ABSTRACT

This study explored three aspects related to ESL students in a mainstream grade 11 biology classroom: 1) the nature of students’ participation in classroom activities, 2) the factors that enhanced or constrained ESL students’ engagement in social interactions, and 3) the role of language in the learning of science. Ten ESL students were observed over an eight-month period in this biology classroom. Data were collected using qualitative research methods such as participant observation, audio-recordings of lessons, field notes, semi-structured interviews, short lesson recall interviews and students’ written work. The study was framed within sociocultural perspectives, particularly the social constructivist perspectives of Vygotsky (1962,1978) and Wertsch (1991).

Data were analysed with respect to the three research aspects. Firstly, the findings showed that ESL students’ preferred and exhibited a variety of participation practices that ranged from personal-individual to socio-interactive in nature. Both personal-individual and socio-interactive practices appeared to support science and language learning.

Secondly, the findings indicated that ESL students’ engagement in classroom social interactions was most likely influenced by the complex interactions between a number of competing factors at the individual, interpersonal and community/cultural levels (Rogoff, Radziszewska, & Masiello, 1995). In this study, six factors that appeared to enhance or constrain ESL students’ engagement in classroom social interactions were identified. These factors were socio-cultural factors, prior classroom practice, teaching practices, affective factors, English language proficiency, and participation in the research project.
Thirdly, the findings indicated that language played a significant mediational role in ESL students’ learning of science. The data revealed that the learning of science terms and concepts can be explained by a functional model of language that includes: 1) the use of discourse to construct meanings, 2) multiple semiotic representations of the thing/process, and 3) constructing taxonomies and ways of reasoning. Other important findings were: talking about language is integral to biology teaching and learning, ESL students’ prior knowledge of everyday words does not necessarily help them interpret written questions on worksheets, and ESL students’ prior knowledge of concepts in their first language does not necessarily support concept learning in the second language.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>x</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xi</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>xii</td>
</tr>
<tr>
<td>CHAPTER ONE</td>
<td>1</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>I. The Problem and its Contexts</td>
<td>1</td>
</tr>
<tr>
<td>ESL Students in Mainstream Classrooms</td>
<td>1</td>
</tr>
<tr>
<td>Students' Learning in Science</td>
<td>3</td>
</tr>
<tr>
<td>II. The Study</td>
<td>11</td>
</tr>
<tr>
<td>Purpose of the Study</td>
<td>11</td>
</tr>
<tr>
<td>Research Questions</td>
<td>12</td>
</tr>
<tr>
<td>Contributions to the Field</td>
<td>13</td>
</tr>
<tr>
<td>De-limitations and Limitations of the Study</td>
<td>16</td>
</tr>
<tr>
<td>Organization of Chapters</td>
<td>18</td>
</tr>
<tr>
<td>CHAPTER TWO</td>
<td>19</td>
</tr>
<tr>
<td>Sociocultural Theories of Learning</td>
<td>19</td>
</tr>
<tr>
<td>I. Theoretical Assumptions</td>
<td>19</td>
</tr>
<tr>
<td>II. Learning as Socially Mediated Action</td>
<td>23</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>V. Factors Enhancing or Constraining Students' Engagement in Social Interactions</td>
<td>110</td>
</tr>
<tr>
<td>Socio-cultural Factors</td>
<td>110</td>
</tr>
<tr>
<td>Prior School Experiences</td>
<td>112</td>
</tr>
<tr>
<td>Teaching Practices</td>
<td>115</td>
</tr>
<tr>
<td>Affective Factors and English Language Proficiency</td>
<td>121</td>
</tr>
<tr>
<td>Participation in the Research Project</td>
<td>124</td>
</tr>
<tr>
<td>VI. Complex Interactions among Factors</td>
<td>127</td>
</tr>
<tr>
<td>VII. Summary</td>
<td>128</td>
</tr>
<tr>
<td>CHAPTER SIX</td>
<td>130</td>
</tr>
<tr>
<td>Relationships between Language and Learning</td>
<td>130</td>
</tr>
<tr>
<td>I. Introduction</td>
<td>130</td>
</tr>
<tr>
<td>II. Teacher’s Teaching of Terms and Concepts</td>
<td>132</td>
</tr>
<tr>
<td>Introduction</td>
<td>132</td>
</tr>
<tr>
<td>Exploring the Meaning and Morphology of Terms and Concepts</td>
<td>133</td>
</tr>
<tr>
<td>Using Multiple Semiotic Representations</td>
<td>139</td>
</tr>
<tr>
<td>Constructing Taxonomies</td>
<td>145</td>
</tr>
<tr>
<td>III. ESL Students’ Interpretation of Terms and Concepts</td>
<td>148</td>
</tr>
<tr>
<td>Introduction</td>
<td>148</td>
</tr>
<tr>
<td>Concept Transfer from L1 to L2</td>
<td>149</td>
</tr>
</tbody>
</table>
Using Everyday Language in Formal Style........................................... 156
Re-labelling Everyday Words and Concepts............................................ 163
Knowledge of Morphology..................................................................... 165
Using Everyday Language to Construct Ways of Scientific Reasoning..... 166
IV. Summary .......................................................................................... 172
CHAPTER SEVEN.................................................................................... 176
Conclusions, Discussion and Implications ................................................ 176
I. Conclusions ....................................................................................... 176
   What is the Nature of ESL Students’ Participation during Biology
   Instruction? ......................................................................................... 176
   What Factors Enhance or Constrain ESL Students’ Engagement in
   Classroom Social Interactions? ............................................................ 179
   What are Some Relationships between Language and Students’ Learning
   Science? ............................................................................................ 184
II. Discussion of Results .......................................................................... 195
III. Implications for Classroom Practice .................................................. 203
   Enhancing Student Participation in Classroom Activities .................... 203
   Supporting English Language Learning and Science Discourse during
   Science Instruction ............................................................................. 204
   Enhancing Science Learning using Structured Small Group Work ....... 208
Using Multiple Semiotic Representations to Construct Meanings .......... 211

Accessing Prior Conceptual Knowledge in the First Language ............... 212

IV. Implications for Teacher Education ............................................. 213

V. Further Research ........................................................................... 215

Studies of Different ESL Student Populations .................................. 215

Studies in Different Academic Contexts .......................................... 215

REFERENCES .................................................................................. 217

APPENDIX 1: Interview Questions - Pilot Study ...................................... 237

APPENDIX 2: Students' Written Responses after Lessons ...................... 240

APPENDIX 3: Background Information ............................................... 241

APPENDIX 4: Revised Interview Protocol ............................................ 243

APPENDIX 5: Parent Consent Form ................................................... 248

APPENDIX 6: Student Consent Forms ............................................... 251

APPENDIX 7: Log of Classroom Observations .................................... 254
## LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Summary of Students' Participation Profiles</td>
<td>108</td>
</tr>
<tr>
<td>2</td>
<td>Some differences between the traditional model of language signification and a functional model of language</td>
<td>173</td>
</tr>
<tr>
<td>3</td>
<td>Summary of findings about language and science learning</td>
<td>186</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The traditional triad model of language signification</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td>The dual iceberg representation of bilingual proficiency</td>
<td>48</td>
</tr>
<tr>
<td>3</td>
<td>Multiple semiotic representations illustrating frequency</td>
<td>56</td>
</tr>
<tr>
<td>4</td>
<td>A technical taxonomy</td>
<td>58</td>
</tr>
<tr>
<td>5</td>
<td>Model of concept transfer from L1 to L2</td>
<td>63</td>
</tr>
<tr>
<td>6</td>
<td>Levels of sociocultural analysis</td>
<td>81</td>
</tr>
<tr>
<td>7</td>
<td>Nominalization – turning a verb into a noun</td>
<td>138</td>
</tr>
<tr>
<td>8</td>
<td>Contrasting “bilateral” and “radial”</td>
<td>146</td>
</tr>
<tr>
<td>9</td>
<td>Contrasting “homogeneous” and “heterogeneous”</td>
<td>147</td>
</tr>
<tr>
<td>10</td>
<td>Concept transfer from L1 to L2 (earlobe)</td>
<td>153</td>
</tr>
<tr>
<td>11</td>
<td>ESL students preferred learning orientations</td>
<td>177</td>
</tr>
<tr>
<td>12</td>
<td>Participation practices - whole class interactions</td>
<td>178</td>
</tr>
<tr>
<td>13</td>
<td>Participation practices - small class interactions</td>
<td>178</td>
</tr>
<tr>
<td>14</td>
<td>A functional model of language</td>
<td>185</td>
</tr>
</tbody>
</table>
ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to the teacher and students of the grade 11 biology class in the Vancouver School District for inviting me to be a participant-observer in their classroom. I especially wish to thank the twelve students who volunteered to share their thoughts and experiences with me.

I would like to thank my supervisor, Dr. Gaalen Erickson, for all his work on my behalf during my graduate program. His constant encouragement, constructive suggestions and flexibility have allowed me to explore ideas and express them with confidence. This thesis is a tribute to Dr. Erickson's faith in my abilities. A special thank you to Dr. Bernard Mohan, committee member, for guiding me through the final draft of the thesis. I will always be grateful to you for your willingness to discuss ideas and carefully review the draft of my final chapters. I wish to thank Dr. Jolie Mayer-Smith, committee member, for her constructive comments during the final stages of the thesis. Also, thank you to the faculty and support staff of CUST and CSTE who assisted me during my graduate program.

I would also like to thank some special people who have been my faithful supporters over the years. Thank you to Dr. Sharon Haggerty for being my good friend and advisor. Thank you to my Mum, sister and the rest of the family in South Africa for their constant encouragement and belief in my endeavours. Finally, thank you to my husband and two little girls who have been my loving companions and strongest supporters during my graduate journey, spurring me on to the finish line.
CHAPTER ONE

Introduction

I. The Problem and its Contexts

ESL Students in Mainstream Classrooms

With increasing numbers of English as a Second Language (ESL) students in Canadian secondary schools, classroom teachers are being faced with diverse and unfamiliar learning situations. For example: How do teachers encourage all students, and particularly ESL students to participate during classroom lessons? How do teachers explain science concepts so that ESL students make sense of teachers' English expressions and simultaneously construct scientific meanings? These questions gain significance in light of the findings of a comprehensive study on the status of ESL in British Columbia schools by Naylor (1994, p.15), who reports that there is “a sense of uncertainty among classroom teachers about ESL ... students, and how to teach them.” As well, in a study involving three grade nine science classes, Krugly-Smolska (1995, p. 54) reports that:

generally the teachers in this study seemed ill-equipped to deal with students experiencing language difficulties in their classrooms. There was even some ambivalence expressed as to whether or not students should be allowed to use other languages.

For ESL students, learning academic content is complex. These students need to learn the English language and to use that language for learning (Allen, 1991). Their
success as learners depends both on the acquisition of English language skills and academic content (Mohan, 1986). Evidence also suggests that students who enter English Second Language programs between the ages of 12 and 15 experience the greatest difficulty learning a second language to study academic content (Collier, 1987).

Many ESL students are placed in mainstream classrooms for a variety of reasons. For example, parents may believe that immersion will facilitate their children's acquisition of English or the school district's policy is to mainstream all students (Carraquillo & Rodriguez, 1996). Whatever the reason for mainstreaming, ESL students are required to meet the same linguistic and academic demands of native English speakers. While many ESL students may appear to be proficient at oral communication, research shows that ESL students may need 5 to 7 years to acquire the level of English language proficiency required to perform well on academic tasks (Collier, 1987; Cummins, 1981; Wong-Fillmore, 1986). Roessingh (1996) examined the development of linguistic proficiency of ESL students in mainstream science classrooms in Alberta. The findings of her study indicate that language learning support is necessary to help ESL students develop the minimum linguistic proficiency required for academic success in mainstream science classrooms.

The research findings cited above highlight some of the problems experienced by teachers and ESL students during the teaching and learning of academic content respectively. More importantly, these findings suggest that there is a need to examine classroom issues related to ESL students and science learning in an attempt to understand and enhance the learning of science for these students. To ascertain what support should be provided for both teachers and ESL students in mainstream academic classes, a better
understanding of the learning experiences of ESL students in mainstream academic classes is required.

Extensive research in science education has focused on students’ learning in science. What contribution has this body of literature made towards investigating the learning experiences of ESL students in science classes? Studies on students’ learning in science will be reviewed to highlight gaps in the science education literature in relation to ESL students’ learning.

Students’ Learning in Science

Constructivist research on students’ learning in science has primarily elicited and categorized students’ pre-instructional and/or post-instructional conceptions about various science phenomena (Andersson, 1990; Boo, 1998; Boo & Watson, 2001; Garnet, Garnet & Hackling, 1995; Hammer, 1996; Osborne & Freyberg, 1985; Palmer, 1999; Pfundt & Duit, 1994; Southerland, Abrams, Cummins, & Anzelmo, 2001; Trowbridge & Mintzes, 1988). The findings of all these studies indicate that students have prior knowledge about natural phenomena and that this prior knowledge is used to interpret the formal science taught in schools. Hence, there is widespread consensus that the learning of school science should begin with an explicit exploration of the prior knowledge of students (Driver & Oldham, 1986; Harlen & Osborne, 1985). While a list or description of students’ alternative conceptions about phenomena may be helpful in devising general teaching strategies, such lists or descriptions of students’ conceptions do not portray the actual personal experiences of the learner as he or she interacts with the science curriculum. The research studies cited
above have primarily focussed on eliciting individual students' conceptions about physical events and phenomena using the interview-about-events technique and have not illuminated the learning process as involving both personal and social interactions. The view that learning involves interactions between the student and his or her social setting (Cobb, 1994; Dewey, 1938; Driver, 1989; Driver, Asoko, Leach, Mortimer, Scott, 1994; Lave & Wenger, 1991; Salomon, 1992) suggests that students' personal and social experiences need to be explored in relation to the classroom learning environment.

A number of studies (Costa, 1995; Krugly-Smolska, 1995; Gustafson, 1991; Shapiro, 1989) have attempted to offer a more holistic picture of the science learner in the classroom learning environment. While Shapiro (1989) and Gustafson (1991) embed their studies within a constructivist theoretical framework, they considered both cognitive and social factors influencing student learning rather than focussing on pre-instructional or post-instructional propositional knowledge only—as is the case in most of the “conceptions” literature.

Both Shapiro's and Gustafson's studies focussed on the personal meanings that a group of elementary school children construct during the teaching of a science unit. Shapiro's inquiry probed children’s learning experiences during an instructional unit on light. She explored six grade five students' personal learning experiences by talking to and observing them in the classroom over a six-month period. Students' views and beliefs concerning cognitive, social and personal factors (e.g., purposes of schooling, purposes of science, self as successful or non-successful learner) were highlighted. Shapiro's study
revealed that concept development is guided by a variety of cognitive, social and personal features which function together in the science classroom.

