Gardner (1975) pointed out the problems that science students encounter with non-technical terms. The number of non-technical terms not understood by even the most proficient students, Patricia, Aya and Yan, surprised all of their teachers. The evidence presented made their teachers reassess their assertions that many of the difficulties with understanding experienced by these students were conceptual and not related to language issues.

Larsen-Freeman (2000) stresses the need for the teacher to have clear language objectives as well as content learning objectives if the ESL learner is to simultaneously acquire scientific understanding and improve communicative competence. In all three schools, at some time during the study, ESL specialist education was inadequate. Consequently, for most of the students, mainstream classes were the only place where the development of academic language was being addressed. Focusing on a particular language need and ensuring that there were plenty of opportunities for practising that skill as suggested by Tiffunoff and Ward (1991) contributed to improvements in both BICS and CALP.

The teaching and learning environment

Clegg's (1996) insistence that mainstream classrooms can be harsh places was supported by many of the students. Anna still felt angry about how she was treated at school and recounted instances of being laughed at and feeling stupid and embarrassed. Fear of ridicule prevented Aya from asking questions in front of other students. Min never spoke in her physics class either to her teacher or her peers. Simon was bullied and Claire was too scared to ask for the requirements for her experimental investigation.

Lee (1997) warns about the problems which can arise when teachers stereotype students. She suggests that this stereotyping often becomes a burden and is capable

of producing complex pressures. Furthermore, it can lead to teachers ignoring the students' emotional needs such as perfectionism, stress and anxiety. Despite severe language difficulties, in the beginning of the study Min was determined to finish all her homework. She perceived that this was expected of her by her father and all of her teachers. This often involved her working from the time she arrived home until one o'clock in the morning. Because none of them knew her background or language skills at this stage, her teachers did not advise her that this was an unreasonable expectation. Lee (1997) further confirms that parental expectations can also be very high for many students. Despite significant improvements in results, many of the parents of the students in this study did not want to accept any result less than an A.

All of the teachers in the study supported Lee and Luykx's (2003) proposal that they felt inadequately prepared to meet their ESL students' learning needs particularly in academically demanding subjects such as science. Observations also confirmed Gutierrez's (2002) view that secondary school teachers' main loyalty was to their subject area, with the students' other needs a secondary concern. One of the strongest pieces of evidence produced in the study supported Bryan and Atwater's (2002) finding that teachers' beliefs had a profound influence on students' success.

Achievement of ESL learners

The gap in achievement levels between the ESL learners and their native speaker counterparts described by Short (2000) was evident in Queensland schools. The literature provides many explanations for this. Gunstone (1978) says that language plays a basic role in the development of understanding concepts. If the students do not have the academic language skills required they will be disadvantaged when it comes to understanding science.

Science education has been under review and three decades of constructivist research have resulted in a move away from teaching content and a move towards encouraging students to engage with science while using language to organise, recognise, and internalise information (Their, 2002). Inquiry science promotes students' construction of meaning through exploration of scientific phenomenon,

observations, experiments, and hands-on activities and provides an authentic context for language use (Stoddart et al., 2002). Although inquiry learning did increase participation and language use for the ESL learners in this study, it assumed a certain level of language. Assessment-wise, this disadvantaged ESL students.

Fradd et al. (2001) concluded that the achievement gains of the students in their study reinforced the important role materials play in making science accessible to all students. The extra materials which were produced in this study served several purposes and contributed to enhanced understanding and the subsequent improvements in achievement levels.

Cummins' (1996) reported that although some students acquire basic communication skills quite quickly it can take much longer to develop cognitive academic language proficiency. This was confirmed by Aya and Anna's experiences. Both had been in Australian educational institutions for many years and still did not have the language skills they required to meet their academic needs.

Ideas for future study

During the course of a study such as this, many issues and questions emerge both in the field and in the literature, which are worthy of further investigation. For example, Lynch (2000) maintains that research-based curricula focusing on science inquiry for diverse learners were yet to be developed.

The difficulties encountered with vocabulary by the students in this study suggest that there is a need to investigate more effective methods of dealing with this issue. Research could be directed into the development of a science glossary with appropriate language levels for ESL learners. This could include technical scientific terms with examples of how the terms can be used. It could also include Gardner's (1975) list of ordinary words which are often found in scientific discourse but which were not understood by a substantial number of native speakers.

Another area of interest emerged when discussing the strategies which ESL students reported using to promote communicative competence. O'Malley and Chamot

(1990) and Oxford (1990) have written extensively about language learning strategies. They say it is assumed that successful language learners are successful strategy users. Yet there appeared to be discrepancies between the strategies that the students in this study perceived they were using and that which they were observed using. It is unusual that they may use certain strategies unconsciously and this would be an interesting area for further research.

For many reasons the ESL specialist assistance which was offered in the three schools involved in this study was not really effective. Some of the teachers did not hold a qualification in ESL teaching and they were provided with little guidance about how to help the ESL students. There is an urgent need to find more effective ways of delivering specialist assistance to students whose language skills are still developing. Both the school students and the postgraduate students felt that if they were accepted by educational institutions, they were entitled to adequate and appropriate language support. The students were paying fees at all three schools. Anna's university tuition fees were very high for her course in orthodontics and she felt that she deserved better treatment. There is also room to develop more effective ways of helping science teachers integrate language and science education.

Finally, some of the students in this study experienced problems related to their living conditions. At one stage Min, as a 16-year-old was living alone in a foreign city with minimal support. Yan's homestay arrangements were inadequate at one time. If international students are accepted by schools, the administration surely has an obligation to ensure that the students are properly cared for. It would be interesting to research the adequacy of living conditions and homestay situations of international students.

Chapter 8   CONCLUSIONS

This final chapter provides an overview of the study and draws some general conclusions by summarising the responses to the research questions. The limitations of the study are outlined and the chapter concludes with an examination of some of the educational implications of the results.

Overview of the study

The study was conducted in three phases using an interpretive methodology based on a modified action research approach in naturalistic settings. The purpose was twofold. The first goal was to describe the current situation with respect to ESL learners of science in selected learning environments in Australia and this constituted the first phase. Secondly, the study sought to investigate how these situations could be improved. To this end, some general interventions were designed in phase two and implemented in phase three. The strategies were aimed at promoting improvements in the three foci of: English literacy; participation and interaction in the science classroom; and understanding and achievement in science. The impact of the specific strategies was examined using a multidimensional interpretive framework. Changes in communicative competence, interactional and participative competencies and academic competence were measured. The stories of the nine linguistically and culturally diverse students involved in the study were presented as case studies. Data for the qualitative case studies were collected using classroom observation, teacher and student interviews, checklists of strategies and language errors, and portfolios of student work.

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For each of the three phases of the study, there was a research question which addressed each of the three foci, making nine research questions in all. For example, in phase one, question 1a was aimed at language, 1b at the teaching and learning environment and 1c at the student. The next sections summarise the general conclusions by providing responses to the research questions. In order to improve the continuity of this summary, the responses to the three questions devoted to language focus are presented together, followed by those pertaining to the teaching

and learning environment. Lastly, the responses which address the student focus are outlined.

The research questions and responses

Language

1a. **What are the difficulties for ESL students with respect to the language used in science classrooms?**

The most obvious problem for ESL science students is that their understanding of scientific concepts, classroom activities and assessment items is affected by their language proficiency level. The length of time the students had been exposed to the language, culture shock, fear of ridicule, embarrassment, depression and issues of motivation were found to affect the development of basic interpersonal communication skills (BICS). At all three schools, the specialist ESL assistance, which science teachers assumed was helping their students, was inadequate at various times during the study.

While some of the students did not have BICS, for others in the study it was failure to develop academic language which caused the greatest problems. It appears that participation in educational communication can be very difficult for some students. Because it is context reduced, exposure to academic discourse requires students to rely heavily on their individual understanding of language in order to construct meaning of the concepts being presented. Corson (1997) explains that, depending on their linguistic or sociocultural position, children may acquire a lexico-semantic range very different from that favoured by the special literate culture of formal education. Furthermore, the Graeco- Latin origin of most scientific words make them difficult to master because they are non-concrete, low in imagery, low in frequency, and semantically opaque. Gee (1991) refers to the *secondary discourses* which are needed for academic study and explains that students who do not speak English at home may fail to develop these.

Other factors which were identified as affecting the development of academic discourse for the students in this study included: no coordinated effort to integrate science and language; the technical and non-technical language used unconsciously by teachers verbally and in assessment items; grammatical patterns of scientific language in textbooks; the specialist nature of academic writing; and more specific language difficulties experienced by individual students, for example, subject verb agreement, the use of correct pronouns and prepositions, and reading the teacher's handwriting.

Because of its abstract nature, Cummins' (1996) reported that it could take up to five years to develop cognitive academic language proficiency (CALP). Findings in this study support the idea that it can sometimes take much longer than this to develop the requisite skills. Anna, after successfully negotiating two undergraduate degrees in English, still, did not have the academic language required to write her masters thesis. Aya has a much poorer understanding of nontechnical terms and concepts than would be expected after exposure to eleven years of education in Australian schools and this led her to misunderstand and misinterpret many scientific concepts and assessment items.

Because some of the students quickly mastered the surface features of the language they often seemed to their teachers and peers to be more fluent in English than they really were. Both Patricia's and Yan's very good spoken language masked the fact that there were many gaps in their understanding. Some of the teachers in this study incorrectly assumed that excellent knowledge of the conversational aspects of a language equated with knowledge of academic language. Consequently, they did not classify the problems experienced by these students in understanding scientific concepts as being associated with language skills at all. Examination of the lists of words which were not understood by Aya, Patricia and Yan supported the fact that developing language skills definitely impeded their understanding.

Corson (1997) provides further explanation as to why the development of academic language is such a huge task for all learners. As well as understanding the background knowledge in several different subjects or fields, learners are expected to master the rules of use for huge numbers of new words encountered mainly in print.

The meanings of these terms are often novel, unusual and changeable across contexts and systems.

2a. What teaching and learning strategies are likely to assist the language development of ESL students in science classrooms?

Analysis of the needs of the ESL students revealed that while Simon, Cliff, Min and Claire required help with BICS, the other students most pressing needs were of an academic nature. For all students important language learning needed to be addressed in mainstream classrooms like science because there was little formal language instruction occurring elsewhere. The literature (DiMarco & Turner, 1998; Fradd et al., 2001; Gutierrez, 2001; O'Toole, 1996; Rollnick, 2000; Stoddart et al., 2002) suggests that in order to assist the development of communicative competence within science there must be assimilation of language and literacy instruction with science education. It was decided to tackle this integration by: constructing language objectives alongside the science objectives (Gutierrez, 2002); the development of alternative supplementary units (O'Toole, 1992); development of worksheets which addressed specific language needs (O'Toole, 1992); and creating both individual and personalised glossaries (Wellington & Osborne, 2001).

3a. What impact do strategies specifically designed to address language development in the science classroom have on ESL students' communicative competence?

Of the three focal areas, assessing the impact of the strategies which dealt with language was the most difficult. Having said this, there were improvements in the language skills of all the students. The high school students all made steps forward in at least two of their ISLPR levels. The students with lower ISLPR ratings improved the most. Because it is such a complex phenomenon and so many factors contribute to development of communicative competence, it was difficult to gauge just how much the introduced strategies were responsible for this progress on the interlanguage continuum.

However, some definite conclusions can be drawn. For Aya, Simon, Patricia and Yan the strategies employed certainly improved their academic language. For the other students better academic achievement suggests that their academic language also experienced some improvement. Strategic competence definitely improved for all students as a result of increased interaction and participation with teachers and peers. Encouragement by their teachers and suggestions from other ESL students and native speaking peers gave them better skills for coping when they did not understand. Of the two postgraduate students, Lenny's skills improved enough for her to write effective case notes and referral letters and so pass her occupational English test. Anna's writing skills reached a standard which allowed for her thesis to be published and for her to pass her course.

Because of the unsatisfactory nature of much of the ESL support in the three schools, it became apparent that mainstream classrooms were the places where communicative competence was being addressed, often without the teachers themselves being aware of the fact. To assist basic interpersonal communication skills, the inclusion of reading, writing, speaking and listening in each lesson, proved a realistic goal. It is worth noting that compared with chemistry and physics, the biology classes in this study naturally afforded more opportunities for development of these four macroskills. In order to assist the development of academic language, the language involved in a particular unit of work was analysed and specific skills were identified. O'Toole's (1992) suggestions of considering word, sentence and paragraph objectives worked well. The inclusion of objectives which dealt with the characteristics of scientific style in texts, laboratory reports and essays were another way of meeting students' needs. The strategy checklist (Appendix B) which was compiled from the literature review proved to be an effective method of informing the development of objectives. The list proved particularly useful for compiling objectives which addressed the more difficult concepts of strategic competence and sociolinguistic competence. Analysing the specific language difficulties for individual students also provided ideas for objectives.

The gaps in vocabulary of the students with better language skills were addressed by the use of glossaries. However, it is important to note that although personalised glossaries proved to be a very effective way of addressing the vocabulary needs of

ESL students, the sheer number of terms which are not understood by students with comparatively good language skills makes the construction of such glossaries so time consuming as to be impractical. Learners' dictionaries, which include an example of how a term is used as well as alternative meanings proved most helpful.

The students in the study believed that the worksheets and alternative units provided valuable assistance. They made implementation of the language objectives easier. They provided structure for individual tutorials, were a means of collaboration between the science teacher and the ESL specialist and were tailored to meet specific needs. For the other science teachers involved in the study, they saved preparation time and provided ideas with which to cater for these students. However, they worked most effectively when the teachers had some input, felt some ownership and provided feedback on their use.

Learning environment

1b.   How do science teachers assist ESL students to interact and participate in science learning environments in Australian schools?

The first phase of the study revealed that teachers' beliefs and experience had a very significant impact on the students' interaction and participation. The students felt more comfortable asking questions of experienced teachers. A teacher's positive and friendly attitude towards ESL students was conveyed to the other students in the class and was often copied by them. The ESL students did better in the classrooms of the teachers who showed an interest in them, believed that students could achieve and made it obvious that they were willing to help.

Many of the teachers in this study did a very good job assisting the ESL students. It was not a simple task as some of the students were very shy and unhappy. They felt isolated by language and culture, were often not accepted by their peers and were removed from family support. They were all extremely determined to improve their academic performance and their parents had different expectations from Australian parents. The teachers that were successful at assisting them: were hospitable and welcoming; intent on building a rapport with the students; used their names often;

provided opportunities for interaction; offered chances for clarification; presented the same concepts in different ways; set realistic goals; paraphrased; and celebrated small gains and successes. It should be noted that some teachers did not believe the ESL students were capable of success in science and so made no attempts to include them.

2b. What teaching and learning strategies are likely to improve the interaction and participation of ESL students in science classroom?

While most teachers would accept that the feelings of belonging and acceptance are vital for students to envision their own success, Baumgarten and Bacher (2005) suggest that the affective domain is often overlooked in science education. All of the students in this study required help with interaction and participation in science classrooms. It was decided to address this need by providing each student with some form of individual attention (Herrell & Jordan, 2004). The literature suggests numerous ways of achieving this and the methods that were chosen included the following: individual or small group tutorials (Carrasquillo & Rodriguez, 2002; Jarrett, 1999); establishing workable cooperative groups (Gutierrez, 2002); marking assignment drafts (Carrasquillo & Rodriquez, 2002; Rosenthal, 1996); answering problems through email (Rollnick, 1994); and the development of customised materials (Fradd et al., 2001).

3b. What impact do strategies specifically designed to improve the science teaching and learning environment have on ESL students' interactional and participative competencies?

The students and teachers in the study agreed that the teaching and learning environments was the domain in which the biggest changes and improvements occurred as a result of the interventions. At the end of phase three all of the ESL students were much happier and involved in their science classrooms and the teachers felt more confident that they were catering to the students' individual needs. The tutorials served many useful purposes. From the researcher's and teachers' points of view they were where information about the students' linguistic backgrounds was gathered and a rapport was established. For the students, they

provided an opportunity to discuss content material in an environment that was protected from native speakers. The extra time required to ask, understand and answer questions was appreciated and utilised productively by the students.

The establishment of workable cooperative groups also contributed to the success experienced by the ESL learners. They benefited most from working in small groups when they were encouraged to participate and their contributions were valued. Group work allowed them to use English in a meaningful way, clarify their understandings with their peers and to develop better relationships with them. However, both students and teachers needed to monitor how effectively the relationships were working, and teachers had to provide guidance to the students on how to work cooperatively.

As Rollnick (2000) acknowledges, reading assignment drafts is time consuming for instructors, nevertheless she emphasises its importance for the ESL student. Reviewing drafts worked best when oral negotiation between the teacher and the student took place. Emailing proved a very successful strategy, but only for the students with the more advanced English language skills. While Yan and Aya embraced the idea of emailing enthusiastically, Min, Claire, Cliff and Simon did not feel able to take advantage of this strategy. Even Patricia, with her very good English did not send questions or drafts by email until towards the end of phase three.

In all cases, the fact that someone was taking an interest in the students had a measurable impact on their interaction and participation. Improvements were seen in their; attitudes to school work; self-confidence and self-esteem; and their adaptation to the Australian classroom. The students found it reassuring that teachers realised that they were not stupid. They became less embarrassed about not understanding terms and concepts and so more likely to ask for clarification. As a direct result both the students' understanding in science and English language development improved.

1c. **What difficulties do ESL students encounter when constructing an understanding of scientific concepts?**

Again, developing BICS and CALP was found to have the greatest effect on ESL students' understanding of scientific concepts. Other factors which caused difficulty included: different cultural backgrounds; different past science instruction; different background knowledge; limited opportunities to clarify understanding; ineffective study skills; reading cursive writing; pronunciation of new words; reading, writing and listening simultaneously; and assessment instruments infused with specific linguistic or cultural knowledge. With respect to assessment, until the students had mastered the language, assessing them in English did not provide adequate feedback about their science knowledge.

The ideas of Corson (1997) and Gee (1991) on the development of academic language have already been outlined. Pingree, Hawkin and Botta (2000), when referring specifically to the development of academic skills and scientific literacy skills, report that family communication and patterns appear to be of importance. This was certainly true in Aya's case where the parental attitude to maintaining her first language and culture was affecting her understanding of academic concepts and her ability to express herself in the specialist scientific language required by assessment tasks. But the problems can be more complicated than failure to develop scientific literacy and academic skills. For many of the students the cultural knowledge they acquired at home was discontinuous with other expectations and assumptions at school. For example, for Yan the idea that an excursion could be enjoyable as well as educational was outside her experience. Simon's and Claire's parents did not see having a social life as appropriate when the students should be focused on attending to their studies. Being silent and not involved in class discussions was seen as a virtue by some of the parents rather than a missed opportunity to clarify understanding and extend reasoning.

2c. What learning strategies are likely to enhance ESL students' understanding of scientific concepts?

Studying academic subjects in a language other than one's first language presents many challenges, but if ESL students wait until their language improves they are left behind (Stoddart et al., 2002). Furtado and Tavares (1996) suggest that content, process and product adaptations may be necessary in order to give the student an entry into the academic discipline of science. The extent of the modifications used varied with the student's level of proficiency in English.

It was decided to attempt the following content modifications: modifying the presentation of material; reducing the amount of material; rewording text using more appropriate vocabulary; and simplifying content while allowing key points to remain. Process adaptations included: presenting materials at a slower rate; using simplified vocabulary to improve comprehension; using various methods of review; allowing more time for learners to understand the language and concepts; identifying and teaching specific vocabulary that cannot be simplified; organising materials into small, easily attainable sequential steps so students can develop learning skills and master content; and teaching study skills. As well as integrating science and language education and providing individual assistance, the development of suitable materials was seen as a way of modifying science courses for ESL students (Sutman & Saxton, 2002).

It was decided that the product adaptations might involve reducing the amount of material the learner was expected to produce where necessary. Assessment procedures could be modified by breaking the tasks down into smaller steps, providing extra time, permitting the use of dictionaries or allowing students to ask the meanings of non-scientific terms.

3c. What impact do strategies specifically designed to assist ESL students' understanding of science have on academic competence?

All of the students made improvements to their achievement levels, some quite dramatic. Cliff's proficiency improved enough from phase one to phase three to

allow him to attempt assessment. Simon's results improved from a limited achievement level to sound level. As with the language focus, numerous factors were involved in the above improvements in academic competence. Better academic language which improves academic performance must be directly influenced by the improvements already noted in communicative competence. However, it is unlikely the achievement gains outlined above would have been realised without the introduction of the strategies designed to address academic competence. It appears that adjustments to the curriculum are necessary if all students are to be experience some success.

The assistance provided by individual and small group tutorials has already been related. The other strategies which proved most successful were: providing more visual support by modifying the presentation of material; supplying copies of class notes and overhead transparencies; rewording text using more appropriate vocabulary; simplifying content while allowing key points to remain; reviewing often; supplying outlines or lists of objectives which highlighted key points; allowing more time for learners to understand the language and concepts; identifying and teaching specific vocabulary; organising materials into small, easily attainable steps; supplying model written answers to practice questions; checking written answers to study guides and questions; and giving written feedback for class work..

Many of the above strategies were integrated into special units and worksheets. The use of these materials proved to be successful for a number of reasons. For learners with low English proficiency they provided a purpose to their science lessons and permitted engagement with important scientific content. They could be tailored to meet specific needs and provided structure for tutorials.

With regards to assessment, some tasks were broken down into small steps and the students were given the opportunity to clarify their understanding of the topic and the requirements. During examinations, even though students were encouraged to ask if they did not understand non-scientific terms, they rarely did this. In some instances they were permitted extra time. While in many cases, meaning rather than expression was assessed, the students usually attempted the same examinations as the native speakers in the class.

Limitations

At the onset of the study it was envisaged that a few specific strategies would be implemented and their impact assessed. It was anticipated that this would make generalising about the findings easier. However, the students had very diverse linguistic and cultural backgrounds and if the strategies were to be effective, they had to be designed to meet the students' specific needs. The strategies suggested in the literature are numerous and vary from broad sweeping policy statements to very specific classroom techniques. Because of this it was decided to concentrate on broad interventions rather than the assessment of the specific strategies which was initially considered.

Although the results were presented in case studies in order to provide the reader with a concrete sense of the personal and shared challenges faced by the students and their teachers, the small sample size probably influenced some of the general conclusions which were reached. On the other hand, as it was essential to develop a rapport with the students and this took time. The nine case studies proved a manageable and practical number.

As a method of triangulation and a useful way of viewing the data, the interpretive framework worked well. Realistically, however, it was impossible to separate the progress made in communicative competence from that made in academic competence and participation and interaction, as the three areas are inexplicably linked.

Finally, where a lone researcher is involved in a study, there is a danger that the data might not be distinguishable from the researcher's interpretation. It is intended that building the techniques of triangulation, prolonged engagement, persistent engagement, provision of thick description, member checks and peer debriefing into the methodology helped to ensure that the work was trustworthy.

Educational implications

Lack of public understanding of science and technology can have serious consequences and so there is a need to develop a scientifically literate community. Science education in schools has an important role to play in working towards this. The growing diversity of school populations around the world means that for many students, the language of instruction in their science classrooms is not their first language. Additionally, proficiency in academic English and the special genres involved in scientific English are necessary if ESL students are to have equal access to science education and not get left behind their native speaker classmates. The ESL students in this study lacked to differing degrees the requisite language skills to participate as fully as they wished in science learning. However, this study demonstrated that strategies can be implemented which assist this process.

Most of the students in this study were relying upon science lessons for much more than access to content knowledge. In order to acculturate fully and for their emotional wellbeing they needed to interact and participate in science classes. Additionally, the students relied largely upon English use in science and other mainstream subjects to help them develop communicative competence.

While the ESL population continues to increase steadily, so too do the needs of the teaching population who prepare to meet their linguistic, social and academic needs. It can no longer be assumed that educating ESL students is the job of specialist teachers. It is now the responsibility of all teachers. The teachers in this study felt underprepared to meet this challenge and so there is a need to be aware of strategies which are effective measures for helping ESL science students.