In a similar fashion, Gustafson’s study examined elementary school children’s changing ideas during a unit on sound. She observed five students during a five-week period and interviewed them after each lesson to explore their perceptions about cognitive, personal and social aspects such as the purpose of the lesson, what they learned and understood during the lesson, how they coped with the lesson, what they believed about the lesson and how their ideas changed. The findings of Gustafson’s study revealed that children have a variety of ideas about phenomena and these ideas are complex and open to many interpretations. For example, children’s ideas about sound on any given day could have been ideas they personally understood, ideas they were tentatively considering, or ideas they had learnt from the teacher during the lesson. The study also revealed that children considered and modified ideas during their classroom experience and that changes to ideas were associated with many factors such as the teacher’s presentation of the lesson and factors associated with the children themselves, such as home situations and personalities.

While the findings of Gustafson and Shapiro’s studies provide insights into the interactions between students and the personal, social and cognitive factors in the classroom setting, their findings do not inform us about the learning experiences of culturally diverse students, specifically the role of these students’ cultural backgrounds and English language proficiency on their participation and learning in science. Also, these two studies focused on the experiences of students in elementary schools and do not inform us directly about the experiences of students in secondary schools.
Costa's (1995) and Krugly-Smolska's (1995) studies have attempted to address the learning experiences of culturally diverse students in North American secondary science classrooms. Costa's (1995) study explored relationships between students' worlds of family and friends and their world of school and science. Forty-three students (including ethnocultural minorities) were interviewed about their perceptions of school and science, and the importance of friends and family conditions significant to them. Further data were obtained from classroom observations and student records. The findings of Costa's study indicate that students' success in school science is related, in part, to the degree of congruency between their worlds of family, friends, school and science as experienced in schools. In particular, various personal and social factors such as different cultural values and norms, different ways of viewing society, and prejudice on the part of teachers, counsellors and administrators have an effect on students' responses to and engagement in science. These findings support the notion that students' learning of science is not confined to the science classroom. Rather, students' engagement and learning in science is also grounded in personal and social experiences (e.g., cultural backgrounds, association with family and friends) outside the science classroom.

Krugly-Smolska's (1995) study specifically examined some of the cultural influences on science learning. Data were collected from students in three grade 9 multicultural classrooms through ethnographic observation techniques. Among other issues, the differences in science achievement and attitudes of students from different ethno-cultural backgrounds and the nature and role of language in science classes were explored. The findings of Krugly-Smolska's study indicate that "even though differences in achievement
by students of different ethnic backgrounds were found, and that cultural factors influenced that achievement, they were by no means strong enough, ... to determine achievement” (p. 55). The findings also indicate that the classroom context plays a significant role in determining how influential these factors are. For example, difficulties in language were not evident when only one-word responses were required from students. While Krugly-Smolska’s study illuminates general trends among student achievement, attitude and behaviour, language related aspects associated with ESL students’ learning science are not directly addressed.

A few studies (Bird & Welford, 1995; Duran, Dugan & Weffer, 1998; Lai, Lucas & Burke, 1995; Lee & Fradd, 1996) have attempted to address language related aspects in relation to ESL students’ science learning. Bird and Welford (1995) examined ESL student performance on a set of multiple choice examination questions. Two papers containing 24 questions were prepared. Each test contained a different combination of original and revised forms of questions. Questions were simplified in a number of ways - for example, change in length, change in words, change in tense or syntax. Several science teachers reviewed the revised questions to check that revised and original questions were testing the same content. The two tests were administered to two groups of students - a group of ESL students from Botswana and a group of English first language speakers from the UK. The findings of the study revealed that simplified forms of questions resulted in significant improvements in the performance of the ESL students.

Lai, Lucas, and Burke (1995) explored student recognition and comprehension of science concept labels in Chinese and then in English. Twenty-three Chinese-speaking
students (recent immigrants from Taiwan) were selected from two high schools in Brisbane, Australia. These students were interviewed in Chinese and in English about their recognition and comprehension of 12 biology concept labels in Chinese and English respectively. A significant finding was that comprehension scores were higher in Chinese than in English. The findings also indicated that students were formulating English responses by translating from Chinese. These findings suggest that ESL students may have a much better understanding of science than is indicated by their responses in English.

The findings of the preceding two studies indicate that language plays a role in how ESL students communicate their understanding of science and construct meanings in science. These two studies were, however, limited to specific language related aspects - namely, wording of examination questions and comprehension of concepts by translation from First Languages into English respectively. Also, these two studies do not illuminate the learning experiences of ESL students in relation to classroom social interactions.

In a more comprehensive study, Lee & Fradd (1996) examined the role of literacy in science performance across three language groups of elementary students. They focussed on two areas of literacy development in communicating science content: interpretation of picture cards illustrating science activities and written language samples summarizing science activities. Students and teachers from three diverse language backgrounds - monolingual English speakers, bilingual Hispanic speakers and bilingual Haitian Creole speakers - participated in the study. Data collection consisted of audio and video taping 12 dyads of students and a teacher from the same language, culture and gender participating in three sets of science tasks - weather phenomena, levers, and buoyancy respectively.
Students' written summaries of the tasks and/or drawings were also collected. The findings of Lee & Fradd's (1996) study highlight the specific difficulties that students experience in developing and expressing their understandings of science content. For example, many Limited English Proficient (LEP) students had difficulties communicating their understanding of science in written form. In these instances, drawings were used as substitutes but drawings did not convey the complexity and completeness as written forms of explanation. Lee & Fradd (1996) recommend that students be provided with concrete experiences connected with written and pictorial representations to facilitate both their understanding and expression of science content.

Duran et al. (1998) explored the role of language in the learning of secondary school science. They examined how a group of fourteen grade 10 Mexican-American students constructed biology concept meanings in terms of the cognitive and linguistic tools employed during science instruction. A second purpose of their study was to design instructional activities to engage students in constructing meanings through mediational means such as science language and signs and symbols. The theoretical framework of their study was grounded in the social constructivist perspective of Vygotsky (1978,1987), as extended by Wertsch (1991). Data were collected through participant observation, questionnaires, interviews, group discussions, and student written work.

Two factors that inhibited student learning were identified. Firstly, students were overly reliant on the teacher's oral explanations as a means to learn and interpret science. This led to rote memorization and difficulties with making connections between theory and its applications. Secondly, students did not recognize the importance of constructing their
own understandings of science and using these understandings to interpret their experiences. This resulted in students not valuing learning resources (e.g. diagrams, models) that would enable them to construct meanings for themselves. Based on these findings, the instructional interactions were modified to show students how to use semiotic tools (e.g. forms of writing, diagrams and other schematics) to construct and express conceptual meaning. As students become more adept at using the tools, their dependency on the teacher for interpretations decreased. Students were gradually able to use the semiotic tools independently to construct meanings. Similar findings have also been reported with regard to native speaking students (Lemke, 1990; Moll, 1990; Roth & Bowen, 1995). However, a significant finding of Duran et al’s study was that semiotic tools played a more critical function in LEP students’ learning of science. Because of their limited experience with the English language, LEP students required detailed, explicit instruction about how to put biology content into language. To this effect, diagrams and visual representations played a critical role in establishing a shared context for constructing meaning.

Although the two preceding studies explicitly explore the learning experiences of ESL students during science learning, Lee and Fradd’s (1996) study was conducted in an elementary school and Duran et al’s (1998) study was conducted in a Saturday enrichment class at a university. The present study builds upon and extends the scope of the two preceding studies.
II. The Study

Purpose of the Study

This study is grounded in sociocultural perspectives, specifically the social constructivist perspectives of Vygotsky (1987) and Wertsch (1991). A fundamental assumption underlying social constructivist perspectives is that knowledge is personally constructed and socially mediated. The assumption that learning is socially mediated suggests that the nature of students’ engagement or their participation in social interactions is a significant factor in learning.

This study therefore extends the work of Duran et al. (1998) by examining the nature of ESL students’ participation and learning during classroom social interactions. In particular, this study offers a comprehensive account of the affective, sociocultural and language related factors enhancing or constraining students’ participation and construction of meanings in science.

A second purpose of this study is to explore the role of different mediational means, particularly language, in ESL students’ learning of science terms and concepts. The role of language is explored by examining the different ways language is used by teacher and students to communicate and construct scientific knowledge.

Overall, this study aims to provide a comprehensive portrayal of the learning experiences and teaching practices associated with ESL students in mainstream science classrooms.
Research Questions

To obtain a comprehensive picture of ESL students' learning experiences in a mainstream classroom setting, the study explores three aspects: the nature of ESL students' participation during biology instruction, the factors that enhance or constrain ESL students' engagement in classroom social interactions, and the role of language in ESL students' learning of science concepts. As such, the three research questions are as follows:

1. What is the nature of ESL students' participation during biology instruction?

This question examines what students say about their participation practices and how students actually participate during observed classroom interactions.

2. What factors enhance or constrain ESL students' classroom social interactions?

This question identifies and describes the effects of affective, sociocultural and language related factors on students' engagement in classroom social interactions.

3. What are the relationships between language and ESL students' learning of science?

Question 3 explores the mediational role of language in ESL students' learning of biology by examining how students communicate and construct meanings of scientific terms and concepts during individual activities and social interactions with the teacher and peers.
Contributions to the Field

The significance of exploring the issues of participation and language related aspects are three-fold. Firstly, the findings of this study contribute to education broadly in the following ways. This study of ESL students in a multicultural classroom setting contributes to an enhanced understanding of the affective, sociocultural and cognitive factors influencing students' participation in education. For example, the study provides practical insights into the ways in which ESL students' cultural backgrounds and social experiences influence their participation in classroom practices. The findings of this study contribute to the body of literature informing possible educational reforms aimed at increasing the participation of ethno-cultural minorities in education. The participation of ethno-cultural minorities in education is a cause for concern in view of high dropout rates and the under-representation of minority groups in science and technology related careers (Aikenhead, 1993; Atwater & Riley, 1993; Kitching, 1988, Sullivan, 1988).

Secondly, this study makes a significant contribution to science education by extending the literature on students' learning in science to include particular groups -i.e. ESL students. In particular, a holistic portrayal of the learning experiences of ESL students in mainstream secondary science classrooms is presented. Naylor (1994) and Krugly-Smolska (1995) have pointed out that teachers are unsure about how to teach ESL students in mainstream academic classes. Some of the teachers' uncertainties may be attributed to their lack of awareness of the ways in which affective, sociocultural and language related factors influence ESL students' participation and learning in science. The findings of this
study provide insights into the role of affective, sociocultural and language aspects on ESL students' learning in science.

Thirdly, this study explores the role of language in the construction of scientific knowledge by examining how the teacher teaches scientific terms and concepts and how students interpret and construct meanings of these terms and concepts. This analysis compares the traditional triad model of language signification (Lyons, 1977) with current notions about the construction of scientific knowledge (Halliday, 1998). The significance of this analysis and critique is that it highlights traditional teaching practices inconsistent with current notions about the nature of scientific knowledge and provides examples of teaching and learning strategies consistent with current notions about the construction of scientific knowledge.

In summary, this study:

1. highlights the range of participation practices exhibited by a group of high school ESL students during the learning of science
2. provides insights into the role of socio-cultural, affective and language related factors in ESL students' participation and learning in a mainstream science classroom
3. enhances our understanding of the role of language in ESL students' learning of biology terms and concepts
4. proposes a functional model of language to explain the learning and teaching of science terms and concepts
5. supports other attempts at enhancing ESL students' learning of
both language and content in academic content courses (Early, 1990; Kessler, Quinn & Fathman, 1992; Mohan, 1986; Roessingh, 1996)

6. adds to a body of literature that may contribute to possible curricular reforms aimed at enhancing ESL students' learning of science in mainstream science classrooms.

Insights from this study are provided through detailed descriptions and analyses of individual and groups of students through the use of vignettes. These descriptive vignettes may provide the reader with some understanding of the diverse experiences of ESL students and may give both science and ESL teachers an awareness of similar issues and learning difficulties in their particular settings. For example the vignettes provide teachers with specific examples about how language may be used to construct meanings in biology to support both language and science learning. These vignettes may also stimulate teachers to reflect on their personal ideas about the construction of scientific knowledge and how these ideas reflect in their teaching practices. The vignettes thus provide teachers with a basis for comparing and contrasting situations (Lincoln & Guba, 1980).

In summary, the overall main contribution of this study is the provision of insights into particular language and content-related issues associated with ESL students' learning science in a mainstream secondary classroom.
De-limitations and Limitations of the Study

The study was delimited to:

1. one classroom in a secondary school in Vancouver
2. a focus on biology content
3. ten ESL students of mainly South Asian origin.
4. qualitative methods of data collection such as interviewing and participant observation.
5. the investigation of two issues: ESL students' participation and relationships between language and learning science content
6. an eight-month observation period.

The study was limited by the following:

1. Interviews of ESL students were not conducted in their first languages. There is the possibility that some students may have misinterpreted the interviewer’s questions. To enhance the credibility of students’ verbal responses during interviews, questions were rephrased during interviews and students were asked about similar issues during a second semi-structured interview at the end of the project. Students’ responses were also supported by informal chats during classroom interactions, written responses on a questionnaire, informal discussions with the class teacher and observations of students’ actual participation and
learning practices.

2. The presence of the researcher, audio recorder and video camera may have inhibited some students' responses and classroom interactions. To minimise this intrusive effect, the researcher spent the month of September making preliminary observations in the classroom. During this time the class teacher introduced the video camera and recorded these initial lessons. Audio recording of lessons began in October and the first round of student interviews began in November. The gradual entry of researcher and equipment over a period of time appeared to make students more comfortable with the presence of the researcher and equipment. The project was also conducted over eight months. This lengthy period of observation significantly increased the credibility of the research observations.

3. The study sample was small and restricted to biology content. It is therefore not possible to generalize the findings of this study to other communities or subjects. Nevertheless, the findings of this study contribute to the body of research literature from which generalizations may be made.
Organization of Chapters

The thesis consists of seven chapters. Chapter one provides an overview of the research problem and context, research questions, limitations, delimitations and significance of the study. Chapters two and three consist of examinations of the literature. Chapter two describes how the underlying assumptions of the thesis are grounded in sociocultural theories of learning, particularly the perspectives of Vygotsky (1978, 1987) and Wertsch (1991, 1998). The factors enhancing or constraining ESL students' participation in classroom social interactions are also examined in chapter two. Chapter three examines the role of language in ESL students' learning of science terms and concepts by comparing current views about the construction of scientific knowledge with the traditional triad model of language signification. The qualitative research methods used in the study are discussed in chapter four. Chapters five and six present the analysis of data. Chapter five explores the nature of students' participation practices and the factors enhancing or constraining their engagement in social interactions. Chapter six examines the relationships between language and ESL students' learning in science by focussing on the teaching and learning of terms and concepts. The final chapter concludes with a summary of results, a discussion of how the study is situated in the literature, and an examination of the implications of the study for classroom practice, teacher education and future research.
In chapter two, I examine the literature on sociocultural theories of learning. Firstly, I examine the theoretical assumptions underlying sociocultural perspectives of learning and its application to science and language learning. In particular, Vygotsky’s notion of mediated action - specifically the role of three types of mediational tools (i.e., sign systems, interpersonal relations and prior knowledge) is highlighted. Thereafter, I explore the factors that enhance or constrain ESL students’ engagement in classroom social interactions. Sociocultural, affective and language related factors are examined in relation to second language and science learning.