This study aimed to add to the existing knowledge on integrating literacy and science for ESL students. The findings show that it is possible to improve upon the current situation for ESL learners of science. Jarrett (1999) insists that effective mainstream education for ESL students is simply just good teaching. It seems that in order to achieve this, there is a need for a holistic approach to the science education of these students.

Science education for ESL learners is most successful when the three areas of language development, participation and interaction in science, and the understanding and achievement in scientific are all given consideration. All three have important educational implications for ESL learners.

Language

Whether science teachers are aware of it or not, ESL students are using science lessons to improve both their social and academic language skills. Furthermore, teachers should be conscious of the demands that mainstream education places upon ESL learners. In order to meet the needs of these students, science teachers need to develop a better understanding of the nature of language proficiency and second language learning. There are many strategies which enhance the integration of science and language education and so make academic content more accessible. The development of language objectives and worksheets which identify specific linguistic and academic demands and difficulties are effective. The use of learners' dictionaries and glossaries are skills which the students themselves can develop in order to promote understanding. For post-graduate students, effective courses for academic writing in context are needed.

Teaching and learning environment

Teachers who have an understanding of differences in language and culture can have a positive effect on students' classroom participation and interaction, as can those who have a belief in the possibility of academic success. Furthermore, their attitudes and behaviour are mirrored by the other students in their classes. Where teachers are welcoming, hospitable and use the students' names often, the creation of an inclusive classroom is much more likely. Workable co-operative groups, inquiry learning and individual assistance are all effective ways of promoting interaction. Tutorials and marking assignment drafts are important ways of checking individual understanding and providing opportunities for language development away from possible embarrassment in front of native speakers. Collaboration between ESL specialists and science teachers is invaluable when coming to understanding specific difficulties

experienced by these students. Emailing questions and drafts is only effective when students are confident with their language skills.

Student

Maatta, Dobb and Ostlund (2006) outline a telling list of questions which they say ESL students often ask themselves while trying to receive, interpret and explain science content.

> *Does this teacher care about me? Does this teacher want me to succeed? Does this teacher realise that I am not intellectually limited even though I am not able to express myself completely in English? Does this teacher understand the fear of ridicule and embarrassment I must overcome every time I open my mouth to speak, participate in a group or hand in written work? (p.39)*

The students in this study who received no extra consideration from their teachers did not prosper. For some students it appears that with no extra assistance it is almost impossible to achieve a satisfactory academic standard in science. Modifications to science courses are necessary and the most successful ones involved a change in the method of delivery of the material. Tutorials, worksheets and alternative units with language objectives, worksheets and tutorials had the most impact. With respect to assessment, most students in this study preferred to complete the same tasks as the native speakers in the class. Consequently, it is important to ensure that the concepts and the scientific English involved in the task are understood. Because the language of science tends to be economical and precise, teachers need to help the students negotiate this formal register. As well as drawing on huge numbers of technical terms and expressions ESL students need to develop oral and written language skills in order to perform the functions of science which include classifying, analysing, summarising, comparing, defining, inferring, hypothesising, describing, and explaining. It is important to concentrate on the language requirements of particular units and model the skills required.

The final word

This study began as a personal quest for strategies which could be used to enhance the learning of science for three students, Cliff, Anna and Lenny. Along the way I came to meet many other ESL science students, all with very different backgrounds and intriguing stories. As I came to know them, it soon became obvious that it was impossible to separate the science from the student. Their struggles to develop their English language skills, interact and participate in their classrooms while improving their achievement levels in science form the basis of this thesis. Indeed, some of the difficulties that these students face, often alone and far from home sometimes seemed insurmountable. Working with these students and being taken into their trust was an experience I have valued. Furthermore, when a teacher has been teaching for as long as I have, it is rare to be given the opportunity to watch other science teachers at work. I was privileged to be welcomed into so many science classrooms and to learn so much from working with other teachers.

Action research seeks to find solutions to problems and the study revealed that there are no prescriptive answers to the myriad of difficulties encountered by these students. Jarrett's (1999) supposition that to create a classroom that caters for culturally and linguistically diverse students is "just good teaching" is true, but not as easy as it sounds. I came to the realization that the students' understanding in science was inextricably linked with their competence in English and the way that they interacted and participated in class with their teachers and peers.

My conclusions are that effective science teachers have an impact if they: consider ESL students' language needs as well as their science needs; are conversant with the students' backgrounds; provide individual assistance; are conscious of the difficulties caused by the special language of science; and structure science lessons to ensure that ESL students are included. It is also essential to pay attention to detail as the following recent incident illustrates.

In her recent Biology examination Yan did poorly on a question which I had expected she would answer well. The question read:

"Account for the presence of radioactively labelled protein in the mitochondrial sample."

When we held the post-mortem of the test which we always do, she explained that she did not understand the term "account for", could not guess its meaning, and so could not attempt an answer. As usual, she was rushed for time and so did not ask the meaning of the term as I have encouraged her to do. Even though I have spent the past three years learning to avoid these kinds of pitfalls for my students, I still make these avoidable errors which result in my assessing their English language knowledge instead of their science knowledge. As a result, the students' understanding and achievement levels are affected. During the past three years I learnt much from reading educational literature and talking to other teachers and ESL experts. However, it seems that the ESL students, from whom I have learnt the most, still have a lot to teach me.

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Appendix A
Glossary

Acculturation - refers to the process by which minority group members acquire the language and culture of the dominant society while retaining their native language and culture.

Adjunct model – Formal pairing of a content-area and an ESL course.

Affective filter – Term coined by Krashen to describe affective variables such as emotion, motivation and anxiety which can promote or inhibit language development.

Assimilation – The process by which minority group members lose their native culture and language replacing them with the language and culture of the dominant members of a society.

Basic Interpersonal Communicative Skills (BICS) – Term coined by Cummins to define everyday conversational ability that is context embedded.

BICS – *See* **Basic Interpersonal Communicative Skills**

Bilingual – Bilingual individuals know more than one language to different degrees and use these languages for a variety of purposes.

Bilingual education – Education where teachers encourage the use of both languages as resources for communicating and learning.

Bridge - Often used to refer to a course which helps students develop the skills they need to succeed in amore academically challenging setting.

CALP – *See* **Cognitive Academic Language Proficiency**

Cognitive Academic Language Proficiency (CALP) – Term coined by Cummins to refer to the kind of language competency needed to learn cognitively demanding academic subject matter where clues to meaning are often lacking.

Colloquialism – an expression which is used in or suitable for, ordinary familiar or informal conversation.

Common underlying proficiency (CUP) – Term coined by Cummins to refer to the knowledge, concepts, and skills which transfer from L1 to L2 (*See* **Linguistic interdependence**)

Communicative competence – Knowledge that users of language need to internalise to enable them to understand and produce language. Canale's (1983) model outlines four components; grammatical competence is the knowledge of lexical items and the rules of morphology, syntax, sentence-grammar, semantics and phonology; discourse competence is concerned with intersentence knowledge and so involves the functional aspect, which includes speech acts and conversational acts; sociolinguistic competence is the knowledge of the sociocultural rules of language and discourse; and strategic competence involves the strategies that can be called into action to compensate for breakdowns in communication.

Community language – A language used within a particular community, including languages spoken by ethic minorities.

Comprehensible input – Term used by Krashen to describe messages in a new language that are mostly understood by the learner.

Content area – A term used for a specific curriculum area such as biology or history.

Context – The situational aspects of any spoken or written text including the audience and the purpose associated with text.

Context embedded – Language for which there are physical and social clues as well as shared background and linguistic knowledge that help clarify the meaning of the words.

Context reduced – Abstract language which requires higher levels of content knowledge and language proficiency in order to be understood: language which is lacking in physical and social clues or shared background and linguistic knowledge.

Culture – A learned way of life: the values, beliefs, behaviour, ways of perceiving and language which are shared by a group of people.

Cummins, J. – Language researcher at the Ontario Institute for Studies in Education who has advanced several hypotheses related to second language acquisition including the existence of two kinds of language proficiencies (BICS and CALP) and linguistic interdependence between L1 and L2 (CUP).

Developmental errors – Errors that reflect the natural order of acquisition of a language; they are the same in children learning their first language and adults who are learning that same language as a second language.

Discourse competence - Concerned with intersentence knowledge and so involves the functional aspect, which includes speech acts and conversational acts.

EAL – English as an additional language.

EAP – *see* English for academic purposes.

ELL – *see* English language learners.

Ellipsis – Refers to the process whereby part of a grammatical unit is left out. This commonly occurs in conversational exchanges.

EFL – *see* English as a foreign language

ESOL – English for speakers of other languages.

English as a foreign language – Students who have learnt English in their native country.

English as a second language (ESL) – Students for whom English is a second language and not a native language. This term could refer to a new learner or a fluent speaker.

English for academic purposes (EAP) – The oral and written English literacy skills needed to succeed in academically challenging content areas.

English language learners (ELL) – Students who are learning English.

Error – According to Corder (1967) it is a deviation in learner language which results from lack of knowledge of the correct rule (Contrast with *mistake*).

Error Analysis – Involves a set of procedures for identifying, describing and explaining errors in learner language. It is used as a tool for investigating how learners learn a language.

ESL – *see* English as a second language.

Foreign language – a foreign language is one not spoken by the local community.

Grammatical competence – The knowledge of lexical items and the rules of morphology, syntax, sentence-grammar, semantics and phonology.

Idiom – a phrase which means something different from the meanings of the separate words.

Instructional congruence - the process of mediating academic disciplines with linguistic and cultural experiences.

Interference errors – Errors which occur when L1 structures or pronunciation influence L2 production.

Interlanguage - Second language learners are thought to progress along a continuum whose two poles are the first language and the target language. This continuum is marked by a series of stages, which are defined by the types of errors the learner makes at each stage. Selinker (1972) uses the term "Interlanguage" to describe these various stages.

International Second Language Proficiency Ratings (ISLPR) - Is a set of four subscales, which trace the development of learners in reading, writing, listening and speaking. The scale rates from zero to five.

ISLPR - International Second Language Proficiency Ratings - Is a set of four subscales, which trace the development of learners in reading, writing, listening and speaking. The scale rates from zero to five.

Krashen, S – Language researcher at the University of Southern California who has advanced several hypotheses related to second language acquisition including the distinction between language learning and language acquisition; the Monitor Hypothesis; the role of comprehensible input; the Affective Filter, and the Natural Order Hypothesis.

L1 – An individual's native language.

L2 – An individual's second language.

Language acquisition – The unconscious development of language proficiency which does not involve schooling, textbooks, memorisation, lessons or drills; by means of acquisition children become fluent in their first language and according to Krashen, only by acquisition can individuals become fluent in a second language.

Language acquisition device – directs the process of acquisition. This device contains information about the possible form that the grammar of any language can take.

Language learning – The conscious study of language generally involving a teacher, textbook, a series of lessons, homework, memorization and drills; according to Krashen, does not lead to second language fluency.

Language minority student – Refers to students who are members of an ethic minority and whose native language is not the dominant language of the country.

LEP – *see* Limited English Proficiency.

Limited English Proficiency (LEP) – used to refer to individuals whose native language is not English and who have difficulty with speaking, reading, writing and/ or understanding English.

LES – *see* Limited English speaker.

Limited English speaker (LES) – used to refer to individuals whose native language is not English and who have difficulty with speaking, reading, writing and/ or understanding English.

LOTE – Languages other than English.

Mainstream – Content areas taught in English.

Mainstream classrooms – Classrooms designed for native speakers.

Mainstreaming – When students are moved out of a program of English as a second language and into content-area courses in which English is the language of instruction.

Mistake – Corder says it is a deviation in learner language that occurs when a learner fails to perform his or her competence (Contrast with *error*).

Monitor Hypothesis – According to Krashen, the ability of some individuals to self-correct second language usage if they have sufficient time, focus on form, and have knowledge of the rules of language.

Morpheme – smallest unit of linguistic meaning or function.

Morphology – the study of the structure of words; the component of the grammar which includes the rules for word formation.

Native speaker – Person who speaks a language as their first language.

Natural Order Hypothesis – According to Krashen, people generally acquire the grammar of a given language in a predictable sequence regardless of their native language.

NESB – Non- English speaking background.

NLE – New learners of English.

Output – Verbal utterances and written forms of language.

Phonology – the sound system of the language; the component of the grammar which includes the inventory of sounds and rules for their combination and pronunciation.

Proficiency - Refers to the learner's skill in using the second language in different tasks.

Second language - the language being learned is that being spoken in the community in which it is learnt.

Sheltered instruction – A content-area course taught in English by a content specialist to a class composed entirely of intermediate and /or advanced ESL students.

Silent period – Some L2 learners go through a lengthy period when they do not try to speak in the L2. However, they may be learning L2 through listening to others speak it and may also be engaging in private speech.

Sociolinguistic competence - The knowledge of the sociocultural rules of language and discourse.

SOLS – Speakers of other languages.

Strategic competence - Involves the strategies that can be called into action to compensate for breakdowns in communication.

Submersion – Refers to educational settings where L2 learners are required to learn in classrooms where most of the students are native speakers so that few input adjustments are made.

Syntax – the way that words may be combined in groups up to the level of the sentence.

Target language – The language the learner is trying to master.

Test of English as a Foreign Language (TOEFL) - A standardised test prepared and administered by the College Entrance Examination Board.

TOEFL - *see* Test of English as a foreign language.

TESOL – Teaching English to speakers of other languages.

Universal Grammar – term used by Chomsky to refer to the abstract knowledge of language which children bring to the task of learning their native language and which constrains the shape of the particular grammar they are trying to learn.

Appendix B
Strategy Checklist

Teacher strategies to address general communicative competence.

- Knowing the student's linguistic background (Larsen-Freeman, 2000).
- Creating language objectives for lessons (Gutierrez, 2002).
- Attempting to make input comprehensible (Krashen, 1977).
- Training in language learning strategies (Chamot & O'Malley, 1994).
- Conducting a needs analysis for individual students (Oxford, 1994)
- Incorporating reading activities (Ur, 1996).
- Incorporating writing activities (Ur, 1996).
- Incorporating listening activities (Ur, 1996).
- Incorporating speaking activities (Ur, 1996).
- Incorporating spelling activities (Ur, 1996).
- Focusing activities explicitly on language forms and functions (Chamot & O'Malley, 1994).
- Using authentic materials (Carrasquillo & Rodriquez, 2002).
- Providing linguistic scaffolding (Westby et al, 1999).
- Providing visual scaffolding (Carrasquillo & Rodriquez, 2002).
- Making language expectations explicit (O'Toole, 1992).

Teacher strategies to address grammatical competence.

<u>Word</u>
- Pre-teaching vocabulary (Ur, 1996).
- Identifying key vocabulary (Carrasquillo & Rodriquez, 2002).
- Highlighting important terms (Oxford, 1990).
- Creating wordbanks (Heney, 1996).
- Decoding essential vocabulary (Carrasquillo & Rodriquez, 2002).
- Demonstrating new vocabulary with objects and actions (Chamot & O'Malley, 1994).
- Limiting new vocabulary to fewer than 12 words per lesson (Jarrett, 1999).
- Giving direct definitions (Richard- Amato & Snow, 1992).
- Providing exercises in word synthesis and analysis (Dalton & O'Toole, 1984).
- Explaining everyday uses of scientific terms e.g. *force, law, cloudy* (Kothecha et al., 1990).

- Paying attention to abstract nouns e.g. *composition, assumptions* (Park, 1986).
- Paying attention to non-technical words e.g. *average, random, emit, effect* (Gardner, 1978).

<u>Sentence</u>
- Paying particular attention to articles e.g. *the, an, a* (Lee & Luykx, 2003).

Teacher strategies to address discourse competence.

- Supporting student use of academic language in academic settings (Herrell & Jordan, 2004).
- Helping students to understand the demands of science language (O'Toole, 1998).
- Guiding students in the development of science related discourse skills (Lee & Luykx, 2003).
- Explaining the differences between everyday and scientific language (Dalton & O'Toole, 1984).
- Relating language to real life models (Oxford, 1990).
- Explicitly modelling scientific discourse, e.g. report writing (O'Toole, 1998).
- Correcting oral errors (Ur, 1996).
- Correcting written errors (Ur, 1996).
- Marking assignment drafts (Carrasquillo & Rodriquez, 2002).
- Writing legibly on the whiteboard (Carrasquillo & Rodriquez, 2002).
- Placing new words in context (Oxford, 1990).
- Simplifying scientific text (O'Toole, 1998).

Teacher strategies to address sociolinguistic competence.

- Asking for clarification (Carrasquillo & Rodriquez, 2002).
- Valuing home cultures (Herrell & Jordan, 2004).
- Developing cultural understanding (Oxford, 1990).
- Becoming aware of others' thoughts and feelings (Oxford, 1990).
- Cultivating a strong supportive classroom structure (Gutierrez, 2002).
- Developing student awareness of differences (Walqui, 2000)

Teacher strategies to address strategic competence.

- Answering problems through email (Rollnick, 1994).
- Providing the form for asking questions (Ellis, 1994).
- Pre-empting problems (Rosenthal, 1996).
- Switching to the first language (Oxford, 1990).
- Using mime or gesture (Oxford, 1990).
- Adjusting or approximating the message (Oxford, 1990).
- Using a synonym (Oxford, 1990).
- Overviewing and linking with already known material (Oxford, 1990).
- Providing a structured review (Oxford, 1990).
- Translating (Chamot & O'Malley, 1994).

Teacher strategies to address participative competence.

<u>Language</u>

- Encouraging students to express ideas, thoughts and experiences (Jarrett, 1999).
- Respecting language skills (Jarrett, 1999).
- Providing bilingual books and labels (Herrell & Jordan, 2004).
- Providing model written answers (Rosenthal, 1996).
- Providing copies of written notes (Rosenthal, 1996).
- Building on students' previous knowledge (Gutierrez, 2002).
- Modifying projects to suit individual demands (Herrell & Jordan, 2004).
- Ensuring assignment and research work demands are understood (Rosenthal, 1996).
- Modeling step by step procedures (Carrasquillo & Rodriquez, 2002).
- Presenting the same information both verbally and visually (Rosenthal, 1996).
- Incorporating routines to use target language (Carrasquillo & Rodriquez, 2002).
- Providing extra time to answer questions (Stansfield & Rivera, 2001)
- Repeating instructions to individual students (Rosenthal, 1996).
- Checking for understanding (Rosenthal, 1996).
- Creating a language rich environment (Shoebottom, 2001).
- Structuring activities so students can participate at a level of comfort (Herrell & Jordan, 2004).

Learning Environment

- Setting realistic goals (Shoebottom, 2003).
- Providing school support for ESL learners (Buck et al, 2003).
- Providing in-service for teachers (Buck et al, 2003).
- Encouraging parental involvement. (Buck, 2000)
- Encouraging peer tutoring (Herrell & Jordan, 2004).
- Providing and planning for more individualized instruction (Herrell & Jordan, 2004).
- Promoting inquiry based learning (Amaral et al, 2002).
- Working with an ESL specialist (Cuttell, 1982).

Student

- Making students welcome and being hospitable (Jarrett, 1999).
- Believing that students are capable of success (Rennie, 1993).
- Providing possibilities for success for all students (Richard-Amato & Snow, 1992).
- Determining individual needs by interacting with students (Gutierrez, 2002).
- Establishing predictable routines and signals to reduce anxiety (Herrell & Jordan, 2004).
- Seating students towards the front (Shoebottom, 2003).
- Treating ESL students as full members of the class community (Shoebottom, 2003).
- Referring to students by name often (Shoebottom, 2003).

Teacher strategies to address interactional competence.

Language

- Emphasizing functional communication (Rennie, 1993).
- Incorporating retelling activities (Heney, 1996).
- Ensuring verbal interaction in partner work (Herrell & Jordan 2004).
- Ensuring entrances to conversations (Jarrett, 1999).
- Providing feedback (Jarrett, 1999).

Learning environment

- Ensuring frequent student interaction through the use of collaborative learning techniques (Rennie, 1993).
- Promoting inquiry based learning (Amaral et al, 2000)
- Introducing a buddy support program (Heney, 1996).
- Establishing workable cooperative groups (Gutierrez, 2002).

- Creating a classroom environment that is not dominated by teacher-student interaction (Buck, 2000).
- Being patient (Rosenthal, 1996).

<u>Student</u>
- Building a rapport with students (Levine, 1992).
- Taking into account a person's culture (Herrell & Jordan 2004)
- Encouraging positive attitudes in other students (Jarrett, 1999).
- Learning how to pronounce the students' names (Shoebottom, 2003).
- Involving families (Barba & Reynolds, 1998).

Teacher strategies to address academic competence.

<u>Language</u>
- Introducing topics and sections with discussion (Ur, 1996).
- Rephrasing language for clarity (Oxford, 1990).
- Modelling logical expression of ideas, description and argument (Gutierrez, 2002).
- Creating visual images to support understanding (Herrell & Jordan 2004).
- Practising scientific functions for example questioning, investigating, observing, classifying, collecting and analysing data (O'Toole, 1992).
- Practising with some language functions such as reflecting, predicting, inferencing, and hypothesizing (O'Toole, 1992).
- Ensuring that students understand language functions such as compare, explain, describe, show, demonstrate, discuss, state, and outline (Park, 1982).
- Paraphrasing or repeating difficult concepts (Jarrett, 1999).
- Speaking slowly and enunciating clearly (Jarrett, 1999).
- Using a controlled vocabulary, with fewer pronouns, simple language structures (Jarrett 1999).
- Avoiding idiomatic expressions and words that have double meanings or synonyms (Jarrett, 1999).
- Providing practice for using keys, constructing tables, drawing scientific diagrams, constructing flow charts, using symbols, constructing graphs, making summaries (O'Toole, 1992).
- Providing previews for reading (Chen & Graves, 1998)

<u>Learning environment</u>

Classroom techniques

- Demonstrating new concepts with hands on experiments and activities (Buck, 2000).
- Developing and providing special materials (Larsen-Freeman, 2000).
- Omitting difficult content (Richard-Amato & Snow, 1992).
- Using matching activities (Heney, 1996).
- Sequencing ideas logically (Heney, 1996).
- Using simplications (Ur, 1996).
- Reviewing frequently (Richard-Amato & Snow, 1992).
- Expanding ideas (Richard-Amato & Snow, 1992).
- Checking for understanding (Richard-Amato & Snow, 1992).
- Providing advanced organizers (Herrell & Jordan 2004).
- Providing a structured review (Oxford, 1990).
- Employing a thematic or interdisciplinary approach (Barba & Reynolds, 1998).
- Integrating technology (Barba & Reynolds, 1998).

Improving comprehensible input

- Using props (Rosenthal, 1996).
- Using graphs (Rosenthal, 1996).
- Using visuals (Rosenthal, 1996).
- Using transparencies (Rosenthal, 1996).
- Using tables (Rosenthal, 1996).
- Using diagrams (Duran et al, 1998).
- Using maps (Rosenthal, 1996).
- Using videos (Rosenthal, 1996).

Assessment

- Assessing using pictures and posters (Tannenbaum, 1996).
- Simplifying the language in test items (Rosenthal, 1996).
- Providing extra time for examinations (Rosenthal, 1996).
- Assisting with interpretation of exam questions and technique (Kothecha et al, 1990).
- Providing a glossary of non-science words or phrases (Abedi et al, 2000)
- Providing a bilingual aide (Gutierrez, 2002).
- Reading the exam paper aloud (Buck, 2000).
- Providing practice at answering questions (Park, 1982).

- Rewriting tests (Cuttell, 1982).
- Providing practice with assessment language (O'Toole, 1992).
- Reviewing tests from a sociocultural perspective (Cuttell, 1982).
- Demonstrating physically (Tannenbaum, 1996).
- KWL charts (Tannenbaum, 1996).
- Collecting a portfolio of work (Tannenbaum, 1996).
- Looking for meaning rather than English expression (Rosenthal, 1996).