I. Theoretical Assumptions

Theoretical assumptions about learning are drawn from sociocultural approaches: specifically the social constructivist perspectives of Vygotsky (1962, 1978) and Wertsch (1985, 1991, 1998). Vygotsky (1978) maintained that a person’s higher mental functions, such as concept formation, have a social nature and a social origin. The term “social” is being used in more than one sense. Firstly, social is used to refer to the social phenomena of face-to-face communication and social interaction (Wertsch, 1985). Social interaction involves more than one individual participating in action mediated by speech. Vygotsky (1978) argued that during social interactions, signs such as language are first used for social
contact, communication and a means of influencing others. Only later does a sign become internalised, leading to transformations in mental functioning (Wertsch, 1985). In this sense, the development of higher psychological processes has its roots in social interactions. Learning is therefore not located within the individual’s head but is constituted within interpersonal relations. Hence, the first assumption underlying this thesis is that learning in classrooms is socially situated - that is, students learn as they participate in social interactions.

The second sense in which Vygotsky (1978) used the term “social” has to do with his account of the relationship between psychological tools and the socio-cultural system. According to Vygotsky, psychological tools mediate higher mental functions. Unlike material tools, which are externally oriented and mediate between the human hand and the object of action, psychological tools are internally oriented and transform mental functions. Psychological tools such as language, mnemonic techniques, diagrams, maps, writing, and drawings mediate the learning of concepts. These psychological tools:

are social in the sense that they are products of sociocultural evolution. Psychological tools are neither invented by each individual nor discovered in the individual’s independent interaction with nature. Furthermore, they are not inherited in the form of instincts or unconditional reflexes. Instead, individuals have access to psychological tools by virtue of being part of a sociocultural milieu - that is, individuals “appropriate” such mediational means (Wertsch, 1985, p. 80).

In extending Vygotsky’s work, Wertsch (1998) describes sociocultural settings as having cultural, historical and institutional aspects. These three aspects refer to ways of
looking at settings associated with the disciplines of anthropology, history and sociology respectively. Wertsch (1998) argues that mediational means are inherently related to action through a description of person(s)-acting-with-mediational-means in a sociocultural setting. Since mediational means are part of any cultural, historical and institutional setting, human action is socioculturally situated (Werstch, 1998). The second assumption underlying this study is that learning is socioculturally situated. Any consideration of learning therefore involves an examination of the interactions of individuals and mediational means in relation to aspects such as past and present cultural background/histories and school and classroom settings.

Wertsch (1998) goes on to argue that all human action, whether it involves an individual acting alone or engaging in social interactions, is mediated action. In his work, Vygotsky emphasized two kinds of mediational means: signs and sign systems (especially the use of language) and interpersonal relations (Daniels, 1996). The latter type of mediation can also be described as mediation through another person (Kozulin, 1990). In addition, learning concepts is also mediated by the prior knowledge and experiences of the learner - that is, what is learned in one situation provides the starting point for further learning (Dewey, 1968, Vygotsky, 1987). The notion of mediated action gives rise to the third assumption underlying this thesis - that classroom learning is mediated by three types of mediational means: sign systems (particularly language), interpersonal relations such as teacher-student social interactions and the learners’ prior knowledge and experiences.

Learners use mediational means during social interactions to make sense of the actions or activities that surround them. External sign mediators such as diagrams or
language first serve a social or communicative function before becoming an internal psychological process. Vygotsky (1978) described the internal reconstruction of an external operation as internalisation, and used the example of the development of pointing to illustrate this process. In the initial stages of pointing, the child's movement may be interpreted as an unsuccessful attempt to grasp the object. When the mother responds, pointing then becomes a gesture aimed at establishing relations with another person. The meaning and functions of pointing are at first created by an objective situation and then during social interactions with other people. The external operation of pointing becomes a true gesture when it manifests all the functions of pointing for others and is understood by others as such as gesture. As this example illustrates, the process of internalisation is characterised by the reconstruction and internalisation of an operation that initially represents an external activity. Vygotsky (1978, p. 57) elaborated further that during the process of internalisation,

An interpersonal process is transformed into an intrapersonal one. Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first between people (interpsychological), and then inside the child (intrapsychological). ... All the higher functions originate as actual relations between human beings.

Thus, learners first make sense of talk and activity at the social or interpersonal level and then at the individual or intrapersonal level. Daniels (1996, p.10) points out, "The social does not become individual by a process of simple transmission. Individuals construct their own sense from socially available meanings". During the individual or intrapersonal
process, the learner uses existing or prior knowledge and experiences to interpret new knowledge and experiences (Ausubel, 1963; Solomon, 1987). Learners therefore reconstruct the talk and activities of the social plane (Scott, 1998). Constructing meanings is thus "social before it is individual, and it is constituted relationally with a social other before it is internalised" (Duran et al., 1998, p. 314). Hence, a fourth assumption underlying this study is that knowledge is personally constructed and socially mediated.

In summary, learning may be viewed as the personal construction of meaning during socially mediated and socioculturally situated action.

II. Learning as Socially Mediated Action

The idea of constructing meaning through social interactions is consistent with current claims about the construction of scientific knowledge. There is widespread acceptance among philosophers and educators that scientific knowledge is socially constructed (Latour, 1987; Harding, 1991; Solomon, 1987; Sutton, 1992). Individual insights contribute to a core of meanings specific to a particular topic through formal processes such as criticism, experiment, negotiation, publication and consensus (Sutton, 1992). The outcome is a system of public agreements about shared understandings; a predominantly linguistic symbolic meaning system through which members communicate, and make sense of particular experiences. These public understandings are not fixed but are tentative in that they are subject to change. For example changes in understandings may occur if the understandings are no longer perceived as useful in communicating a shared
system of meanings. Similarly, learning science in a classroom may be viewed as constructing a shared, publicly agreed way of understanding phenomena through participation in socially mediated activity.

Learning a second language through social interactions is also a widely held perspective (Ellis, 1999). According to the sociocultural perspective, an important psychological tool mediating language learning is the talk that takes place during interpersonal interactions (Vygotsky, 1987). Language is initially learnt through collaboration during interpersonal interactions where the more knowledgeable person assists the learner in performing a function that he/she could not perform alone or learners collaborate among themselves and manage a task that would be beyond their individual capabilities. In the latter two instances, the interaction provides scaffolding - that is, supporting activities and/or verbal guidance that acts as a bridge between what the learner knows and the new task to be learnt or performed. Scaffolding assists language learners to construct conversations using linguistic forms that lie outside their existing competence. Scaffolding also provides social, cognitive and affective support for learners. Examples of scaffolding activities that support second language learning are: engaging students' interest in the task, simplifying the task, marking critical features and discrepancies between what has been produced and the ideal solution and demonstrating an idealized version of the act to be performed (Wood, Bruner & Ross, 1976 quoted in Ellis, 1999).

Once students have learnt language through social interaction (interpersonal interactions), the language is subsequently internalised (intrapersonal interaction) and used to perform linguistic tasks independently. The sociocultural perspective therefore explains
language learning as involving both interpersonal interactions and intrapersonal interactions. Hence, from sociocultural perspectives, language learning may be described as the personal construction of shared linguistic forms through participation in socially mediated activity.

The mediating role of interpersonal relations and prior knowledge during science and language learning is examined in the next section. The role of language as a mediating tool during science and language learning is examined in chapter three.

**Mediational Role of the Teacher**

Learning scientific concepts is a socially mediated process and in most cases involves deliberate intervention by a more knowledgeable person (Vygotsky, 1987). Vygotsky (1987) describes this process as non-spontaneous, deliberate, and reflective in comparison to learning everyday concepts. He viewed scientific concepts as originating in the structured and specialized activity of classroom instruction and everyday concepts as originating spontaneously from the learners’ reflections on immediate, everyday experiences. He maintained, “problems involving scientific concepts are solved correctly more often than similar problems involving everyday concepts” (p. 190). Vygotsky’s point is that students solve problems involving scientific concepts correctly more often because of the guidance offered by the knowledgeable person. During problem solving the utterances of the more knowledgeable person serve “as a “thinking device”, a mechanism “to generate new meanings” for the child as well as the adult (Wertsch, 1991, p. 91).

In classrooms, the knowledgeable person who mediates students’ learning is most often the teacher. For example, the science teacher has knowledge of the specialized
scientific register required to explain science phenomena, and the language teacher has knowledge of the specialized linguistic forms required to communicate in the English language. Social mediation in most classrooms involves the teacher and student working in collaboration to solve a problem. During the collaboration process the teacher could explain, supply information, question, correct, and ask the pupil to explain (Vygotsky, 1987). In addition, the mediation process is “one in which there is a kind of negotiation of meaning” (Wertsch, 1991, p. 116). Individuals communicate and negotiate meanings between personal and new ways of knowing while engaging in shared problems and tasks (Ellis, 1999; Solomon, 1987; Lemke, 1990). During these interactions the teacher often uses directives “to regulate students mental processes (such as thinking or attention) in ways that are appropriate for the [social] setting of the classroom” (Wertsch, 1991, p. 112).

Directives can be interrogative (e.g., question form), declarative (e.g., statement form) or imperative (e.g., command form) and do not usually require a response from the student. The use of directives in social mediation is to primarily get students accustomed to thinking in the specific rhetorical forms associated with the activity or problem (e.g., learning the proof sequence associated with a Geometry problem).

Driver et al. (1994) maintain that the teacher serves two important roles. Firstly, the teacher mediates between students’ everyday world and the new way of knowing by introducing students to new ideas in ways that support and guide students to make sense of the new ideas themselves. Secondly, the teacher listens to students’ responses and interpretations of new ideas and uses them to modify instructional activities for future instruction. Overall, teacher mediation often translates into the teacher engaging students in
activities and discourse that support students in constructing new ways of knowing. Changes in understandings of knowledge may be brought about by the extension of an individual's existing knowledge or the construction of new, shared understandings developed through efforts to understand and contribute to the shared activity. In this way individuals are enculturated into new ways of knowing (e.g., school science) that involve personal sense making of a shared system of meanings during social interactions.

**Mediational Role of Peers**

Research shows that interpersonal relations among peers play a significant role mediating students' learning of science and language concepts (Fathman & Kessler, 1993; Lumpe & Staver, 1995; Mason, 1998; McGroarty, 1992; Nunan, 1999).

With regard to science education, research indicates that peer collaboration enhances students' learning of science concepts. Jones and Carter (1994) explored the social interactions of ability-grouped dyads as they constructed knowledge about levers. Thirty fifth-grade students participated in the study. Students were assigned to dyads based on the California Achievement Reading Test scores. Some findings of this study were: 1) higher ability students provided focus and verbal encouragement for low ability students, 2) higher ability students modelled thinking processes and strategies for manipulating equipment, and 3) low ability students working with high ability students made significant achievement gains. In another study, Lumpe & Staver (1995) examined the effect of peer collaboration on high school biology students' acquisition of concepts related to photosynthesis. Twenty-five students participated in the study. Eighteen students were randomly assigned to six
collaborative triads and seven students worked alone. Quantitative and qualitative data techniques were employed to analyse data. A significant finding of their study was that students working in collaborative groups developed more scientifically correct conceptions of photosynthesis than did students working alone.

Mason (1998) also explored how sharing cognition among peers stimulated the construction of more advanced knowledge about a topic, in this case the study of ecological concepts. The study was conducted in a fifth grade class and twelve students volunteered as participants. Data sources included eighteen audio taped group discussions, students’ individual written productions for each session, and pre-and post-instruction interviews. Findings of Mason’s study suggest that the sharing of cognition among students (through discussions) led to students constructing more advanced knowledge and that written texts revealed evidence of appropriation of information introduced during discussions.

Research in language learning also shows that peer assistance resulted in increased verbal skills and vocabulary comprehension among ESL students (Richard-Amoto, 1992). Peers who are more fluent in the second language mediate the language learning of less fluent peers. For example when ESL students discuss a problem with each other or with native speakers, they work to communicate meanings using language even if the language is not grammatically correct. McGroarty (1992, p. 62) explains that peers provide:

a greater range of verbal skills than those typically found in teacher-centred instruction, where student responses are often constrained by time and teacher concern for the “right” answers.
Peer interactions therefore provide ESL students with frequent, diverse and varied opportunities for practicing and improving English language proficiency.

**Mediation Role of Prior Knowledge of Science Concepts**

Vygotsky (1987) contends that the child's previous experiences (in particular, knowledge of prior concepts) are used as the foundation for learning new scientific concepts. Previously acquired concepts are used to mediate the learning of new scientific concepts. Vygotsky (1987) used the term concept to refer to word meanings. Vygotsky's ideas about the development of concepts are grounded in investigations of learning scientific concepts in a social science course. The findings of these investigations led to him visualizing a concept as being related to other concepts within a system of concepts at different levels of generality. Scientific concepts are characterised by hierarchical, logical organization. Vygotsky used the example of a child learning the word flower and then the word rose to illustrate a concept. When the relationship between the two concepts is established - that is when the term flower becomes generalized and the term rose is seen as a subordinate of flower - then a system of relations comprising concepts at different levels of generality is constructed. It is in this sense that learning the meaning of a new concept is mediated by one's knowledge of other related or pre-requisite concepts.

Vygotsky's ideas about the development of concepts are supported by research findings in science education. For example, the meanings students associate with certain science concepts and phenomena (e.g., heat and force) are derived from everyday experiences (Hewson, 1981; Minstrell, 1982; Bell & Freyberg, 1985). Everyday
understandings of concepts are “spontaneously acquired through interaction with the world and other people” (Reif & Larkin, 1991, p. 741). These everyday understandings of concepts are different for different groups of students. Individual students are associated with different social and cultural groups (e.g., family, community, and youth groups). The values, beliefs and experiences associated with these groups contribute to the students’ everyday understandings of various science concepts. For example parental expectations about schooling and religious perspectives are personal factors that contribute to students’ everyday understandings of the world. In summary, many of the differences in students’ everyday understandings of words and concepts can be attributed to the ways in which communities and groups within communities construct relationships between words and their everyday experiences (Lemke, 1990).

Conflicts often exist between students’ everyday understandings and classroom scientific understandings (Osborne & Freyberg, 1985; Strike & Posner, 1985). For example, confusion exists between the meanings of certain words in the students’ everyday language (e.g., animal, living) and in a specialised science sense (Bell & Freyberg, 1985). Rutherford (1993) highlights another potential problem with learning the meanings of science concepts—the use of a single science term (e.g., cell) to denote more than one science concept. The word “cell” is used in biology to refer to living tissue; in physics “cell” denotes an energy source. “Cell” also has an everyday meaning such as a prison cell. Rutherford does point out “most students can keep the different meanings side by side and call on the correct one in the correct context” (p. 143). However, this may not always be the case, especially for ESL students whose range of vocabulary in the English language is not
as extensive as native English speakers. It therefore becomes necessary to explore the
variety of connections between students’ everyday understandings of concepts and scientific
ways of understanding in order to help students see the range of possible meanings in both
everyday and scientific contexts.