<u>Student</u>
- Helping the student understand how a more experienced person connects ideas (Rosenthal, 1996).
- Assisting with information gathering (Kothecha et al, 1990).
- Accepting an oral performance or presentation (Tannenbaum, 1996).
- Accepting group laboratory reports (Rosenthal, 1996).
- Accepting an oral response to exam questions (Buck, 2000).

Student strategies to address general communicative competence

- Creating wordbanks (Heney, 1996).
- Undergoing training in language learning strategies (Chamot & O'Malley, 1994).
- Expressing needs (Oxford, 1994)
- Taking part in reading activities (Ur, 1996).
- Taking part in writing activities (Ur, 1996).
- Taking part in listening activities (Ur, 1996).
- Taking part in speaking activities (Ur, 1996).
- Taking part in spelling activities (Ur, 1996).
- Highlighting important terms (Oxford, 1990).

Student strategies to address grammatical competence.

- Using the first language as a base for understanding the second language (O'Malley & Chamot, 1990).
- Grouping material by common attributes (O'Malley & Chamot, 1990).

Student strategies to address discourse competence

- Placing new words in context (Oxford, 1990).
- Relating language to real life models (Oxford, 1990).
- Imitating a language model (O'Malley & Chamot, 1990).
- Consciously applying rules (O'Malley & Chamot, 1990).

Student strategies to address sociolinguistic competence

- Asking for clarification (Carrasquillo & Rodriquez, 2002
- Asking for correction (Oxford, 1990).
- Cooperating with peers (Rosenthal, 1996).
- Cooperating with proficient users of the new language (Rosenthal, 1996).
- Developing cultural understanding (Oxford, 1990).
- Becoming aware of others' thoughts and feelings (Oxford, 1990).

Student strategies to address strategic competence

- Using an electronic translator (Carrasquillo & Rodriquez, 2002).
- Using a glossary (Stansfield & Rivera, 2001).
- Creating a list of newly encountered words (Heney, 1996).
- Using a dictionary (Oxford, 1990).
- Understanding the conditions that help one learn and arranging for them to be present (O'Malley & Chamot, 1990).
- Relating new information to visual concepts (O'Malley & Chamot, 1990).
- Using available information to guess meanings of new items (O'Malley & Chamot, 1990).
- Delaying speech production in order to learn by listening (O'Malley & Chamot, 1990).

Student strategies to address participative competence

- Presenting information verbally and visually (Rosenthal, 1996).
- Checking for understanding (Rosenthal, 1996).
- Asking for repetition and meaning (Oxford, 1990).

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Student strategies to address interactional competence

- Practising verbal interaction in partner work (Duran et al, 1998).
- Participating in discussions (Chamot & O'Malley, 1990).
- Providing feedback (Rosenthal, 1996).
- Expressing an opinion (Rosenthal, 1996).
- Verifying results (Gutierrez, 2002).
- Explaining reasoning (Gutierrez, 2002).
- Participating in group work (Buck, 2000).
- Participating in practical work (Gutierrez, 2002).
- Taking into account a person's culture (Oxford, 1990).
- Building a rapport with other students (Chamot & O'Malley, 1990).
- Telling others how to do things (Buck, 2000).

Student strategies to address academic competence

- Constructing and expressing points of view (Tiffunoff & Ward, 1991).
- Rephrasing language for clarity (Oxford, 1990).
- Using simplications (Carrasquillo & Rodriquez, 2002)
- Demonstrating new vocabulary with objects and actions (Carrasquillo & Rodriquez, 2002)
- Practising with scientific discourse, for example passive voice, past tense, third person (O'Toole, 1992).
- Practising scientific functions for example questioning, investigating, observing, classifying, collecting and analysing data (O'Toole, 1992).
- Practising with some language functions such as reflecting, predicting, inferencing, and hypothesizing (O'Toole, 1992).
- Demonstrating new concepts with hands on experiments and activities (Buck, 2000)
- Choosing examination questions involving diagrams and graphs (Buck, 2000).
- Responding orally to examination questions (Buck, 2000).
- Using advanced organizers, matrixes and retrieval charts (O'Malley & Chamot, 1990).
- Reflecting on learning with a learning log (Herrell & Jordan, 2004).
- Deciding in advance to attend in general and to ignore irrelevant distractors (O'Malley & Chamot, 1990).
- Using props (Carrasquillo & Rodriquez, 2002).

- Using graphs (Carrasquillo & Rodriquez, 2002).
- Using visuals (Rosenthal, 1996).
- Using tables (Heney, 1996).
- Using diagrams (Buck, 2000).
- Using maps (Rosenthal, 1996).
- Omitting difficult material (Gutierrez, 2002).
- Using matching activities (Herrell & Jordan 2004).
- Sequencing ideas logically (Chamot & O'Malley, 1990)
- Reviewing frequently (Heney, 1996).
- Expanding ideas (Richard- Amato & Snow, 1992).
- Checking for understanding (Rosenthal, 1996).
- Writing down the main ideas (O'Malley & Chamot, 1990).

Appendix C
Aya's words

Aya's words

Word	Word	Word	Word
Absurdly	butcher's paper	domestic	gruff
Accumulate	callous	doting parents	hacksaw
agenda	carcass	driftwood spear	heady
ageist	cat-o'-nine-tails	dry dock	hold your horses
airhead	charwoman	dry legumes	homogenised
albumin proteins	chucked	duffle coat	hormone
Al Jonson	coagulation	ecstatic	hostile
already into the turps	complacency	eh?	hostile stares
ambitious	conniving	elude	hue
amputee	contrary	engrossed	imminent
anaesthetised	convulsed	entourage chortled	immobile
anarchist	copious	epiphany	impervious
aneurism	counteract shock	episodically	inept
angst	cowlick	estrangement	inorganic substances
antibody	craters on the moon	eternal	insulin
antigen	crypt-like	excerpt	insistent noise
apprentice	crescendo	fair dinkum	instigate
arbitrarily	cultishly	falsetto	intact skin
arrogant	cumulus	fib	interminable
arterioles	cyst	fickle	interstitial fluid
autonomously	Czerny, Carl	fiddle-scraping	intervened
azure	dais	flippant	introverted
ballistic	deceitfully	fossicked	inventiveness
bare birches	deadpan voice	fugitives from justice	ion
battered tome	degenerates	gag	irony
becalmed	delectable	garbled	irredeemably smug
bemused	delinquent	gawky	jargon
bereavement	delusional	Gilbert and Sullivan	jeopardy
bespectacled	diabetes	triumphs	jeopardising
big yakka	diapers	gilded	kneading
bloke	diastole	gleanings	levitated
Bob's your uncle	din of applause	Glenelg tram	leviathan buttresses
bobbsey twins	discotheque décor	glissade	looks like
bonza	disc jockey patter	gnarled	everybody's kicked a
bourgeoisie	disembarkation point	golden glove	goal
bowels	disgorging	champion	lymphatic tissue
brood	dismally	gramophone cabinet	lysosome
budgerigar	distressed	gravelly	maintenance dodgers
bulge	diverged	greasy wop	manifestation

Word	Word	Word	Word
marooned	push bike	surreal	
martyr	quarantine station	surrealism	
massacre	rapture	systole	
matriculation class	rear-view	tell him he's	
menacing	rebel	dreaming	
microbes	reconcile	temperate wheat	
misapprehension	record jacket	country	
modified	redundancy	tentatively	
monsoon of beer	reeling	terminus	
mop	reluctantly	territorians	
mugger	remedy	thawed	
mundane	replenished	tithe	
mystic	reprieve	tolling for mass	
niche	retaliating	tonsils	
normalcy	reticulation systems	too much sugar	
not cutting anyone's	retort	top end	
lunch	reverie	torpor	
nucleated	rhapsodising	traits	
nunnery	rhetoric	tribesman	
obscene	sarcophagus	trivia	
offal	sawed	truanting	
opting	scaffold	turmoil	
organic substances	schnozzer	unethical	
outmuscled	seething	uninhabitable	
oversupply	shock	vacillate	
paced	shove it	vasoconstriction	
pancreas	sing-song voice	Vatican	
panel van	schnapps	venules	
paradigm	snickering	wane	
paraliturgy	snide	ward rounds	
patriarchal	somber bell	we do it this way	
perpetrators	sorority	western oriental	
pisspot	southerners	wheat-belt towns	
placating	southern comfort	white panama	
plodders	spurning	wog	
ploy	squabble	yobbo	
plying	squandering	you ripper	
precede	stirs		
prevailed	stealthily		
profusion	stern		
proletariat	strung		
prominent	subliminal		
put in the laundry	techniques		
pseudopodia	suffering your joke		

Appendix D
Aya's Glossary

GLOSSARY

Absurdly   ridiculously, oddly. *He was behaving absurdly when he jumped so high into the air.*

Agenda   a program or list of things to be done. *The agenda for the House meeting listed a number of things to be done.*

Ageist   a person who discriminates on the basis of age. *When she did not get the job because she was 18 she called the manager ageist.*

Airhead   a person who is a dreamer or does not think clearly. The word implies that their head is full of air instead of brains. *She was acting like an airhead when she could not remember her pin number.*

Albumin proteins   water soluble proteins found in the blood.

Al Jonson   an American stage and film performer who lived from 1886- 1950. In 1927 he starred in a musical film called the *Jazz Singer* which was the first important film with sound. He used to black his face and sing in a minstrel style.

Already into the turps   a person who is already drinking large quantities of alcohol. Turps refers to turpentine which is a substance with an alcoholic base used to remove paint. Only an alcoholic would drink this. Even though it was only 10 o'clock in the morning he was already on the turps.

Ambitious   determined to do well, pushy, motivated. *He progressed quickly in the company because he was so ambitious.*

Amputee   a person or animal that has lost an arm or a leg. *John became an amputee after the car accident.*

Anaesthetised   a loss of sense, feeling or pain. It is usually caused by a drug. You need to be anaesthetised to have an operation. *The dentist anaesthetised my tooth before doing the filling.*

Anarchist   a person who is a rebel and promotes confusion and general disorder. *The anarchist burnt down the palace.*

Aneurism	a swelling in an artery caused by a weakness in the wall.
Angst	a feeling of dread or fear. *Many kids suffer from angst and acne.*
Antibody	a protein produced by an organism to counteract harmful invaders or *antigens*.
Antigen	a foreign substance (like a protein or a bacterium) which is introduced into a living thing which causes a defence response like the production of *antibodies*.
Apprentice	a trainee or learner. *The apprentice hairdresser is only allowed to wash hair.*
Arbitrarily dispensed	given out randomly or by chance. *The perfume samples were arbitrarily dispensed to the crowd.*
Arrogant	appearing superior or overconfident. *The boss' son was arrogant to all the employees.*
Arterioles	a small artery.
Autonomously	1. self-governing, independent or governed by its own laws. 2. to do things for yourself. *The tuckshop at the school was run autonomously.*
Azure	of a sky blue colour. *That azure shirt goes well with her blonde hair.*
Ballistic	1. related to bullets, shells and bombs. 2. Explosive eg *she went ballistic* – she was very angry.
Bare birches	a birch is a kind of tree and if it is bare it has shed its leaves. *There was no place for the bird to build its nest in the bare birches.*
Battered tome	worn out volume of a book.
Becalmed	at a standstill, stuck. *When the wind dropped the sailing ship was becalmed.*
Bemused	confused, puzzled, mystified or bewildered. *The joke left him bemused.*

Bereavement	a loss due to death. *Bereavement is the grief you feel when a close friend dies.*
Bespectacled	a person who wears glasses or spectacles. *The bespectacled boy looked intelligent.*
Big yakka	hard work. *That looks like hard yakka. (Colloquialism)*
Bloke	fellow, man eg *he's a good bloke.*
Bob's your uncle	everything is perfect, going extremely well and as planned.
Bobbsey twins	a family with two sets of twins who appeared in numerous children's novels. They were always having adventures.
Bonza	excellent, very good. *That was a bonza meal. (Colloquialism)*
Bourgeoisie	1. the middle class or someone whose outlook is determined by property values 2. lacking in elegance 3. conventional. *The princess was frowned upon for marrying a bourgeoisie.*
Bowels	intestines or insides. *The small and large bowels are another name for the large and small intestine. Her classroom was in the bowels of the school.* This means it was at the bottom of a building.
Brood	1. to worry about or think deeply about 2. a group of. *1. Do not brood over lost opportunities. 2. The hen drove the intruders away from her brood of chickens.*
Budgerigar	small parrot which is often yellow and green in colour. *The boy had a pet budgerigar.*
Bulge	to stick out or a big bump. *What is that bulge in your pocket? The Christmas stocking bulged with presents.*
Butcher's paper	cheap white paper which is used by butchers to wrap up meat. Because it is inexpensive, it is often used for brainstorming ideas in classrooms.
Callous	heartless, cold-hearted, unfeeling. *Years of pain made him a callous man.*