III. ESL Students’ Participation and Learning During Social Interactions

In this section, I examine the factors (cited in both the Science Education literature
and Second Language Learning literature) that enhance or constrain ESL students’
participation and learning during classroom social interactions. Since this study involves
ESL students in a mainstream science classroom, factors salient to the general science
student population are also included.

I begin the section by exploring the construct “social interaction”. Next, I examine
six factors that appear salient to ESL students’ participation and learning during classroom
social interactions. The six factors are: teaching practices; small group interactions; nature
of communication during interactions; and cultural, affective and linguistic factors. This
examination of the literature provides a basis for comparing and contrasting the findings of
this study with those in the literature and for interpreting particular data in this study related
to the nature of ESL students’ participation and learning in a science classroom.
Social Interaction

The construct social interaction as used in this thesis is based upon Vygotsky’s (1978) notion of social interaction as explicated at the beginning of this chapter. Social interaction refers to the interpersonal interactions between people where two or more persons participate in action mediated by face-to-face verbal communication. A fundamental assumption underlying the notion of social interaction is that the talk that takes place during interpersonal interactions mediates both science and language learning (Ellis, 1999; Mercer, 1996; Vygotsky, 1968). During interpersonal interactions, persons participate in joint activities, and learn through collaboration and negotiation. Social interaction thus incorporates students’ participation in communicative discourse and activity, and the learning of academic content. This definition of social interaction also highlights three aspects of social interactions that appear significant in language and science learning: the nature of social interactions, the nature of participants and the nature of the communication during social interactions. These aspects are examined in the next section in the context of learning science concepts and learning a second language during social interactions.

Aspects Mediating Science and Second Language Learning

Teaching practices

While teacher mediation is important for the development of scientific concepts (Vygotsky, 1978), various studies show that some teaching practices enhance students’ participation and learning in science more than others. Crawford, Krajcik & Marx (1999)
examined student-student and student-teacher interactions in a science classroom where students (Caucasian and African-American) were involved in a project that focussed on an authentic and real world problem: hazardous chemicals in our lives. The main source of data was 25-videotaped lessons that provided information about classroom interactions and how these interactions changed over time. The researchers found that: 1) tasks related to real-world questions generated more collaborative interactions than topic-bound tasks, 2) when students were involved in the design of the task and were given an opportunity to ask their own questions – collaborative interactions increased, and 3) providing instructional support for students such as a handout detailing more explicit directions and expectations enhanced group decision making. These findings suggest that allowing students to choose their own questions (related to everyday problems) to explore, coupled with opportunities to exchange ideas, and, substantial teacher support enhanced collaborative social interactions. While these findings pertain to the general student population in a science classroom, the findings are also relevant for ESL students.

In another recent study, Crawford, Kelly and Brown (2000) examined how teachers, students and guest scientists constructed ways of investigating and knowing in science. This ethnographic study was conducted over two years in one grade three class with the same teacher, then in her combination fourth and fifth grade class in an elementary school in California. The same students from the third grade were in the fourth grade in the second year of the study. There were 30 students in the class and approximately half of the students were Caucasian and the other half were Hispanic. Data were collected using video and audio recordings of classroom events, field notes, and formal and informal interviews.
Additional data was obtained from artefacts and an ongoing log of events. The findings were derived from an analysis of participants' discourse and actions during an investigation of the behaviour of the sea animals in a marine science observation tank. The findings indicated that particular teaching practices led to student-initiated inquiries. For example, the teacher surrounded students with science resources such as reading materials, magnifying glasses, and microscopes at all times. She also allotted time for students to explore these materials outside formal science instruction. Overall, by providing time, tools, texts and technologies for students' exploration, the teacher created opportunities for students to engage in scientific discussions, collaboration and inquiry beyond the traditional teacher-planned and teacher-led curriculum. Another significant finding of this study was that "whole class discussions can be a valuable pedagogical tool with the potential to add to the effectiveness of small group work" (Crawford et al., 2000, p. 254). For example, there was evidence that through the use of particular discourse strategies during whole class discussions, the teacher modelled, and created opportunities for students to model specific ways of talking science such as providing evidence for claims and recommendations. Such modelling may influence the participatory levels and quality of discussions of both ESL and non-ESL students during student group work.

Another study highlighting teaching practices in learning science involved fluent English speaking students in kindergarten (90), grade three (90) and grade six (90). Staab (1986) explored possible teaching strategies that could be used to encourage students to use language to forecast/reason or predict. Instances of forecasting/reasoning were identified by utterances representative of, for example, explaining a process, recognizing causal and
dependent relationships, and justifying judgements and actions. In the study, two of the problem-solving activities given to participants were science related. The third was art-related. A major finding of the study was that the strategy that used a questioning technique during the activity was more effective at eliciting language related to forecasting and reasoning than students working at the activity alone or when students were exposed to a modelling technique. Staab (1986) therefore suggests that focusing "the students' attention by specific questions within the context of an appropriate situation" may be the most successful way to elicit responses of forecasting/reasoning. Another finding was that verbal forecasting/reasoning is elicited by a variety of carefully structured activities which contain the essence of problem solving. Learning science involves in large part learning the linguistic elements of argumentation such as raising questions about a problem, generating hypothesis, and making predictions (Fathman & Kessler, 1993). Since ESL students are still in the process of learning the English language, greater intervention and guidance may be necessary to help ESL students develop the language functions used to communicate scientific understandings.

In summary, the findings of the studies discussed above suggest that teaching practices based on real-world problems; student-initiated tasks and questions; instructional support during group work; provision of time, texts, technology for student exploration; whole-class discussions modelling scientific discourse; questioning strategies and problem-solving activities may enhance students' participation, collaboration and learning in science. All these strategies may also be used to support ESL students' participation during science
learning. The use of group work as a strategy enhancing participation and learning among ESL students is elaborated upon in the next section.

Small group interactions

Meyers (1993) stresses that group work needs to be structured so as to promote the learning of both social and language skills necessary for cooperation as ESL students learn content/concepts. During group work, ESL students are encouraged to talk and share information. More importantly, Meyers (1993) states that they are exposed to repeated use of new vocabulary and grammatical structures in meaningful situations. Small group interactions therefore can provide students with opportunities to develop both oral and written language naturally. In this regard, Meyers (1993) suggests that the teacher should play an active role in firstly, presenting activities that help students acquire social skills such as building team spirit and secondly, identifying the behaviours and language that support mutual cooperation.

Meyer’s assertion about structuring activities and encouraging behaviours and language that support ESL students’ learning during group work supports Johnson and Johnson’s (1990) claim, that it is only under certain conditions that group efforts are more productive than individual efforts. Firstly, positive interdependence needs to be structured into the learning situation. There are two kinds of interdependence involved in group learning: outcome (goal or reward) interdependence and means (resource, role and task) interdependence. Cooperative learning situations should be structured so that all students work towards a mutual goal and/or reward and the efforts of all group members in terms of resources; roles and tasks should contribute to the group’s success. Secondly, group work
should be characterised by promotive interactions where individuals encourage each other, exchange resources, provide mutual feedback, challenge each other's conclusions and reasoning, act in trusting and trustworthy ways and advocate and facilitate each other's efforts to achieve mutual goals. Thirdly, effective cooperation is supported by group members having a sense of personal responsibility or accountability to other group members for contributing their efforts to accomplish the group's goals. Fourthly, students must be taught the interpersonal and small-group skills needed for effective cooperation. Fifthly, group work should be characterised by periodic and regular group processing - where teacher and students reflect on member actions and make decisions about what actions to continue or change.

The findings of a number of studies that have incorporated Johnson and Johnson's (1995) five conditions for cooperative learning indicate that group work has positive effects on ESL students' participation and language learning. Some of the findings are: 1) during group work, ESL students produced more talk with other learners than with native speaking peers; 2) students did not learn each others' errors; 3) students produced a greater quantity and variety of language in group work than in teacher-fronted tasks; and 4) opportunities to negotiate meaning (make clarification requests and check comprehension) enhanced language comprehension (Nunan, 1999). These findings suggest that group work can promote ESL students' participation and language learning.

With regard to academic content learning, Johnson, Johnson and Smith (1995, p. 30) conclude from the findings of numerous research studies that, "generally achievement is higher in cooperative situations than in competitive or individualistic ones and that
cooperative efforts result in more frequent use of higher level reasoning strategies.” In relation to achievement in science, Lazarowitz and Karsenty (1990) developed a cooperative learning unit in photosynthesis. Their goal was to assess the impact of a cooperative method of learning and instruction on two domains: the cognitive - students’ achievement and process skills and the affective - students’ perception of the learning environment and their self-esteem. The cooperative approach was implemented in ten schools. Seven hundred and eight grade ten students participated in the study. Seventeen high school biology teachers were trained in the cooperative method of instruction. The control group studied the same subject matter in a traditional classroom instruction-laboratory work setting with the teacher presenting the material through whole class lecture/discussion method. Pre-tests, post-tests and questionnaires were used to assess changes in academic achievement, process skills, learning environment and self-esteem. The results of the study showed that academic achievement of students taught in a cooperative setting were both statistically and qualitatively higher. Students in cooperative classes also achieved higher scores in process skills. Although the scores on learning environment and self-esteem were higher in the cooperative group, the cooperative approach had a greater impact on the academic-cognitive domain than on the affective domain in this study. Overall, the findings of this study suggest that cooperative group work can be used to enhance science learning of native and ESL students.

Other research studies (Johnson & Johnson, 1995) have also shown that cooperative experiences promote higher self-esteem than competitive or individualistic efforts. Johnson & Johnson found that in cooperative efforts, students realized that they are accepted and
liked by peers and knew that they had contributed to their own, others and the group’s success. Their findings suggest that group work can be used to promote self-esteem among ESL students.

The findings of the studies cited above indicate that if cooperative group work is structured around the five elements suggested by Johnson and Johnson (1995), it can: (1) lead to improved relationships among group members, (2) provide academic and personal social support, (3) increase self-esteem (4) enable the acquisition of social competencies and (5) promote the internalisation of attitudes and behavioural patterns of both ESL and non-ESL students. Structured small group work is therefore a strategy that can be used to enhance ESL students’ participation and learning in language and science learning.

Nature of communication during interactions

The nature of the communication during social interactions plays a significant role in ESL students’ learning of academic content. Cummins (1992) distinguishes between context-embedded communication and context-reduced communication.

In context-embedded communication participants can actively negotiate meaning, and language is supported by a wide range of external, meaningful linguistic and situational cues. For example, indexical words—words that point to a part of the situation, (e.g., this, that, he, next) - are completely context dependent (Brown, Collins, & Duguid, 1989). These abstract words become meaningful through conversation about and participation in a situation involving a purposeful task or activity (Peregoy & Boyle, 1997). Intonation also plays a significant role in the meanings of spoken words. A particular choice of word or a characteristic intonation pattern (e.g., pronouncing a word in a higher tone of voice) may be
used to convey things such as doubt, irony, inquiry, seriousness, and humour. In the everyday context, linguistic cues are supported by situational cues such as the action or situations giving rise to the emotion, facial expressions, and vocal expressions of emotion (e.g., anger or laughter) and students can easily interpret linguistic cues. Cummins (1992) therefore maintains that context-embedded communication is “more typical of the everyday world outside the classroom” (p. 18).

He points out that most academic classroom learning is characterized by context-reduced communication - that is, communicative activities (e.g., listening to the teacher, reading a text) that rely heavily on linguistic cues to meaning and comprehending meaning depends mainly on one’s internal knowledge of the language. For example, the use of linguistic cues is a common feature of science discourse.

Lemke (1990, pp. 176-177) contends that:

many of the techniques we use to communicate the thematic content of science depend on extremely subtle linguistic cues. A change from singular to plural, active to passive voice, even a difference in a single preposition can change the meaning of a statement or its logical relation to something else. It is very common for the key meaning of a sentence to depend on a change in stress or emphasis on a single word.

The interpretation of linguistic cues may be difficult for most students to follow. ESL students, with their limited exposure to prior English academic discourse, are more likely to experience greater difficulty interpreting linguistic cues during science discourse and inferring scientific meanings.
The learning of academic subject matter should therefore be characterized by more context-embedded communication. As Cummins (1992, p. 21) argues:

a major aim of schooling is to develop students’ ability to manipulate and interpret cognitively demanding context-reduced text..... The more context-embedded the initial L2 input, the more comprehensible it is likely to be, and paradoxically, the more successful in ultimately developing L2 skills in context-reduced situations.

Hence there is need to support ESL students’ learning of science concepts by situating academic learning within contexts that involve face-to-face communication and by providing situational cues (e.g., reference to concrete materials) to support linguistic cues to meaning. The present study contributes to the literature by highlighting specific situational cues that support ESL students’ biology learning.

Cultural, Affective and Linguistic Factors

ESL students’ participation practices and reluctance to speak in classroom learning situations may be linked to cultural factors, affective factors, linguistic factors, views of themselves as language learners, perceptions of each other, and adult expectations (Allen, 1991; B.C. Ministry of Education, 1999; Cazden, 1992; Kohonen, 1992; Nunan, 1999; Peregoy & Boyle, 1997).

Cultural factors are defined by Saville-Troike (1978) and Spradley (1980) as, the shared beliefs, values, and rule-governed patterns of knowledge and behaviour that define a group and are used to interpret, experience and generate behaviour. The nature of ESL students’ participation in particular classroom situations may be linked to their cultural values and beliefs (B.C. Ministry of Education, 1999). For example, a possible cultural
explanation for a student not participating actively in group work or collaborating with peers on cooperative assignments could be that the student views sharing as "giving away knowledge" and may equate collaboration with cheating. Another example of how cultural factors influence students' interactions is the perceptions and expectations that Asian students and parents have of teachers. In Asian culture, the teacher is highly respected and their advice and orders are strictly followed. Also in many Asian schools, students stand up and bow to the teacher to show reverence and respect (Carrasquillo & Rodriquez, 1996). Such cultural values may be possible explanations for ESL students' reluctance to reveal their own opinions or challenge the teacher's statements.

Cultural factors may also be linked to learners' prior learning experiences and the expectations created by these experiences (Nunan, 1999, p. 231). For example, in many non-Western contexts, learning is characterised by teacher-dominated transmission of knowledge (Jayalakshmi, 1993 in Mercer, 1995; Nunan, 1999). Learners having these prior classroom experiences may engage in classroom learning tasks or activities by observing and listening to the teacher or being reluctant to speak in communicative learning situations.

Affective factors concern emotional responses to learning and include self-esteem, anxiety and shyness. Emotional responses related to English language proficiency play a significant role in ESL students' participation practices (Cazden, 1992; Kahonen, 1992). For example, students may not participate in discussions because of feelings of embarrassment about their pronunciation of English words. Studies (Ellis, 1990; Krashen, 1981) suggest that extroverted learners learn to speak a second language more rapidly and are more successful than introverted learners because of their ability to make contact with
and interact with second language speakers. Therefore, affective factors appear to constrain ESL students’ participation practices and language learning.

Linguistic factors that inhibit the use of the spoken language include difficulties in transferring from the first language to the sounds, rhythms and stress patterns of English, difficulties with native speaker pronunciation of teacher, lack of understanding of grammatical patterns in English, and a lack of familiarity with the cultural or social knowledge required to process meaning (Burns & Joyce, 1997 in Nunan, 1999).

With regard to the learners’ perceptions about peers and teacher, the role expectations of participants in relation to two aspects, interpersonal relations and nature of the learning tasks, can either enhance or constrain the language learning process (Nunan, 1999). Interpersonal relations include views about status and position, attitudes and values, and individual’s and group personalities. For example, students used to highly structured transmission modes of teaching may expect to play a passive role in their language learning.

A number of studies (Bianchini, 1999; Hogan, 1999; Lumpe & Staver, 1995; Richmond and Striley, 1996) in science education have also explored issues of inequitable participation and group roles. The findings of these studies reveal that students’ participation and learning of science during small group interactions is influenced by the social and leadership roles of participants. With regard to nature of the learning task in language learning, Nunan (1999) found that: 1) students who were reluctant to participate in other kinds of oral tasks, participated enthusiastically in debates, especially if they had chosen the topic; and 2) student participation in oral activities increased when group size was reduced.
Enhancing social interactions of all students in the science classroom implies that teachers need to be more sensitive to the role of cultural, affective, and linguistic factors on the role expectations of all students. Peregoy and Boyle (1997, p. 12) suggest that teachers “use a variety of formats to meet the multiple needs of your diverse students.” They advise further that the teacher’s best route is to observe and interpret student responses with thoughtful sensitivity and modify participation structures (i.e., grouping formats) as needed. The present study provides exemplars of how cultural, affective and linguistic factors influence ESL students’ participation and learning in a mainstream biology classroom. These findings contribute to the literature and further our understanding of the role of these factors in a particular context and on a particular group of ESL students.

Critique of Sociocultural Perspectives of Learning

The examination of the literature above suggests that sociocultural perspectives of learning tend to emphasize participation in small group work as a way to enhance the learning of a second language and science. While research indicates that small group interactions are a significant way of learning language and science, the sociocultural literature reviewed tends to downplay or ignore the role of individual learning practices. Small group learning activities are advocated as a means of learning academic content while individual learning tasks do not warrant much attention.

The overt message communicated by this literature is that group work is the way to enhance learning among all students. Such an assumption is problematic. The data in this study suggests that for some ESL students, individual based learning activities also play a
significant role in their learning of science concepts. For example, some students preferred learning through individual engagement in tasks such as assignments and reading books. The present study extends the literature by exploring ESL students' perceptions of and engagement in small group work, whole class interactions and individual based activities. Such an examination provides insights into the role of all types of learning activities on ESL students' learning. The role of social interactions and individual based activities on ESL students' participation and learning is examined in chapter five.

In the next chapter, the role of language as a mediational means in ESL students' learning is examined by demonstrating how the learning and teaching of biology terms and concepts can be explained by a more complex theory than the traditional triad theory of language signification.
CHAPTER THREE

Learning and Teaching Biology Terms and Concepts

I. Introduction

This chapter begins with a brief review of the traditional model of language signification. I argue that this traditional model does not adequately explain the learning and teaching of biology terms and concepts – current notions in the literature and evidence from this study point towards a more complex explanation for the learning and teaching of scientific terms and concepts. I make this argument by exploring how language is used as a mediational tool in biology learning, particularly, but not solely, with respect to ESL students. The works of Sutton, (1992), Halliday (1998), and Lemke (1998) are used to illustrate the ways in which the traditional theory falls short in explaining how scientific language is learnt. Finally, I conclude that: 1) language learning is integral to biology learning and 2) the teaching and learning of biology terms and concepts can be explained by a more complex theory than that proffered by the traditional model of language signification.

II. Traditional Notions about Language Learning and Teaching

Theories about meaning or semantics, as it relates to words and expressions has its roots in traditional sacred or mythological accounts of the origin of language (Lyons, 1977).
In these sacred or mythological accounts, the basic semantic function of words is that of naming. For example, in St Augustine’s account of language acquisition by children, an adult points to things in the child’s environment and names these things with words. Words are therefore regarded as names for things. This simplistic view of language acquisition (word signifies thing), was later expanded by writers such as Ogden and Richards (1923) and Ullmann (1957) to include the notion of concept or meaning, and is commonly described by a triadic relation (Lyons, 1977). In this traditional triad model of language signification, the meaning of the word or expression is what it refers to or denotes or stands for - that is, a word or term labels a “thing” via a meaning or concept (as shown in figure 1).

![Figure 1. The traditional triad model of language signification](image)

Notice that the traditional model tends to assume that the word “names” the thing with a unique name and meaning, so that the word has only one meaning. In this model, words with more than one meaning would be problematic because they would name more than one kind of thing.

This traditional model of language signification has also been used to explain the learning of a second language (L2). Cummins (1992) explains the bilingual’s knowledge of two languages using the dual iceberg metaphor illustrated in figure 2.
According to Cummins (1992), two different languages may use different surface features such as words and pronunciations to refer to a thing, but the underlying meanings or concepts are the same in the two languages. In terms of the traditional model, Cummin's model may be interpreted as the existence of two words (one in each language) for the same concept and thing. As such, a student who knows a concept in his or her first language (L1) merely needs to learn a new label or word in the second language (L2). Already existing concepts are transferred from one language to the other.

In my experience, the traditional model of language signification based on the triad of word, concept, thing, appears to be the unacknowledged theory that many science teachers hold. In the science classroom, this traditional theory of language is often reflected in the teaching and learning of scientific terms as labels for things, places, properties, processes and activities, and in the teaching of new terms and concepts by showing what the "thing" is or by saying what the meaning is (explaining or describing examples).

My initial intuition about teaching and learning biology also seemed to parallel the traditional triad model. For example, I initially looked at the learning of science terms and
concepts as learning the meanings of individual terms and concepts through showing and
describing. However, a critical examination of the data in this study revealed that the
traditional model of language signification did not adequately explain the way biology was
being learnt and taught in this classroom.

Thus, the central argument of this chapter is that the teaching and learning of terms
and concepts is not as simplistic as portrayed by the traditional triad model of language
signification described above. In the sub-sections that follow, I use evidence from the
literature (especially the works of Sutton, Halliday and Lemke) to support my contention
that the learning of scientific terms and concepts by L1 and L2 learners involves more than
the learning of concepts as labels that correspond to things “out there”. The interpretative
function of language, the morphology of scientific terms, multiple semiotic representations,
technical terms and taxonomies, ways of scientific reasoning, and knowledge of everyday
words and concepts in L1, play a significant role in ESL students’ learning of science terms
and concepts. These aspects, firstly, point toward a more complex theory of language in the
direction of Halliday’s (1998) explanation and secondly, often make the learning of biology
for both ESL and non-ESL students complex and problematic.

III. Current Notions of Language in Science Learning

In this section, I draw upon the works of Sutton (1992), Lemke (1998), and Halliday
(1998) and examine six aspects related to language to show the limitations of the traditional
model in explaining the learning and teaching of biology terms and concepts.
These six aspects are:

1. Using language as an interpretative system
2. The morphology of scientific terms
3. Multiple semiotic systems of representations
4. Technical terms and taxonomies
5. Discourses of reasoning

Using Language as an Interpretative System

Language is the dominant mediational means used in constructing shared ways of understanding in science classrooms (Lemke, 1990; Mercer, 1996; Sutton, 1992, 1993; Wertsch, 1991). The way language is used as a mediational means has important implications for both science and second language learning.

Sutton (1993) outlines the assumptions underlying two ways of using language: a labelling system and an interpretive system. Some of the assumptions concerning the meanings of words in a labelling system are: words have a fixed meaning in a particular context, if well stated words are assumed to be unambiguous and clear to all, and that a definition will capture the meaning of a word. Sutton’s explication of how language is used as a labelling system is consistent with the triad model of language signification where the word is a label for a thing and meaning of the word can be defined by a single concept. He goes a step further and suggests that learning under the labelling system becomes communication through transmission of information from teacher to learner.
In the science classroom, the goal of educators is to move away from transmissive teaching and learning. According to Sutton (1993), learning science should involve more than the learning of facts and information where students learn the right labels for certain concepts. Language should be used to interpret facts and information. In an interpretive language system, the meanings of words "vary from person to person as well as from context to context, and are influenced by a host of factors" (Sutton, 1993, p. 1225). Also, multiple meanings may be associated with a single word or statement. Therefore, using language in an interpretive way implies that learning science involves "the active interpretation and re-expression of ideas by the learner" (Sutton, 1993, p. 1225). In the science classroom, this entails using language to explore the meanings of concepts, analogies and metaphors used in science instruction.

Learning a language also involves learning more than the capacity of a word to label or represent objects or to elicit associations (Luria, 1982; Sutton, 1993). Learning the meaning of a word involves knowing how the word is connected to a system of complex associations and categories in different situations. According to Luria (1982), a word involves object reference and meaning. Object reference is the function of the word to refer to an object (e.g., table), property (e.g., brown leaf), action (e.g., stand), or relation (e.g., the boy sits on a chair). The meaning of a word is its function of "isolating and generalizing various features of an object, thereby relating the object to a system of categories" (p. 41). For example, knowing that a cow (the word/object) is an animal (a category) as well as knowing that the cow produces dairy products (a system of complex associations).
Learning a language also involves knowing metaphorical associations. For example, in the case of the metaphor "water is like money for a plant," students need to have an understanding of why water and money are compared and equated as essential for sustaining life. Many students who do not value and talk about money in the same way as many North American's do may find this metaphor difficult to understand. As Lyons (1977) so aptly points out, learning what a word denotes cannot be separated from learning the meaning of the word, and both these processes cannot be separated from learning the applicability of words in actual situations of language use.

Thus, learning the meanings of words involves learning both the labels and its underlying meanings in different situations and settings (Maiguashca, 1993; Richards, 1976; Sutton, 1992). This approach to learning language implies that learning a second language is not "simply learning the forms, structures, and vocabulary of the new language. It also means learning how to use that language for a wide variety of purposes in a wide variety of settings" (Allen, 1991, p. 356). English language proficiency includes among other things knowing many of the different meanings associated with the word (Richards, 1976), knowing how to use words in a metaphorical sense (Maiguashca, 1993) and using language "as a medium of interpretation ... and not simply a system of descriptive labelling" (Sutton, 1993, p. 1215). In essence, language should be "a means of trying to sort out ideas and capture meanings" (Sutton, 1993, p. 1223). All these descriptions of language suggest that a word is more than a label for a thing or process and that there can be more than one meaning or concept linked to the thing or process. The traditional triad model therefore falls short in that it explains language learning as a system of labelling and does not account for the
metaphorical and interpretive use of language in the learning of scientific terms and concepts.

The present study supports Sutton’s views on language learning by providing examples to illustrate how language is used as more than a labelling system (as compared to the traditional triad model) in the learning of biology term and concepts. The fact that ESL students have limited language experiences in English as compared to native English speakers suggests that greater effort is required to assist ESL students understand and use language in an interpretive way.

The Morphology of Scientific Terms

The traditional triad model of language signification explains the learning of language in terms of learning the meaning of a word for a thing. Words, are however, made up of one or more morphemes - that is, meaningful units of sound (Hipkiss, 1995). Knowledge of the meanings of morphemes and the changes they undergo - that is, knowing the morphology of words - becomes a significant aspect of language learning.

Morphemes may be single words but they can also be prefixes such as “pro” in “produce” or suffixes such as “ed” (“ed” changes the action described by the word into the past). For example, adding the suffix “ed” to the word “move”, changes it to “moved”.

Scientific terms are characterised by words made up of two or more morphemes. Many of the prefixes and suffixes in scientific terms are derived from Latin and Greek. For example, the prefixes “bi” and “homo” (common in scientific terms) originate from Classical Latin and Greek. The meanings of many scientific terms are thus not signified by a single word
but by the combination of two or more morphemes - an aspect that is not accounted for in the traditional triad model.

Suffixes can also change a word into a different part of speech. For example, adding “er” to “produce” forms the noun, “producer” - a process called nominalization. Scientific language has evolved as a result of mainly nominalization - that is, turning verbs and adjectives into nouns (Halliday, 1998). Halliday uses the following example to illustrate the process of nominalization in science. A process such as “move” is observed, generalized, and then theorized about. In this way, the process becomes a virtual entity “motion”. The process “move” is now transformed into a noun functioning as “thing”. The word “motion”, a noun, now has the potential to be expanded into a taxonomy (e.g., linear motion, orbital motion, periodic motion) and functions as a theoretical abstraction within a taxonomic structure. The register of science is characterized by such technical terms derived from nominalization of words. Learning scientific language involves in part knowing how terms are derived and related to similar terms. For example, knowing how the word “move” is related to “motion”. The traditional triad model falls short in that it does not explain the role of morphology during language and science learning.

The data in this study supports Halliday’s (1998) views and extends it by showing that the morphology of words can make the learning of scientific terms and concepts more complex and problematic than portrayed by the traditional model. Furthermore, ESL students’ are likely to experience more problems with morphology of terms than native English speakers as they are still in the process of learning the English language.
Multiple Semiotic Systems of Representations

Lemke (1998) argues that science is not communicated through verbal language alone because science concepts are not solely verbal concepts. Science concepts can be simultaneously verbal, mathematical, visual-graphical, and actional-operational (sensorimotor). The assumption that each of these semiotic representations is independent of each other and that the meaning of the concept can be communicated equally well by any one representation, is false. Lemke (1998) asserts that concepts “are not defined by the common denominator of their representations, but by the sum, the union of meanings implied by all these representations” (p. 110). While there may be a common meaning constructed by the different representations, each representation constructs a unique meaning that together and in relation to one another constitutes the concept.

For example, when illustrating the concept of “frequency” of light waves, a variety of semiotic representations can be used to jointly construct the meaning of “frequency”. For example, a verbal explanation in relation to colours, an experiment where a beam of white light is passed through a prism to produce a continuous spectrum, a graphical representation of the electromagnetic spectrum and a mathematical relationship between wavelength and frequency could be used to illustrate various ideas about the concept “frequency”. These four semiotic representations are shown in figure 3.
Verbal: Each colour of light in the continuous spectrum corresponds to waves of light of different frequencies.

Actional-operational:

Experiment:

Graphical: 

Mathematical: $c = f \times \lambda$ (velocity of light is equal to the product of frequency and wavelength)

Figure 3. Multiple semiotic representations illustrating "frequency"
Each of the representations shown above communicates a different meaning and/or relationship about the frequency of light. For example, the experiment shows how white light is separated or refracted by glass into different colours. It visually illustrates the positions of the colours in relation to each other in the continuous spectrum. The graphical representation of the electromagnetic spectrum shows the relationship of visible light to other electromagnetic waves in terms of frequency and wavelength. Finally, the mathematical representation illustrates a general mathematical relationship between wavelength and frequency for any electromagnetic wave.