Carcass	dead remains or body of an animal. *The vultures were picking at the carcass of the dead kangaroo.*
Cat-o'-nine-tails	whip.
Charwoman	a cleaner. *The charwoman cleans the house every Tuesday.*
Chucked	1. vomit 2. throw. *He chucked the ball. After he got food poisoning he chucked. (Colloquialism)*
Coagulation	to change from a fluid to a thickened mass eg when blood clots. *Platelets and other blood proteins are involved in blood coagulation.*
Complacency	a feeling of quiet pleasure or satisfaction. *When you know your work a feeling of complacency comes over you.*
Conniving	making secret plans to get things for themselves. *The conniving man was left all his uncle's money when he died.*
Contrary	opposite or different. *Contrary to what you are saying it is in your best interests to continue your study in Ancient History.*
Convulsed	1. shaking violently 2. laughing violently. *1. During an epileptic fit the boy convulsed. 2. We were convulsed with laughter when we saw what he had done.*
Copious	a large quantity or number. *On a hot day you need to drink copious glasses of water.*
Counteract shock	to help reverse the changes which occur during *shock. He required a blood transfusion to counteract the shock.*
Cowlick	a tuft of hair turned up over the forehead of a person. *A cowlick is a little piece of hair that sticks up.*
Craters in the moon	a hole on the surface of the moon. Because the moon has no pocket of gas or atmosphere surrounding it, any junk from space hits the surface and leaves a large void or hole. *Note: If a big enough piece of rock hits the Earth it can leave a crater – there is one on Arizona.*

Crypt-like	a crypt is a burial place under the main floor of the church. Crypt-like probably means a dark, cold and scary room.
Crescendo	a gradual increase in force or loudness. *The piece of music reached a crescendo.*
Cult	a religious group with unusual practices or opinions. *The cult believed in worshipping cows.*
Cultishly	alternative, out of the ordinary. *He followed their teachings cultishly.*
Cumulus	1. heap or a pile 2. A cumulus cloud is a big white fluffy cloud.
Czerny, Carl (1791-1857)	Austrian pianist, composer, and teacher, born in Vienna. He was a pupil and friend of Ludwig van Beethoven, and the Hungarian pianist and composer Franz Liszt was one of his students. He composed nearly a thousand works in almost every form, including opera; best known are his sets of progressively difficult piano exercises. Among these are *The School of Fingering* and *The School of Velocity.*
Dais	platform or podium. *She stepped up onto the dais to give her lecture.*
Deceitfully	dishonestly. *He obtained the money deceitfully.*
Deadpan voice	saying something without expression in a monotonous voice. *She told the joke in a deadpan voice.*
Degenerates	get worse, deteriorate, collapse or break down. *Her condition will gradually degenerate if she does not take the doctor's advice.*
Delectable	delicious, delightful or pleasing. *This chocolate is delectable.*
Delinquent	1. not doing your duty. 2. a young person who does the wrong thing or is antisocial. *The delinquent student graffitied the locker room.*

Delusional	imagining, a fantasy, a mirage. *You are delusional if you think all students do their homework.*
Diabetes	a disease caused by insufficient production of the *hormone insulin* in the *pancreas.* It results in increased blood sugar, which is lost in the urine. The sugar is needed for energy in the body.
Diapers	an American term for baby's nappies. *The baby only wore a diaper.*
Diastole	part of the cycle of the heart during which the ventricles relax and receive blood from the atria.
Din of applause	the din (loud noise) of clapping. *After the play the din of applause hurt her ears.*
Disc jockey patter	disc jockeys are people who play music for others usually on the radio or sometimes at a party. Between songs they talk quickly and try to be amusing. This talk is called "patter".
Discotheque décor	a discotheque is a nightclub. The décor is the decoration or furnishings of the club.
Disembarkation point	the place where you get off eg where a boat, train, plane or bus stops.
Disgorging	1. to eject or throw out 2. to give up unwillingly. *We can see where the ground is opening up and disgorging molten lava.*
Dismally	gloomily, miserably, bleakly. *She looked dismally at all the homework she had for the weekend.*
Distressed	upset, troubled. *She was very distressed when she thought she had hurt her friend's feelings.*
Diverged	to move in different directions. *The road diverged at the corner.*
Domestic	home or within the country. 1. *Her plane to Melbourne left from the domestic terminal. 2. She studied sewing and cooking in domestic science at school.*

Doting parents	devoted, loving, fond parents. *Her doing parents gave her a car for her 18th birthday.*
Driftwood spear	a long sharp piece of wood washed up on the beach.
Dry dock	a place where is a ship is taken out of the water to be repaired.
Dry legumes	a plant from the pea family which is used for food, feed or soli improvement. If it is dried the water has been removed or evaporated.
Duffle coat	a heavy woollen coat, knee length, with a hood and wooden toggles for buttons.
Ecstatic	very happy, overjoyed, delighted or thrilled. *The girl was ecstatic when she received her biology results.*
Eh?	I did not understand your meaning.
Elude	get away from or escape. *The bank robber continues to elude police.*
Engrossed	to be completely involved, occupied or absorbed in. *The little boy was engrossed in the book.*
Entourage chortled	the group of people attending laughed or chuckled. *The entourage around the movie star chortled at his every joke.*
Epiphany	1. coming to an understanding 2. a Christian feast day which remembers the wise men visiting the baby Jesus. *He had an epiphany on the way to work and decided to quit his job and go travelling.*
Episodically	at regular intervals, like clockwork. *He fears returned episodically.*
Estrangement	separation, division or rift. *The estrangement between his parents made the little boy very unhappy.*
Eternal	lasts forever. *The eternal flame burns in Anzac Square to help us to remember the soldiers that have died in the wars.*

Excerpt	a short part taken from a speech, book, etc. *This excerpt was taken from the bible.*
Falsetto	a high voice. *One of the Bee Gees always sang falsetto.*
Fair dinkum	genuine, real, authentic, the truth. *He was always fair dinkum in his dealings with others. (Colloquialism)*
Fib	a little lie or untruth. *He was telling a fib when he said that the dog had eaten his homework.*
Fickle	inconsistent or changeable. *His feelings for the girl were fickle.*
Fiddle-scraping	playing the violin.
Flippant	frivolous, superficial, offhand. *His answer to the serious questions was too flippant.*
Fossicked	searched for. *He fossicked for his pencil case in the bottom of his bag.*
Fugitives from justice	someone who has run away from the law. *The bank robbers were fugitives from justice.*
Gag	1. to choke or cough 2. a joke. 1. *When the dentist took an impression of her mouth it made her gag.* 2. *She told a funny gag.*
Garbled	jumbled, confused, not clear. *The witness gave a garbled account of what had happened.*
Gawky	awkward, clumsy, inelegant. *He looked a bit gawky in his new suit.*
Gilbert and Sullivan triumphs	Gilbert and Sullivan were two English musicians who wrote a number of famous light operas in the 19th century. Some examples of their best ones or triumphs are the *Mikado* and *Pirates of Penzance*.
Gilded	covered with gold. *The ring was not pure gold but only gilded.*
Gleaning	things that have been discovered or found out. *We are gleaning information from all sources.*

Glenelg tram	this is a tram which travels on rails from central Adelaide to the seaside suburb of Glenelg. *A tram is a form of public transport powered by electricity.*
Glissade	a sliding or gliding step in a dance or when skiing.
Gnarled	having a knotty appearance eg a bump on the side of a tree. *The arthritis made her hands look gnarled.*
Golden glove champion	a golden glove competition is an amateur (not for money) boxing competition. The champion is the winner of that competition.
Gravelly	1. lots of little stones 2. harsh or deep and rough eg *He spoke in a* gravelly voice when he had a cold.
Gramophone cabinet	a piece of furniture which contains a record player or disc spinner.
Greasy wop	an insulting term for a person of Italian or Greek origin.
Gruff	1. low and harsh eg a gruff voice 2. bad-tempered and grumpy, rough and surly eg *She is a very gruff person.*
Hacksaw	a tool used for cutting metal.
Heady	thrilling, exciting, simulating. *The rollercoaster was a heady experience.*
Hold your horses	wait. (Colloquialism)
Homogenised	all the parts are the same throughout eg *We always get homogenised milk.*
Hormone	a chemical messenger which is produced in one part of the body but acts in another part eg insulin is produced in the pancreas but promotes uptake of sugar by all cells of the body.
Hostile	unfriendly, an enemy that is against you in feeling or action. *Captain Cook found that the natives were hostile.*
Hostile stares	unfriendly looks. *The natives gave him hostile stares.*

Hue	colour *The summer collection includes tops of natural hues and fibres.*
Imminent	likely to occur at any moment. *The storm is imminent.*
Immobile	not moving. *Plants are largely immobile.*
Impervious	does not allow things to get in or not accessible.
Inept	incompetent, useless or hopeless. *The boy was completely inept at writing.*
Inhabitants	people who live there. *The inhabitants of the island were very friendly.*
Inorganic substances	generally do not contain carbon or are not made up of branching carbon chains. Eg CO_2, CO and H_2O are inorganic substances.
Insulin	a *hormone*, which controls blood sugar concentration and other bodily processes.
Insistent noise	a continuing noise – one that will not stop and is annoying. *The insistent noise of the practising band drove us crazy.*
Instigate	start or bring about. *The teacher instigated the beginning of a science club in the school.*
Intact skin	skin which has no breaks in the surface where micro-organisms (germs) could enter the body. *The skin provides an intact layer which protects us from germs.*
Interminable	endless – goes on forever. *The interminable noise of the party annoyed us all night.*
Interstitial fluid	the fluid in which all the cells are bathed. *Interstitial fluid surrounds all cells.*
Intervened	to come between, interfere or interrupt. *The teacher intervened before the fight got out of hand.*
Introverted	shy, reserved or quiet. *She is so introverted that she hates having to speak in class.*

Inventiveness	resourcefulness, creativeness, originality. *His inventiveness at coming up with excuses for not doing his homework surprises us all.*
Irony	when the meaning or outcome is the opposite of that intended, sarcasm. There seemed to be no hint of irony in his voice.
Irredeemably smug	hopelessly full of yourself. *She appeared irredeemably smug when she was made a captain of the House.*
Jargon	special terminology or language eg scientific jargon refers to the terms or special words that a science uses. *Any area of study or work has its own special jargon. For example computing jargon includes: Byte, email, font, Times new Roman.*
Jeopardising	to put at risk. *By bringing alcohol to the formal the student was jeopardising the whole event.*
Jeopardy	danger, risk, peril. *The terrorists put the tourists' lives in jeopardy.*
Kneading	to press and fold eg with the dough for making bread. *He is kneading the dough to make a pizza base.*
Levitated	to rise or float in the air. *The body appeared to levitate into the air and float across the room.*
Leviathan buttresses	huge size structure which props up or supports. *The side of the church had leviathan buttresses.*
Looks like everybody's kicked a goal	Everyone has achieved something special. (Literally means everyone has kicked a football over the posts.)
Lymphatic tissue	a network of cells which produces white blood cells to fight infection in the body.
Lysosome	small organelle which contains enzymes for intracellular digestion (within the cell).
Maintenance dodgers	a person who is not paying their divorced wife and family the money they should. It is against the law to do this.