Each of the representations above has a common link, "frequency", but each representation also communicates a different idea about the term frequency. Together, the meanings communicated by the different representations contribute to the overall meaning of the concept "frequency". This example shows that concepts are not represented by a single definition or meaning - concepts are multifaceted and the different facets/meanings (communicated by different semiotic representations) are required for the construction of the overall meaning of the concept.

The view that multiple semiotic representations jointly contribute towards the meaning of a concept highlights another shortfall of the traditional language model - pointing and describing are not, by themselves, adequate representations of the meanings of scientific words and concepts. The literature and data in this study suggest that multiple semiotic representations appear to be necessary to construct meanings of science terms and concepts.
Technical Terms and Taxonomies

Halliday (1998) maintains that scientific language is characterised by technical terms that are related to each other in taxonomies (constructing classes of classes). For example, the classes of backboned animals, birds and mammals, are contrasted in the following technical taxonomy:

```
Vertebrates
  /   \
Aves   Mammalia
```

Figure 4. A technical taxonomy

The technical terms “aves” and “mammalia” replace the everyday words “bird” and “mammals” and give rise to a highly abstract, theoretical taxonomy. The existence of taxonomies of technical terms raises two important issues that have significant implications for the way science concepts are learnt and taught. Firstly, replacing everyday words with technical terms makes the learning of terms and concepts unfamiliar to and difficult for most students. This study provides specific examples of how ESL students exhibited learning difficulties when everyday technical terms replaced familiar, everyday words. Secondly, scientific knowledge is characterised by numerous taxonomies where technical terms and concepts are compared and contrasted. Learning science therefore cannot be explained as the learning of terms and concepts in isolation. Rather, the meaning of terms and concepts are also learnt by comparing and contrasting concepts within taxonomies. This view of scientific knowledge implies that the traditional triad model, which links a word to a thing or
process via a single, isolated concept, is inadequate at explaining the learning of scientific concepts. Any explanatory model of language therefore needs to take into account the existence of taxonomies and the relationships between technical terms and concepts within taxonomies.

As well, the existence of technical taxonomies also implies that the teaching of terms and concepts in science involves more than the traditional showing and describing of terms and concepts in isolation. The data in this study suggests that the teaching and learning of terms and concepts is more complex than portrayed by the traditional model and it points towards a more complex explanation of language that takes into account the existence and construction of technical taxonomies.

Discourses of Reasoning

Halliday (1998, p. 201) maintains that “technicality by itself would be of little value unless accompanied by a discourse of reasoning: constructing a flow of argument based, in its prototypical form in experimental science, on observation and logical progression.” Scientific language is characterized by particular discourses of reasoning such as thesis-evidence-conclusion, compare/contrast, cause/effect, and problem/solution where language is used for hypothesizing, predicting, explaining, inferring, generalizing, classifying, and problem-solving (Halliday, 1998; Lemke, 1990; Sutton, 1992).

Learning how to construct these discourses of reasoning in science classrooms involves learning in large part the special ways of speaking and writing science - i.e., learning the scientific register (Lemke, 1989; Sutton 1992). A register may be defined as “a
configuration of meaning” that is typically associated with a particular situation (Halliday & Hasan, 1985, p. 38). The language used in legal documents, the language of pilots or the language used in science classroom discourse, are examples of registers.

The concept of register arises out of a view of learning that assumes that language is developed and used for different functions in different situations (Halliday, 1975). Hence, most registers are associated with specific language functions. Some language functions in school settings are requesting information, reporting, predicting, imagining, and forecasting (Staab, 1987). Particular indexical features such as the use of particular vocabulary or grammar characterize most registers. For example, “once upon a time” is an indexical feature that typically signals the introduction to a fairytale (Halliday & Hasan, 1985). In science classrooms, students need to learn how to combine concepts in ways that convey scientific understandings. In this regard, Lemke (1990) maintains that learning science involves the use of terms and definitions “in relation to one another, across a variety of contexts. Students have to learn how to combine the meanings of different terms according to the accepted ways of talking science” (p. 12). For example, students need to know more than the conceptual meanings associated with individual concepts like voltage, current and resistance. Students also need to know how to combine these concepts in different ways to construct and communicate scientific relationships (e.g., constructing proportional relationships using words). Thus the successful combination of concepts entails knowing both the specialized vocabulary and grammar (e.g., tenses, articles, endings) required to construct scientific discourses of reasoning.
Writing and speaking in science involves to some extent the use of certain preferred figures of speech and grammar (Lemke, 1990). The use of analogies and verbs of abstract relation (e.g., be, have, represent) are commonly used in the scientific register. Also, knowledge of how to use logical connectors such as “because”, “however”, “consequently” become necessary as these words are often used to connect ideas that express similarity, contradiction, and cause/effect in science (Kessler, Quinn, & Fathman, 1992).

The notion that learning science involves the use of certain types of grammar and language terms (e.g., consequently) to construct discourses of reasoning suggests that science learning cannot be explained by the simple notion of the word, thing, and concept model. The data in this study supports Halliday’s views of scientific language and suggests a more complex model of language incorporating discourses of reasoning.

Also, the differences in reasoning patterns between everyday language and scientific language often act as barriers in students’ construction of meanings (Lemke, 1990). It is often the case that the specialized vocabulary and grammar necessary for talking and writing in science may not be part of most students’ everyday experiences. In the case of ESL students, most of whom are still in the process of learning English grammar and figures of speech, greater intervention and guidance may be necessary in the classroom. This study provides examples of how the teacher attempts to support students in constructing ways of scientific reasoning in a grade 11 biology class. Some of the problematic issues associated with ESL students’ learning the scientific register are also highlighted.
Prior Knowledge of Words and Concepts in L1

According to Vygotsky (1987), when a child learns a second language the child “uses the semantics of the native language as its foundation” (p. 160). That is the child uses his or her prior knowledge of the meanings of words in the first language (L1) to learn the meanings of words in the second language (L2). In this way, the native or first language is used “as a mediator between the world of objects and the new language” (p. 161). The literature on second language learning also indicates that literacy related skills and conceptual knowledge acquired in the first language are transferred during second language acquisition (Carrasquillo & Rodriques, 1996; Cummins, 1992; McGroarty, 1992). This evidence suggests that a strong conceptual foundation in the first language enhances the development of similarly high levels of conceptual abilities in the second language. The view that learning a concept or word in a second language is mediated by one’s knowledge of the meaning of the concept or word in the first language is widely accepted.

Both Vygotsky (1987) and Cummins (1992) views, however, seem to have their roots in the traditional model of language signification where the word is related to a thing via a meaning or concept. Vygotsky (1987) maintains that, “we use word meanings that are already well developed in the native language, and only translate them” (p. 157). Cummins states that, the child “has only to acquire a new label [in the second language] for an already existing concept” (p. 22). In these two explanations of concept learning in L2, a word or term in L1 is linked to a word or term in L2 by a common concept or meaning as illustrated in figure 5. This, though, is only a partial description of Cummins’ model.
This model explains the learning of words in L2 in terms of the simple transfer of concepts from L1 to L2.

The assumption, that students are learning a new label for an available word or concept in their first language, has been questioned (Allen, 1991, McNaught, 1993). Translation of words from the first language into the second language does not necessarily convey the conceptual meanings underlying the new word. The findings of McNaught’s (1993) study shows that the meanings of some words in the first language may elicit associations and meanings that are different from the meaning associated with its English label. In the first language, words may be used in ways that conjure different everyday associations as compared to the English word. For example, in Shona (a language spoken in Zimbabwe), birds are associated with insects and locusts whereas in English, birds and insects are classified into separate groups (McNaught, 1993).

The view of second language learning stemming from the traditional model of language signification—learning new “labels” in L2 for a concept already learnt in L1 - does not adequately explain the learning of concepts in L2. Meanings and/or concepts are not simply transferred from L1 to L2. The data in this study suggests that the learning of scientific terms and concepts in L2 is complex and problematic. While many cognitive or literacy related skills learnt in the first language may be transferred to the second language,
the assumption that ESL students already understand what a concept means because they have learned the concept in their first language cannot be taken for granted.

IV. A More Complex Model of Language

I have argued in the preceding sections that the traditional model of language signification does not adequately explain the learning of science terms and concepts. The simple notion that a word signifies a thing via a concept cannot account for the complexities involved when ESL and native English speakers learn science terms and concepts. I have examined six aspects drawn from the literature, namely: using language as an interpretative system, the morphology of scientific terms, multiple semiotic systems of representations, technical terms and taxonomies, discourses of reasoning, and prior knowledge of words and concepts in L1 to point out the shortcomings of the traditional model of language signification.

These shortcomings suggest that the learning of science concepts should be explained by a more complex theory of language that takes into account the six aspects examined above. In chapter six, I use the data to highlight the shortcomings of the traditional model and illustrate the construction of a more complex theoretical model of language, one that can explain the learning of science terms and concepts more adequately than the traditional model of language signification.

The six aspects discussed above also illustrate how language learning is an integral aspect of science learning. Many science teachers believe that biology teaching involves
teaching biology concepts only. However, research indicates that ESL students need to be provided with opportunities that will further their understanding of both the English language and science concepts if they are to succeed in learning academic content (Kessler, Quinn & Fathman, 1992; Roessingh, 1996). The analysis of data in chapter six also highlights the ways in which an experienced biology teacher teaches language skills and concepts while teaching biology concepts to ESL and native English speakers in a mainstream biology classroom.
CHAPTER FOUR

Methods of the Study

The main purpose of this study is to provide insights into the nature of ESL students' participation and learning during classroom social interactions. Obtaining such insights requires the researcher to observe and talk to students in the classroom setting. Qualitative research methods, which include observing and asking people about their experiences in natural settings, were therefore used to collect data for this study.

This chapter describes the methods used to collect and analyse data. There are six sections in this chapter: qualitative research methods, the pilot study, the setting and participants, data collection, analysis and limitations of data collecting procedures.

The first section begins with an overview of qualitative research methods and includes a discussion of issues such as validity and generalizability. The second section describes the pilot study and explains how the research methods used to collect data in the pilot study informed the main study. In the third section, the setting and participants are described. The next two sections describe the procedures used during data collection and data analysis respectively. Finally, the last section examines some of the limitations encountered during data collecting procedures.
I. Qualitative Research Methods

Since a qualitative research approach was adopted in this study, an understanding of how I perceived this research approach will enable the reader to get a better sense of the methods used to collect data. According to Denzin and Lincoln (2000, p. 3), “qualitative researchers study things in their natural settings, attempting to make sense of, or to interpret, phenomena in terms of the meanings people bring to them.” Qualitative researchers focus on how participants participate in, construct, experience or imagine their lives (Gubrium & Holstein, 1997). Understanding phenomenon in natural settings involves seeing first hand what occurs and/or asking people for their points of views and interpretations (Altheide & Johnson, 1994). Participants, however, are only able to offer accounts about what they did and why (Denzin and Lincoln, 2000). Hence, there is need for a wide range of interconnected interpretive methods to illuminate participants’ experiences. Qualitative researchers therefore use a wide range of research methods or practices to acquire an interpretive understanding of human experience (Denzin & Lincoln, 2000). As such, I located myself in a school setting where I used a variety of research methods such as interviewing and participant observation to acquire insights into participants’ words and actions.

The researcher in qualitative research is not an objective by-stander, detached from observations, interpretations and findings. Guba and Lincoln (1994, p. 107) maintain, “Findings are created through the interaction of inquirer and phenomenon (which, in the social sciences, is usually people).” All inquiry is guided by a set of beliefs and feelings
about the world and how it should be studied (Denzin & Lincoln, 2000). The notion that observations, interpretations and findings are theory-laden and value-laden - that is the researcher has a theoretical and value lens through which observations are made and findings inferred - suggests that the researcher's subjective experiences (e.g., intentions, goals, emotions, and prior assumptions) play a significant role in shaping the methods, interpretations and findings (Goldstein & Goldstein, 1978; Guba & Lincoln, 1994; Jacob, 1988). Hence, qualitative research is characterized by findings and interpretations that take into account both researcher's and participants' subjective experiences. Therefore, qualitative research accounts often consist of descriptions and personalistic interpretations of the perspectives of groups of people or patterns of interactions associated with particular settings (Hammersley & Atkinson, 1983; Stake, 1994). In this study, I provide interpretations of what students' say about their participation and learning and how they actually participate and learn during classroom interactions. My observations and interpretations are shaped by my personal experiences as a high school science teacher, science education graduate student and research assistant. As well, my observations and interpretations are bounded by my research focus and the theoretical assumptions reflected in the literature review.

Interpretations do not constitute interpretive truths. Qualitative researchers claim that there is no single "correct" interpretation (Janesick, 2000). They maintain that all observations are filtered through the researcher's lenses of language, gender, social class, race, and ethnicity. Hence, there may be multiple interpretations of the same situation depending on the researcher's interpretive framework. I approach this study from a
constructivist interpretive framework. A fundamental assumption underlying the constructivist paradigm with regard to the nature of the world is that reality "is a construction in the minds of individuals" (Schwandt, 1994, p. 128). The purpose of research is to therefore understand and reconstruct the constructions of individuals through negotiation and consensus of meanings (Guba & Lincoln, 1994). Also, since the social world is an interpreted world, the reconstruction process is not confined to one interpretation (Altheide & Johnson, 1994). There could be multiple and conflicting constructions or interpretations of the same phenomenon. However, one construction could take precedence over the others by virtue of group consensus. As Denzin and Lincoln (2000) argue, "there are multiple interpretive communities, each with its own criteria for evaluating an interpretation" (p. 23).

Since I approach this research from a constructivist interpretive framework, a different set of criteria is used to judge the validity and reliability of findings as compared to quantitative research. In quantitative research, "the 'reliability,' or the stability of methods and findings, is an indicator of 'validity' or accuracy and truthfulness of the findings" (Altheide and Johnson, 1994, p. 487). In other words valid methods and findings are those that are repeatable (that is, reliable) and generalizable. The assumption inherent in this view is that, "there is a single reality which if studied repeatedly will give the same results" (Merriam, 1988, p. 170). In qualitative research, however, "there is no single interpretive truth" (Denzin & Lincoln, 2000, p. 23). Janesick (2000, p. 393) asserts:

validity in qualitative research has to do with description and explanation and whether or not the explanation fits the description. In other words, is the explanation credible?
Lincoln and Guba (1985) suggest that the credibility of findings and interpretations may be enhanced by:

- providing evidence of persistent observation (for the sake of identifying and assessing salient factors and crucial atypical happenings)
- using multiple data sources or triangulation
- negotiating outcomes by having key participants review and corroborate the interpretations.

Triangulation commonly involves the use of multiple data sources, multiple methods of data collection, and multiple researchers and is often seen as a way to eliminate bias and lead to corroboration of one perspective as being more valid or truthful than others (Denzin, 1978, 1989; Hammersley & Atkinson, 1983, 1995; Lincoln & Guba, 1985). In this study, the credibility of findings was enhanced by an eight-month observation period, the use of a variety of data collecting procedures, establishing rapport with participants, using formal and informal interviews to clarify meanings with participants and corroborating with the classroom teacher (elaborated in later sections).

The credibility of qualitative research may also be judged by its transparency, consistency-coherence, and communicability (Rubin & Rubin, 1995). Transparency is defined as being able to see the basic processes of data collection (e.g., having transcripts of interviews and logs of how data was transcribed). Consistency is described as checking out ideas and responses that appeared inconsistent in individuals and across cases (e.g.,
following up a theme in another interview to understand why inconsistency occurred).
Communicability refers to providing readers with rich detail, abundance of evidence and vivid descriptions that help convince the reader that the material is believable. In this study, in addition to audio and video recording of lessons, detailed field notes logged the daily events, all participants were interviewed by me using the same set of interview protocols, observations were made over a long period of time to account for changing conditions in students’ interactions, and rich case descriptions and vignettes were provided to enhance the credibility of findings and interpretations. The credibility of the study was also enhanced by stating the parameters and boundaries of the study (Marshall & Rossman, 1995)—e.g., outlining possible limitations and delimitations and stating the research focus and theoretical assumptions underlying the study.

With regard to the generalizability of qualitative research, Firestone (1993) maintains that, "when researchers generalize, they really make claims about the applicability of their findings to other settings" (p. 16). Firestone (1993) suggests two types of generalizations most applicable to qualitative research. The first type of generalization is called analytic generalization where findings/results are generalized to a broader theory. Yin (1989) contends that generalization to a theory is not automatic but occurs when the theory has been tested through replication of findings in other settings. Hence, findings may become generalizable when the theory is applicable to a range of settings and populations.

The second type of generalization is case-to-case transfer where programs or ideas from one setting are adaptable to other similar settings. Lincoln and Guba (1990) go a step further and suggest that the applicability of a case to dissimilar contexts or situations can
also be made in the following three ways: the reader learns from the experience described in the case report, the case serves as a metaphor to compare and contrast the two situations and lastly the case can be used as a basis to re-examine and reconstruct one's own construction of teaching and learning experiences. These types of generalizations and applicability of cases to other settings depend upon rich, thick descriptions of the participants and contexts in the case (Firestone, 1993; Lincoln & Guba, 1990). The reader has to assess in what ways and to what extent aspects of the case applies to her or his own context or situation (Lincoln & Guba, 1990). Knowledge of the particular enables one to see similarities in new and foreign contexts (Stake, 1995). Since this study describes the learning experiences of ten ESL students in a particular science classroom setting, the applicability of findings can be explained in terms of the case-to-case generalizability described above. For example, the case descriptions in this study may enhance teachers' and pre-service teachers' understanding of ESL students' classroom learning experiences in similar settings.

II. The Pilot Study

The pilot study was conducted in a secondary school in Vancouver. Prior to the pilot study, I worked on another research project at the same school. During that time, I developed a rapport with a biology teacher who was doing his Master's degree. He was also interested in understanding ESL students' learning experiences. We agreed to conduct a pilot study in his grade 11 biology class over a six-week period. At the onset of the pilot, all students were observed and their participatory practices noted (e.g., whether they asked
questions during lessons and the types of questions asked). After interacting with students for a period of one to two weeks, the teacher and I discussed possible participants. The basis for selection of ESL student volunteers was proficiency in conversational English and diversity of language and science academic backgrounds. Two students were selected and parental consent was obtained.

A Spanish-speaking student from El Salvador and a Polish-speaking student were the focus of observations during classroom lessons involving the study of plant biology. These two students were interviewed about their backgrounds, participation, and language experiences (appendix 1). All interviews were audio-recorded. Classrooms lessons were audio recorded from the second week onwards. During lessons, extensive field notes were used to record critical lesson incidents involving the participating students (e.g., they may have asked questions, answered questions, made gestures or facial expressions). As well, all students handed in written responses to two questions (appendix 2) about what they learnt and what they did not understand during the lesson. Based on classroom observations, written field notes and student written responses, students were prompted to recall and elaborate on their understanding of a particular word or concept in relation to language related aspects and teaching and learning strategies. In these short recall interviews (unstructured at that stage) I explored how students made sense of science concepts by firstly asking them to explain their understanding of a concept or word used during the lessons (i.e., their conceptualisations), secondly, asking them to explain how they learned and what strategies helped them gain a better understanding of the concept (i.e., asking students to reflect on the learning process itself) and thirdly exploring with them how their
language experiences interacted with their learning of science concepts. These short discussion sessions were conducted during the lunch breaks at the students' convenience. Most of the times, these short interviews occurred on the same day as the lesson or the next day. All recall sessions were audio taped.

The pilot served two useful purposes. Firstly, interview protocols (appendix 1) developed and used in the pilot were refined. The interview protocols used in the pilot changed and evolved in response to questions that emerged as I observed the students in class. I therefore adapted, changed and added questions to the original interview protocol. This process led to a revised set of questions used to guide student interviews in the main study (appendix 4). Secondly, preliminary analysis of the data revealed that the data collection procedures were successful in providing insights into students' learning experiences - particularly students' participation and construction of meanings in biology. As a result, the data collection and analysis procedures used in the pilot study were adopted in the main study. Also, the data related to one of the participants in the pilot was included in the results of the main study.

### III. Setting and Participants

In keeping with Lincoln and Guba's (1985) recommendation that demonstrating a prolonged period of engagement (to learn the context and to build trust) enhances the credibility of the findings, the main study was conducted in the same secondary school as the pilot. This school is a large inner-city school in a multi-ethnic community. At the time
of the pilot study, 42% of the students were born outside Canada. Majority of these students came from Vietnam, China, Hong Kong, El Salvador, the Philippines, and Poland. The school therefore has a well-established English as a Second Language program and many ESL students are integrated into regular science classes.

The school was very familiar to me as I spent the year prior to the main study collecting data for the ethnographic research project at this school. My prolonged engagement at the site enabled me to get a sense of the ethos of the school, to become familiar with teachers and students, and to interact with ESL students. As explained in the second section of this chapter, I was able to make contact with and establish rapport with a biology teacher. The pilot study and main study were conducted in this teacher's grade 11 biology classes during successive school years.

In the main study, the biology class was an honours class. This class was selected as the study site because this class was the only grade 11 biology class allocated to the teacher. The honours class covered the prescribed curriculum topics more extensively and included more labs and projects than the regular biology 11 class. Selection of students for the honours class was not based on merit. Any student was allowed to choose the class if he/she desired to do so. Students in this honours class were representative of a broad range of academic abilities.

Most students in the biology 11 honours class (one student was of European origin) were of South Asian origin. Ten ESL students were selected to participate in the study. Six students were Cantonese speaking, two students spoke Vietnamese, one spoke Cambodian and one student spoke Tagalog.
IV. Data Collection Methods

Data were collected primarily using qualitative research methods such as participant observation and interviewing techniques (Atkinson & Hammersley, 1994). Lincoln and Guba (1985) assert that the success of interviews is influenced to a large extent by the trust and rapport established with interviewees. Some ways that have been suggested for building trust and rapport with participants is through prolonged engagement on the site, negotiating consent with interviewees, being familiar with the language and culture of interviewees, and the researcher presenting herself or himself to the interviewees in an honest and non-threatening way (Lincoln & Guba, 1985; Fontana & Frey, 1994).

I spent two months prior to data collection familiarizing myself with the students and the classroom setting. During this period, I established a rapport with individual students and minimized my role as an intruder. Technical equipment such as an audio-recorder and a video-recorder were also introduced into the classroom to minimize its intrusive effects on student and teacher behaviour. Written parental and student consents were obtained from all students in the class (appendix 5 and 6). The ten students selected for the study were representative of a range of English language abilities, cultural backgrounds, academic ability in science and gender. Criteria for selection also included the teacher’s recommendations, students' willingness to be audio-recorded and their desire to communicate on issues about learning.
The following data collecting procedures (adapted from the pilot study) were adopted over an eight-month period:

1. audio-recordings of forty-four, seventy-minute lessons
   video recordings of eight classroom lessons.
2. field notes of fifty-four observed classroom lessons, three field trips, and my informal interactions with participants and teacher.
3. audio-recording of two semi-structured interviews with ten students prior to and at the completion of the study (appendix 4).
   Questions asked in these semi-structured interviews were used to gather information about students' cultural, linguistic and personal backgrounds as well as to elicit specific information related to the research questions. The initial interview explored students' prior education and language experiences, their conceptions of learning and their views about classroom language and participation practices. It should be noted that all questions may not apply to all students. The final interview explored students' reflections of their learning and participation in relation to specific academic and general contexts.
4. students’ written feedback on their learning during lessons (appendix 2).
5. a questionnaire about students’ personal backgrounds and prior school experiences filled in at the beginning of the project (appendix 3).
6. audio-recordings of recall sessions of lesson incidents with individual and groups of students. These short interviews focussed on students' specific experiences and/or difficulties in understanding concepts during lessons.

7. document analysis of student work such as written assignments, laboratory write-ups and tests.

The purpose of audio- and video-recording classroom lessons was to obtain insights into social interactions during classroom learning. Video-recordings were primarily used to supplement observational data on students' participation practices. With regard to the recall sessions, the larger number of participants in the main study as compared to the pilot, a greater student work-load, and timetable constraints resulted in students not being available to discuss lesson incidents immediately after the lesson. With the larger number of participants in the study (as compared to the pilot), the two semi-structured interviews were spread over a period of time. It became more practical to incorporate questions regarding specific lesson incidents during the two semi-structured interviews. Students were asked to recall and talk about incidents occurring a week prior to the interview. I found that the use of my detailed field notes of lesson incidents, students' feedback on their learning during the lesson, and references to the biology text and students' notebooks or test responses an effective means of prompting students to talk about their construction of meanings in science.

The final interview was used to explore students' reflections of their learning and participation practices during the course of the project. This interview was also used to
verify the researchers' interpretation of student responses in prior interviews. Exploring and verifying the researchers' interpretation of students' views at different times during the course of the study is one way of negotiating outcomes and corroborating data with participants (Lincoln & Guba, 1985; Merriam, 1985; Rubin & Rubin, 1995). In addition to follow-up interviews with students, I had informal discussions with the biology teacher to discuss and corroborate my interpretation of students' participation practices and learning difficulties.

The multiple data sources discussed (i.e., classroom observations, audio and video recordings, field notes, semi-structured interviews, recall sessions, informal discussions with the teacher, student written feedback and document analysis) were used to make inferences about students' participation and construction of meanings. Such multiple sources of evidence develop converging lines of inquiry and "essentially provide multiple measures of the same phenomenon" (Yin, 1989, p. 97). In this way, the credibility of findings and interpretations in the study was enhanced.

V. Analysis

The analysis of data is consistent with a sociocultural approach to development. Rogoff, Radziszewska and Masiello (1995) maintain that individual, social and cultural analyses are inseparable. They contend that the aim of this approach "is to understand the developmental processes involved in activities, at the level of individual, interpersonal, and community (or cultural) processes" (Rogoff et al., p. 129). For the purposes of this thesis,
the individual level focuses on the activities of individual students and the cognitive, social and affective changes that he or she experiences as a result of engaging in these activities in the classroom. The interpersonal level focuses on the nature of the interactions between students and peers or teacher and how the actions of all individuals during the interaction contribute to changes in shared understandings about the activity. The community or cultural level focuses on actions within the community (e.g., home, peer groups) and its role in the nature of social interactions and in individual students' engagement and understanding of activities in the classroom. As described, each level of analysis is linked to the other and cannot be separated from each other.

Rogoff et al (1995) suggest that any of these planes of observation can be the focus of analysis with the other planes acting as the background. This sociocultural approach is applied to the analysis of ESL students' learning in the present study. Data were analysed by focusing on the contributions of individual students as they interacted with the teacher and other students during whole class and small group interactions. The analysis was conducted within the larger context of the community (For example: how did family or cultural expectations influence students' interactions in class?). The diagram that follows illustrates how the three levels are woven together into the fabric of the analysis.

Data on students at the individual and community level were obtained from the two semi-structured interviews, students' written responses and field notes. Audio and video recordings of lessons, and field notes provided data on students at the interpersonal level. All interviews with individual and groups of students were transcribed verbatim.
Transcripts of interviews and field notes were coded in terms of categories taken from the interview protocol (appendix 1) and from the recurring patterns (e.g., words, phrases, ideas, events) in the data (Straus & Corbin, 1998). Coding categories such as personal biography, participation, affective factors, views of learning, teaching strategies, group work and language experiences were used to classify and organize excerpts of transcribed data in response to the research questions. For example, in relation to research question three, coded excerpts of all transcripts were placed into three broad categories of analysis - teacher and peer mediation, prior knowledge and language aspects - which were the factors identified in the literature as mediating ESL students' learning.

A log describing how all lessons and field trips were recorded was made during the project (appendix 7). Detailed field notes described the events and activities recorded on all audio and videotapes. As field notes were coded, selected excerpts of audio and video
recordings illustrating the three broad categories of analysis were transcribed verbatim. Background questionnaires, notes on informal discussions with the teacher, and students' written work were used to supplement information and triangulate data.

VI. Limitations of Data Collection Procedures

My fieldwork on the research project prior to the pilot study gave me first-hand experiences in using different qualitative methods to collect data. This research project was an ethnographic study of various practices in the school and involved classroom observations, extensive field note taking and semi-structured interviews with teachers, students and parents. It looked broadly at various aspects (administrative leadership, parental involvement, student culture, teacher's work) that contributed to the school's success. My experiences during this project made me aware of some of the limitations involved in the data collecting procedures. In particular, some of the methodological limitations involved in interviewing ESL students came to the fore.

As part of my fieldwork on this ethnographic project, I observed, interacted with and interviewed several ESL students at the school. Interviews were guided by the interview protocols of the research project. These semi-structured interviews focused on biographical, social, cultural, and language concerns dealing with school life. During these interviews, communication and interpretation of the meanings of words and sentences as well as problems of pronunciation were some of the language-related problems that I encountered. For example, there were many instances when students' limited proficiency of English
meant that I had to rephrase questions or explain the meanings of words that I used. There
were times when I did not understand their utterances because of their pronunciation of
words. These interviewing experiences led to modifications in interviewing techniques
during the pilot and main study. For example, using simple words, repetition, rephrasing
and elaboration of questions, and probing student responses were some techniques used
during the pilot and main study interviews. Also, the selection of students in the pilot and
main study were limited to those students who appeared fairly proficient at communicating
in English.

Students’ responses during interviews were also clarified by non-verbal means.
According to Mohan (1986), key visuals (e.g., diagrams, concept maps, webs) can be used
to successfully organize, simplify and convey meanings about content. Early (1990, p. 570)
argues that key visuals are particularly appropriate for ESL students as key visuals have "no
or lowered linguistic demands." In the main study, students’ verbal responses about
academic understandings were verified by their written responses in paragraph or diagram
form (appendix 2). These changes (brought about by my experiences as a researcher on the
research project and in the pilot study) concerning selection of students and interviewing
procedures enhance the internal validity of this study.