Manifestation	1. appearance 2. evident or obvious 3. a public demonstration as for a political event. *There are different manifestations of a disease like AIDS. The girl claimed to have seen a manifestation of an angel.*
Martyr	someone who suffers for a principle or the benefit of others. *The martyr was killed for he believed in.*
Massacre	mass murder or slaughter. *The army caused a massacre in the town square.*
Matriculation class	the year at school which it is necessary to pass in order to gain entrance into university – year 12.
Menacing	bothering or dangerous. *He had a menacing look on his face.*
Misapprehension	misunderstanding, the wrong idea, a false impression. *She was suffering from a misapprehension when she thought I was angry with her.*
Monsoon of beer(?)	a huge amount of beer.
Mop	to rub, wipe, clean or remove. *I will mop up the acid I spilt on the desk.*
Marooned	stranded *I was marooned on the island.*
Mugger	a person who steals violently. *The mugger stole the old lady's purse.*
Mundane	ordinary, dull, routine, everyday. *Everything that happened today was mundane. It was a mundane day.*
Mystic	1. of a mysterious nature 2. a person who claims to have insight into spiritual knowledge. *The mystic was called in to help solve the murder.*
Niche	a place or position suitable for a person or thing. 1. *Aya has found her niche as a science student. 2. The whale has a special niche in the food chain.*
Normalcy	being normal or usual. *Underneath this image of normalcy, divorce threatened to tear the family apart.*

Not cutting anyone's lunch not interfering with something that isn't yours. (Colloquialism)

Nucleated a cell with a nucleus. Frog's red blood cells are nucleated whereas human red blood cells are not.

Nunnery a convent or a place where nuns live.

Obscene offensive or disgusting. *The boy who used obscene language was asked to leave the party.*

Offal internal organs of animals used for food eg brains, liver, kidney and heart. *You could have steak and offal pie for breakfast.*

Opts choses or decides *I opt to study biology.*

Organic substances Complex compounds containing carbon. Living things are made of organic substances like proteins, carbohydrates or fats.

Outmuscled was stronger than. *He outmuscled his weaker opponent.*

Oversupply too much of. *We had an oversupply of chocolate at the lolly stall.*

Paced stepped out. *He did not want to tire quickly so he paced himself in the beginning.*

Pancreas gland which produces insulin and digestive enzymes.

Panel van a type of car which has only one row of seats and space in the back for sleeping. Often used by surfies for sleeping in at the beach.

Paradigm a set of concepts, or a hypothesis, a theory or an idea.

Paraliturgy a small, modified religious service. *Students prayed and read from the bible at the paraliturgy.*

Patriarchal the male head of a church, family or tribe. Woman - matriarchal.

Perpetrators	the ones who carried it out. *The perpetrators of the crime were punished.*
Pisspot	someone who drinks large quantities of alcohol. (Colloquialism – not a very nice term)
Placating	pacify or calm down. The teacher's arrival had a placating effect on the angry class.
Plodder	a slow but effective worker. He is a plodder with his school work.
Ploy	a trick or a plan to gain advantage. *That was just a ploy to get my permission.*
Plying	1. to work (to ply one's trade) 2. to provide with a lot (to ply a person with alcohol). *He is plying me with delicious food so I will allow him to go.*
Precede	to come before. *That chapter precedes the one on the kidney.*
Prevailed	1. to persuade 2. to exist everywhere eg silence prevailed 3. to triumph 3. to be superior to. *I was prevailed upon to take another class.*
Profusion	abundance or large amount. There was a profusion of mosquitoes after the rain.
Proletariat	In socialist theory the proletariat is the working class.
Prominent	important or easily seen. That girl has a prominent nose.
Pseudopodium	a temporary protrusion (something that sticks out) of cytoplasm of a cell. The word literally means "false foot." Amoeba use pseudopodia for movement.
Push bike	an old term used to describe a bicycle.
Put in the laundry	to send something to get washed. *My mother says to put my dirty clothes in the laundry.*
Quarantine station	a building where people, animals or plants who are coming from overseas are kept isolation to prevent the spread of disease.

Rapture	joy or delight, *ecstatically* joyful. *Her rapture in his present was clear to everyone.*
Rearview	the view out the back eg looking in the rearview mirror in a car shows you what is behind.
Rebel	radical or revolutionary person.
Reconcile	settle, reunite, bring together or resolve.
Record jacket	the cardboard cover for musical records (the big black flat round things before CDs and tapes)
Redundancy	unemployment or job loss; something extra which is not needed. *They offered him a redundancy package when he was no longer needed at work.*
Reeling	1. to have a sensation of whirling or swaying 2. to wind around something circular. *The shock of the accident left him reeling.*
Reluctantly	unwillingly or unenthusiastically. *She left the class reluctantly to go to her music lesson.*
Remedy	solution, cure or answer. 1. *By offering her a second chance he hoped to remedy the situation.* 2. *The flu remedy did not really work.*
Replenished	replaced. *After they had been on camp their water supplies need to be replenished.*
Reprieve	a pardon or being let off. *He was offered a reprieve because of his work in the community.*
Retaliating	to hit back or strike back eg if a person injures you do the same to them. *When he hit the boy he was just retaliating because of what had been done to him.*
Reticulation systems	systems which transport services through a network eg water through the pipes of a building. *Blood vessels form a reticulation system throughout the body.*
Retort	reply angrily. *She retorted angrily tot eh suggestion that she had cheated.*

Reverie	a state of dreamy meditation. *She came out of her reverie and back into the real world.*
Rhapsodising	expressing great joy or enthusiasm. *She was rhapsodising over the play she had just seen.*
Rhetoric	special way to use language eg to use language to influence listeners. *The prime minister was well known for his rhetoric.*
Sarcophagus	stone coffin. *The church contained a sarcophagus where a knight from the 12th century had been buried.*
Sawed	cut through with a zigzag blade. *The tree was sawed down.*
Scaffold	to support. *The scaffold was used by the builders to repair the house. A good teacher scaffolds new language with diagrams when she introduces it.*
Schnozzer	a big nose. *Derek has a schnozzer. (Colloquialism)*
Seething	1. crowded, full, packed 2. furious or very angry. *When Sally found out what Betty had said about her she was seething.*
Shock	1.a progressive condition in which insufficient circulation of blood to the brain or tissues can lead to collapse or death 2. Horrified by what has happened. *I was shocked to hear what had happened in the accident.*
Shove it	dismiss it or get rid of it. *I told her to shove it. (Colloquialism)*
Sing-song voice	a voice which goes up and down. *The children said good morning to the teacher in a sing-song voice.*
Schnapps	an alcoholic drink based on gin.
Snickering	a little laugh. *He was snickering behind his hand at the joke.*
Snide	in a manner which is not very nice. *During the lecture he made a snide remark about the lecturer's clothes.*

Spurning	to look down on or reject. *He is spurning her love for him.*
Sombre bell	a bell ringing for a sad reason eg someone has died.
Sorority	a society or club for woman or girls as in a college.
Southerners	people who live in the South of Australia eg in Tasmania, Victoria or South Australia.
Southern Comfort	a sweet strong alcoholic drink.
Squandering	to waste. *By not studying he is squandering his chance of getting to university.*
Stirs	1. move around 2. cause trouble. *That girl is stirring the teacher by asking those silly questions.*
Stealthily	to carry out in a secret manner. *The thief crept stealthily off into the night.*
Stern	strict or firm. *That teacher gets a stern expression on her face when she is angry.*
	StrungSpread out. *The washing was strung out on the line.*
Squabble	argue or quarrel. *The squabble seemed to be about the party on Saturday night.*

Subliminal techniques things that happen without a person being aware eg with subliminal advertising a person is not conscious that they are being persuaded to buy something.

Suffering your joke (?) Having to listening to a bad joke.

Surreal	strange, bizarre, unreal. *The play was a surreal experience.*
Surrealism	a movement in literature or art which is based on imagination not controlled by reason.
Systole	part of the cycle of the heart during which the ventricles contract and force blood into the arteries.

Tell him he's dreaming imagining or believing in an unrealistic manner.

Temperate wheat country the temperate zone is the part of the Earth's surface the tropics and the polar circle; wheat grows well in this area.

Tentatively cautiously, carefully or uncertainly. *She tentatively opened the door.*

Terminus finishing point, the last stop or the end of the line. She stayed on the bus all the way to the terminus.

Territorians people who live in the Northern Territory of Australia.

Thawed unfrozen. She thawed out the meat by putting it in the microwave.

Tithe a tenth of a person's wages (money that they earn) or produce which is given to a body like the church.

Tolling for mass(?) Bell ringing for catholic church service.

Too much sugar sugars like glucose are needed for energy in all cells of the body. If there is not enough *insulin* the sugars so not get into the body cells but stay in the blood resulting in too much blood sugar. The sugar needs to be in the cells for energy.

Tonsils areas of *lymphatic tissue* found at the back of the mouth and behind the nose.

Top End the top or northern part of Australia.

Torpor feeling tired and having no energy, being inactive. *He has slumped into a state of torpor and we could not wake him.*

Traits characteristics or qualities. *She has many admirable traits.*

Tribesman a member of a tribe or related group of people.

Trivia 1. details or finer points 2. not important. *Girls' fashion magazines are often filled with trivia.*

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Truanting	being absent or not attending school or work, wagging. *He hates school and is often caught truanting.*
Unethical	immoral, wrong, bad. *If a doctor talks about his patients to others he is being unethical.*
Uninhabitable	not fit to live in. The house was *uninhabitable.*
Vacillate	waver or hesitate. *She vacillates between wanting to go and wanting to stay home.*
Vasoconstriction	blood vessels get smaller in diameter.
Vatican	home of the Catholic Church in Rome – where the Pope lives and rules.
Venules	small veins.
Ward rounds	when medical persons like doctors or nurses go around reviewing all the patients in the ward of a hospital. A ward is a special section of the hospital where people with similar illnesses are kept. Eg the maternity ward is where mothers and babies are.
We do it this way	probably refers to local customs of a particular area.
Western oriental	a person from the East or Middle East eg India who now lives in the West.
Wheat-belt towns	towns found in the wheat growing area. Belt means a strip.
White panama	a white straw hat.
Within the cyst	A cyst is a fluid filled sac in the body. Sometimes other material can be found in the middle of the cyst. For example a cyst in the ovary can contain bits of hair or even teeth.
Wog	1. disease or a germ 2. a derogatory (not very nice) term for a person of Italian or Greek extraction.
Yobbo	uncouth ruffian or a lout.
You ripper	admirable (good) person or thing. *(Colloquialism)*

Wane

1. get smaller 2. pale and sick. *His interest in tennis is beginning to wane. She looks wane.*

Appendix E
Patricia's Glossary

Patricia's Glossary

Abolition	closing down or ending. *The government insisted on the abolition of slavery.*
Acquaintance	someone you have met and know slightly but not well. *He waved to the person in the distance who was an old acquaintance of his.*
Acquire	get, obtain, gain. *She acquired a very good understanding of Ecology by reading her notes.*
Adolescent	teenage or young person. *Being an adolescent can be difficult sometimes.*
Aerial	airborne or above. *The aerial photograph showed all the rivers in the area.*
Altered	changed. *Her new haircut altered her appearance completely. In genetic engineering genes are altered.*
Analogy	a likeness or similarity. *If you make an analogy between two things you show that they are alike in some way. The teacher used an analogy to explain electric current by comparing it to water in a pipe.*
Appraise	Assess or evaluate. *The teacher will appraise our performance in the lab.*
Arboreal	lives in trees. *Monkeys are arboreal.*
Arced	curved. *The rainbow arced across the sky.*
Assertion	declaration, statement or claim. *He made the assertion that he had been unfairly treated.*
Assimilation	becoming part of or fitting in. *The assimilation of the new student was going well.*
Bachelor	single person usually male, not married. *Even though he was sixty years old the bachelor still lived with his mother.*
Bales	large quantities of something. *The bales of hay were left in the field.*

Beggar	a tramp or homeless person. *The beggar sat on the street asking people for money.*
Bulge	to stick out or a big bump. *What is that bulge in your pocket? The Christmas stocking bulged with presents.*
Benign	1. kind and caring. *The king was regarded as a benign monarch.* 2. does not cause harm. *The woman was very pleased when the doctor said her tumour was benign.*
Burrow	A burrow (noun) is a tunnel or a hole in the ground dug by animal like a rabbit. *The frogs burrow (verb) into the ground so they do not lose too much water.*
Canopy	A layer of something that spreads out and covers an area. *The tall trees in the forest formed such a dense canopy that little sunlight reached the ground.*
Capacity	ability. *The area of land had the capacity to support 10 head of cattle.*
Captivity	being imprisoned or enclosed. *When the baby panda was born at the zoo it was the first to be born in captivity for a long time.*
Cargo	load, shipment. *The cargo of the ship or plane is the goods it is carrying.*
Charred	burnt. *John liked his steak to be charred on the outside and raw in the middle.*
Combustion	a reaction when something is burnt in air or oxygen. *The combustion of petrol results in greenhouse gases being released into the atmosphere.*
Companionway	is a staircase or ladder that leads from one deck to another on a ship.
Composition	is the way something is made up. *The composition of the Biology class is three boys and five girls.*
Convey	communicate, put across, put into words. *I tried to convey how the process of photosynthesis works to the class.*

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Conviction	1. a firm belief. *It is our firm conviction that he should be released form prison.* 2. If someone has a conviction they have been found guilty of a crime. *He had a conviction for drink driving recorded against him.*
Corpse	a dead body. *The murder victim's corpse was examined for evidence at the post mortem.*
Correspondence	messages, mail, letters, emails. *He carried out a long correspondence with his tutor about his research.*
Crevices	a gap or tiny space. *Many birds made nests in the crevices of the cliffs.*
Cyanophytes	bacteria which have pigments that allow them to photosynthesize.
Dabbed	apply or wipe on a small amount. *My mother dabbed her hand cream on.*
Dally	hang around or dawdle. *The teacher told the students not to dally near the toilet block.*
Destruction	ruin or damage. *Destruction of the rainforest meant that the habitats of several birds were destroyed.*
Dinghy	a small boat. Many children learn to sail in a dinghy.
Dismal	gloomy, miserable, bleak. *She felt dismal when she saw all the homework she had for the weekend.*
Distribution	1. The distribution of something is how much of it there is in each place or a each time. 2. the regions in which as species is found. *The distribution of crocodiles in Queensland is limited to the north.*
Diurnal	Active during the day. *Animals that are awake at night are said to be nocturnal while humans are diurnal.*
Drained	water moves away easily. *Some plants will only grow in well drained soil.*
Dread	fear, terror or anxiety. *He has a dread of biology exams.*

Dusk	sunset. *The kangaroos went down to the creek to drink at dusk.*
Ectothermic	Gaining heat from the outside environment (cold-blooded). *Snakes are said to be ectothermic.*
Eligible	Someone who is eligible for something is entitled or able to have it. *He was eligible for an extra tax return.*
Endothermic	Gaining heat from within. *Because humans are endothermic they are able to maintain a constant body temperature.*
Encroachment	If something encroaches it spreads or takes over more and more of that place. *The slow encroachment of rabbits into central Australia meant that there was less food for native species like kangaroos.*
Erosion	Erosion is the gradual destruction and removal of rock or soil by rivers, waves or wind. *After the storm the beach erosion was very bad.*
Eutrophication	the build up of nutrients like phosphates in water, may result in oxygen depletion. *The rain washed the fertilizer into the lake resulting in eutrophication.*
Evaporate	a change of state where a liquid changes to a gas. *Because water evaporates the lake loses 3 meters of water every year.*
Exaggerate	If you exaggerate you make something sound like it is worse or more important than it really is. *Students often exaggerate the amount of homework they have.*
Exerted	apply or use. *He exerted a big force on the car to make it move.*
Exploit	take advantage of. *The boss was accused of exploiting his workers by underpaying them.*
Feign	pretend, put on or fake. *The student feigned illness so she would not have to sit her exams.*
Feral	untamed, undomesticated, wild. *The feral pigs cause problems in the rainforest by killing small mammals.*

Fermentation	a chemical change that takes place which results in alcohol being formed. *Fermentation in grapes results in wine being produced.*
Fiery	burning, hot. *The fiery lava came out of the volcano.*
Forfeit	give up. *Because of a false start he had to forfeit his place on the Olympic team.*
Flinging	throwing around wildly. 1. *After he won the lotto he began flinging money around.* 2. *When he gets upset my little brother flings his arms around.*
Gash	a cut or wound. *He had a nasty gash from where he slipped with a knife.*
Gauge	1. an instrument for measuring. *The rain gauge showed that we had 3mm of rain overnight.* 2. measure. *You can gauge her mood by the expressions on her face.*
Gaunt	thin, boney. *She looked very gaunt after her long illness.*
Gem	jewel. *The ring contained a beautiful blue gem.*
Grazing	when animals graze they eat grass or other plants that are growing in a particular area. *The sheep are grazing in the field.*
Hull	*The hull of the boat is the main body of it.*
Hurling	to throw violently. *The soldier was seen hurling the grenade.*
Illegible	unable to be read. *The boy's handwriting was illegible.*
Immigration	people or animals moving into a particular area or country. *Immigration increases the population in the Springfield area.*
Impaled	pierced or stabbed. *The boy needed surgery after he was impaled on the fence.*
Inflammable	catches fire and burns easily. *Petrol is a highly inflammable liquid*

Intone	chant, drone, sing, to say something in a slow and serious way. *The priests intone the prayer.*
Jutting	sticking out. *From the plane the northern end of the island could be seen jutting into the sea.*
Kelp	seaweed. *When the tide changed lots of kelp was washed up on the beach.*
Lapped	To touch something gently. *The building was right on the river and the water lapped its walls.*
Lee	The lee side of the ship is the one that is away from the wind.
Legislation	laws. *Legislation was passed by the government to protect children's rights.*
Lone	single, solitary, distinct. *The lone tree stood out on the hill.*
Loot	1. rob (v). *The shops were looted after the fire.* 2. proceeds from a robbery (n). *The robber buried the loot in the garden.*
Literature	written material like novels, plays, and poetry. *He is a teacher of English literature.*
Manoeuvre	A skilful movement. *He manoeuvred the car into a very small space.*
Merchant	Someone who sells things. *The tobacco merchant sold the cigars that my father liked.*
Mesmerized	fascinated. *The children were mesmerized by the TV show.*
Modules	small sections. Tom studied some Biology modules as part of his degree.
Mottled	Something that is mottled is covered with several patches of different colours. *When the child had chicken pox his skin was very mottled.*

Milled	when grain is crushed to make flour.
Mischievous	naughty or not well behaved. *The boys in Year 9 are often mischievous.*
Nauseous	feeling sick in the stomach. *The ride in the boat made him feel quite nauseous.*
Neglect	forgotten or overlooked. *The neglected child did not have any lunch to bring to school.*
Negligible	unimportant, minor. *The mistake in his test made a negligible difference to his overall mark.*
Nosing	to look around somewhere that does not belong to you. *The inspector was nosing around the building site to see if there were any faults.*
Nutrient	any substance used as food by an organism. *The breakfast cereal contains many important nutrients.*
Oar	long poles with a flat blade which are used for rowing a boat. *The boy used the oars to row across to the other side of the river.*
Oblige	if you are obliged to do something you are required to do it. *If you borrow a book from the library you are obliged to return it.*
Omitted	gone, left out or not there. *The student omitted to do the last question on the test.*
Pennants	1. a long flag. 2. a flag given to someone who wins a sporting competition. *When he came first in the high jump he was presented with a pennant.*
Phony	fake or not genuine. *He gave a phony excuse for not completing his homework.*
Plausible	believable or likely to be true. *It is plausible that she did not know what was going on.*
Poised	balanced, suspended or hovering. *His finger was poised above the keyboard while he tried to find the correct key.*

Precision	accuracy or exactness. *The student typed with precision.*
Prejudice	discrimination, intolerance, injustice. There is a prejudice against workers over 45 years of age.
Preserve	protect, conserve, safeguard. *The beautiful stretch of beach was worth preserving in its natural state.*
Pursue	follow, chase. *The student wished to pursue a career in medicine*
Quarrel	fight or argument. *The girls had a silly quarrel over what to wear to the party.*
Queue	a line of people that are waiting for something. *The students formed a queue at the tuckshop.*
Raft	a small platform or boat that floats. *The students made a raft out of some planks of wood.*
Random	accidental, haphazard, unsystematic. If you choose someone at random you do not use a particular method. *The sporting competition will conduct random drug samples on the athletes.*
Reluctantly	unwillingly or unenthusiastically. *She left the class reluctantly to go to her music lesson.*
Remnant	remains, left over, trace. *Fossils are remnants of things that were once living.*
Resolute	stubborn, determined, definite. *She remained resolute in speaking Chinese to his friends at lunch time.*
Respectively	in the same order. *The brothers, Sam and David were three and six, respectively.*
Rigging	ropes, chains or wires. *On a ship the rigging supports the sails.*
Roosting	resting for birds and bats. *It was possible to see the birds roosting in the trees for the night.*

Salvage	save, rescue or recover. *After the ship wreck, parts of the boat were salvaged form the beach.*
Scarcely	barely, hardly, not quite or only just. *You could scarcely see the bruise on her arm.*
Scene	prospect, picture, view. *The murder occurred in the third scene of the play.*
Scenery	landscape or surroundings. *There is some beautiful scenery on Stradbroke Island.*
Scrabble	a game which involves making words.
Seared	scorched or baked. *The steak was seared in the pan.*
Sedentary	inactive, sitting around. *The hydra is a sedentary organism found attached to a rock in freshwater.*
Seizing	grab hold of or take hold of. *He was seizing the dog by its collar to hold it back.*
Semaphore	the use of flags to signal messages.
Sergeant	a person in the army or police force.
Severely	harshly, strictly, cruelly. *He was severely punished when he was caught bullying another student.*
Sluggish	slow. *The car was sluggish in the cold weather.*
Snarl	roar, sneer. *The dog snarled at the boy who had hit it.*
Sodden	soaking wet. *Her clothes were sodden after she walked home in the rain.*
Sovereigns	**1. royal family or leaders.** *All of the world sovereigns attended the wedding.* **2. old coins.** *Some gold sovereigns were found in the ship wreck.*
Spars	argue or box. *He spars with his boxing partner.*
Stash	hide or put away. He stashed the proceeds of the robbery in a locker at the railway station.

Stony	rocky. *Instead of being sandy, the beach was stony.*
Stooped	bent over. *The old lady had a stooped back.*
Stow	put away. *She stowed her clothes in the cupboard.*
Subsiding	collapse, drop, sink. *After heavy rain the house was subsiding down the hill.*
Summon	call to. *The student was summoned to the principal's office.*
Surge	rush, flow, pour, gush. *The water surged during the storm.*
Sustain	support, keep up. *The food will sustain the family through the winter.*
Swathe	wrap. *After he was burnt he was swathed in bandages.*
Tendrils	vine or stem. *The tendrils of the vine could be seen climbing the fence.*
Terrestrial	related to the land. *The kangaroo lives in a terrestrial environment.*
Tether	to tie. *He tethered the horse to the fence.*
Thrive	prosper, succeed. *The boy thrived on his success.*
Tomahawk	an axe. *He cut down the tree using his tomahawk.*
Topple	to fall over. *The tree toppled to the ground,*
Torpor	feeling tired and having no energy, being inactive. *He has slumped into a state of torpor and we could not wake him.*
Torso	the middle part of the body not including the head, legs or arms.
Transfixed	fascinated, engrossed. *For hours he stood transfixed.*
Treacherously	deceitfully, dangerously. *The terrorists obtained the money treacherously.*
Trudged	tramp, plod, hike. *He trudged up the steep mountain.*

Unanimously	generally, commonly. *The group accepted the decision unanimously.*
Undulations	wave or crinkle. *The boat sailed over the undulations in the water.*
Unfurling	unrolling. *He was unfurling the flag as the ship sailed out of the harbor.*
Vague	not clear. *She gave a vague explanation of respiration.*
Vengeance	revenge or settling a score. *He swore vengeance on everyone involved in the murder.*
Venture	scheme or project. *He set out on his exciting venture.*
Vessel	boat, ship. *The Australian navy vessel went to war.*
Villain	a bad person. *The villain stole the old people's money.*