A limitation noted after data analysis, was that the available data did not lend itself
to an analysis which examined the interactions of the various factors identified in chapter
five. As such, the factors appear as separate categories. Subsequent studies in this area
might be more sensitive to the way data may be collected to explore the interactions among
various factors.
CHAPTER FIVE

Students' Participation Practices

I. Introduction

The results and analysis of data are presented in the next two chapters. As explained in chapter four, the analysis involves an examination of classroom activities at the level of individual, interpersonal and community or cultural processes. In this study, I focus on processes at the individual and interpersonal level because the main purpose of this study is to acquire insights into ESL students’ participation and learning during classroom social interactions. The research therefore focuses on the individual student as he/she interacts with other students and the teacher in the classroom setting. Students are not, however, isolated from their lives outside the classroom. Students’ social and cultural relationships outside the classroom have an impact on how they participate and learn in the classroom (Costa, 1995; Shapiro, 1989). Hence, the community or cultural level acts as the background in this study. At the individual level, I focus on individual students’ participation practices in classroom activities. At the interpersonal level I examine students’ interactions with other students and the teacher during whole class and small group activities.

Chapter five consists of two sections. In the first section, I present six case profiles about the nature of students’ participation practices in this biology classroom. Data were collected on 10 participants. Six of these case profiles were selected to illustrate the
diversity and range of participation practices observed among the ten participants. Transcript and field notes are analysed with respect to the following analytical categories: learning orientation, role of teacher, whole class interactions, and small group interactions. Relationships between students' expressed beliefs and their actual participation during classroom interactions are highlighted. The range of participation practices preferred by and supporting ESL students' learning raises questions about the assumption that more group work and cooperative learning is the way to go to enhance language and science learning. This section concludes with a summary table of the six cases. The table enables the reader to review individual cases and compare across cases.

In the second section of chapter five, I identify six factors that either enhance or constrain students' engagement in social interactions. Transcript excerpts from both the pilot and research study are used to support assertions. Chapter five concludes with a summary of the two sections.

In chapter six, I analyse students' interactions during whole class and small group activities for the purpose of revealing potential relationships between language and learning. These relationships are used to support my contention that the learning of science terms and concepts can be explained by a model of language that is more complex than that offered by the traditional triad model. Transcript excerpts are analysed with respect to two main areas: teacher's teaching of terms and concepts and students' interpretation of terms and concepts.
II. Classroom Context

As explained in the previous chapter, all grade eleven students were given the option of selecting this biology 11 honours course. This flexibility in course selection has enabled a cross-section of the student biology 11 community to be represented in the study. The ten participants in the study indicated that they had chosen the course for one of two reasons. Some were motivated to choose the course to enhance university entrance and career opportunities. These students (Shen, Sue, Jenny and Zack) were focussed in their interests and saw this course as helping in "university acceptance" or "becoming a doctor". Other participants chose the course because of their intrinsic interest in nature. Steve, David, Pete, Joe, Mai and Nancy saw the course as helping them "to better understand nature," to know "what's evolving around us and why things are changing the way they are" and "to know how nature works miraculously."

The course itself was designed to include a variety of whole class and small group activities such as whole class instruction and demonstrations, labs, cooperative reading and research assignments, projects and field trips. The general format of whole class instruction was teacher explanations interspersed by questions that were sometimes directed to individual students. Most times students volunteered answers.

During the eight-month observation period, 53 lessons were observed. Of these, 30 lessons were whole class instruction (including tests and reviews), 20 lessons involved small group activities and 3 lessons were used for fieldtrips. For most small group work and labs, students worked in groups of three or four. Students usually formed their own groups.
III. Students' Participation Profiles

The analysis of data revealed that students' participation ranged from a primarily individual engagement to a highly social form of engagement during classroom activities. For purposes of conceptual clarity, these two forms of engagement will be described as personal-individual participation practices and socio-interactive participation practices respectively. Personal-individual participation practices were characterised by primarily individual engagement in classroom activities - that is students worked by themselves and engaged in activities on their own. This type of engagement was also characterised by few social interactions with peers or teacher about the activity and/or about shared understandings of concepts. Socio-interactive participation practices were characterised by social engagement in classroom activities - that is, students worked with other students and engaged in activities with other students. This type of engagement was also characterised by many social interactions involving peers and teacher about the activity and/or about shared understandings of concepts. Six case profiles (selected to represent a range of participation practices) will be used to illustrate the nature of students' participation practices in this biology class.

Sue's Participation Profile

Background

Sue's parents were born in China and they emigrated to Canada about twenty years ago. Sue was born in Canada and spoke fluent English and some Cantonese. The language
spoken at home was a mixture of Cantonese and English. Sue spoke mostly in English with her parents. Her parents worked, two older siblings were at university and one younger sibling was in grade eight.

**Learning orientation - individual engagement**

Sue was very soft-spoken and came across as a quiet, reserved individual. During the first interview, she stated her preference for learning on her own: "I usually like to learn by myself. I don't really like to interact with other students." According to Sue, she preferred: "using a book and answering questions and then understanding." Although Sue participated in group activities, she made her feelings about group interactions clear: "Honestly, no. I would rather work alone." Sue felt that what would help her in her learning was more homework and projects where "you're more individualized [and where] you can learn the concepts as you're doing the report." Sue's comments about learning on her own suggest a strong tendency towards personal-individual participation practices.

**Teacher as explainer of textbook facts**

Sue saw the teacher as being there "to clarify things that we do not understand...."

The "things" that Sue wanted explained were the prescribed curriculum contents.

Sue: He always explains things beyond what you want to know.

Interviewer: You want to know the facts?

Sue: Yeah, just straight facts. I don't want to, you know, elaborate on different things.

Sue wanted to learn the facts from the text. She preferred explanations that were simple and direct without additional analogies and elaborations.
Besides having the teacher explain the facts from the text, Sue saw the teacher as being there "...to help you and to test you." She chose to receive help from the teacher after school. During these few occasions, questions asked were most often related to "tests" and "what I got wrong [in the tests]." Occasionally, she asked the teacher to explain concepts during group work or labs. Her view of the teacher as the explainer of facts to individuals and the private nature of her interactions with the teacher further indicate a tendency towards personal-individual participation practices.

**Individual whole class interactions**

Throughout the school year Sue occupied the outermost seat in the front row of the lab. Most times, she sat quietly, looking either at the textbook before her or at the chalkboard ahead. She seldom made eye contact with the teacher and rarely interacted with neighbouring students during whole class discussions. During teacher led discussions, she usually stared in front of her with an expressionless face. Even when the teacher used amusing analogies to illustrate concepts, her facial expression remained impassive for the most part.

Sue rarely answered teacher questions and she seldom asked questions during whole class discussions. Throughout the period of observation, Sue asked one question and responded to the teacher's questions twice [field notes]. The solitary nature of Sue's interactions during whole class activities reflects a student with a strong tendency towards personal-individual participation practices.
Individual and collaborative small group interactions

Sue felt that small group interactions with other students were helpful if "they know the stuff, and if you know the stuff, then you can communicate better." She preferred to work with students who "can explain things." Sue usually worked with two or more girls who sat next to her in the first row. During these larger group interactions, Sue was quiet and non-aggressive. When she did interact with other students, her communication was purposeful. That is, to elicit explanations or answers related to the task (illustrated in the next section). On the few occasions when Sue worked with a partner, she engaged in collaborative social interactions.

The following excerpt illustrates how Sue and Mai collaborated to describe and compare the characteristics of different bacterial colonies. In the previous lesson, students had added different kinds of bacteria to plates containing agar. Agar is a gelatinous substance produced by red algae and it is used as a growth medium for bacteria. All bacteria plates were then left at the same temperature in the same location for 45 hours. In this subsequent lesson, students worked in pairs to record what had actually grown on their bacteria plates. Students were expected to draw a map of the bacteria colonies on their plates, to identify characteristics such as the location, size, texture and colour of the colonies, and to group together colonies that were similar. The overall purpose of the lab was to look for a variety of characteristics of colonies to identify different bacteria.

1. Sue: Well, what do you think looks similar? The circle thing here?

2. Mai: there’s so many of them, there’s a brown one…

3. Sue: and what else? Is there another one [bacteria colony] but like the same
colour?

4. Mai: Ya, the colour seems ...[inaudible].

5. Sue: So is it like creamy white kind of or yellow like this?

6. Mai: You know what, in the middle it seems like it’s like a darker yellow and then outside it’s like white.

7. Sue: So, it’s more creamy white.

8. Mai: Ya, but look at this. It’s more creamy white but this one has a like a yellow inside and the outside of the circle is more white.

9. Sue: So it’s like yellowish white outside.

10. Mai: Ya, like yellow inside like white outside.

11. Sue: Okay. A light yellow centre and then just white.

12. Mai: It’s creamy white.

In this episode, Sue and Mai negotiate about one of the characteristics of a bacteria colony, colour, in order to come to some form of consensus regarding their observations (L. 5-13). Sue communicated and contributed towards a shared understanding about the characteristics of a bacterial colony.

Overall, Sue's preference to engage in classroom activities by herself and the individual nature of her engagement during whole-class activities throughout the 8-month observation period indicates a student with a strong tendency towards personal-individual participation practices.
Shen’s Participation Profile

Background

Shen was a recent immigrant from Hong Kong and was an only child. Although English was Shen’s second language (Cantonese was the language spoken at home), Shen was confident and comfortable conversing and learning in English. Much of her confidence and comfort seemed to be related to her previous exposure to English in academic settings. Prior to her arrival in Canada, Shen learnt English as a second language at her school in Hong Kong. These English classes focussed on reading and writing skills but did not provide many opportunities for practising English conversational skills. Hence, when Shen arrived in Canada (at 12 years old), she was not very fluent in conversational English. She spent approximately half a year in ESL in secondary school before progressing to regular English classes.

After three years in a Canadian secondary school, Shen was confident in her use of both written and spoken English language in conversational talk as well as academic talk. During our interviews and informal classroom interactions she was vocal, expressive and often initiated the conversation. She aspired to become a doctor and was motivated to achieve high marks in biology.

Learning orientation - individual engagement

Shen indicated during the interviews that the best way for her to learn was by reading the text. When she did not understand something she usually read the text again. In this regard, she seemed to be following a piece of advice given to her by her dad: "My dad
always told me that if you don't understand it read it again and again until you understand it."

With regard to group work, Shen felt that she did not really learn much during group work, particularly dissection labs. She stated that most times they "don't really share information .... [students] read up and tell the others what the function of this and what the function of that is." She indicated that group work involving such discussion was not beneficial to her as the facts were in the text.

Shen also felt that tests and quizzes were ways to help her learn. According to Shen: "If you do not get good test marks that means that you didn't really understand the concept that well. If you get good test marks that usually means that you learn something - that means you understand what he [teacher] taught in class." She commented further that: "quizzes is the best way to review things, to know how much you actually learn."

Shen's preference to learn by reading the text and writing tests and quizzes suggest a tendency towards personal-individual participation practices.

Teacher as extender of concepts

Understanding concepts was important to Shen. Unlike Sue, Shen wanted explanations of concepts to go beyond the facts in the text. She wanted to have a complete and in-depth understanding of scientific phenomena as offered by experts. In the classroom, the teacher was regarded as the expert. Shen therefore preferred to ask the teacher to explain or clarify concepts rather than ask other students in class "cause he knows the correct answers that we don't know." She felt that the "clear explanation" offered by the teacher
benefited her most. The teacher was therefore seen as a resource that supported the text by clarifying and extending text explanations.

Shen interacted with the teacher on a personal and social level (as explained in the sections below). She asked for explanations before and after school, during whole class activities and during group work. Her view of the teacher as explainer and extender of facts to individuals and the nature of her interactions with the teacher suggest a student with a tendency for personal-individual participation practices.

Personalized whole class interactions

Although Shen’s participation was social during whole class activities, her social interactions were limited to the teacher only. She had developed a highly personal and individualised way of communicating with the teacher during class discussions. She asked questions and frequently responded to questions from the teacher but these were in a soft tone of voice that could be heard only by the teacher or students sitting next to her. Her seat, which was in the first row directly in front of the teacher’s usual position beside the overhead projector, facilitated this personal one-on-one communication. Using this personal-individual practice she was able to ask the teacher for further explanations and clarification without involving other students in her interactions. Most times the teacher repeated Shen’s questions or responses to his questions to include the rest of the class in the interaction. The personal nature of her interactions during whole class activities indicates a student with a tendency for personal-individual participation practices.
Social small group interactions

During small group work, Shen often assumed the role of initiator and leader in her group. She took the lead, both in carrying out tasks and communicating verbally. In the following lab, Shen worked with a group of five girls. They are engaged in comparing specimens of the frog and the rat.

1. Shen: OK. Let’s compare the lungs now, please. We don’t have much time. What do you want to compare it as?
2. Tina: What?
3. Shen: It looks like your eye....
4. Shen: Can we compare the size now?
5. Sue: How many times is it bigger?
7. Tina: No, Shen.
8. Shen: Ya, it is.

In this excerpt, Shen engaged in the activity by interacting with other students. She actively communicated with her peers by issuing directives (line 1), asking questions (line 1, 4) and offering explanations and answers (line 3, 6). Shen also used group work and labs as opportunities to ask the teacher to explain and clarify concepts [illustrated in the next section]. Her participation practices during small group work were socio-interactive in nature.
Overall, Shen’s preference to learn by reading a text and writing tests and quizzes and her personalized whole class interactions with the teacher indicate a student with a tendency for personal-individual participation practices.

David’s Participation Profile

Background

David was born in Vietnam. His family came to Canada when he was a young child. He went to pre-school and kindergarten in Canada and progressed through the school system without any ESL classes. David’s parents spoke a mixture of Vietnamese and Chinese at home. David spoke mostly Vietnamese and some English with his family.

Learning orientation - visual and social

David preferred to learn through visual means and social interactions rather than read a text.

It's quite harder to read it and understand it than it is to show a diagram or see a video or make a graph or see something. ... because then words sometimes are complicated to actually visualize. If you see a picture it's much easier to understand. [David, interview]
With regard to social interactions, David preferred "doing labs and doing hands on work rather than just sitting there and listening to the teacher". He preferred learning in groups with peers.

You actually get to find out other people's opinion, see if you are wrong. Cause sometimes if you are doing work alone you don't know if you are right until the end. You find out from the teacher. But from a friend at least, you know, you get an idea of what people think. [David, interview]

The above excerpt suggests that David exhibited a strong tendency to communicate and negotiate meanings with peers - a characteristic of socio-interactive participation practices.

For David, even homework practices were socio-interactive in nature. Rather than working alone, David got together with a group of students to discuss their homework and assignments.

... we do it ourself but sometimes the work that he gives, it [sic] a bi honours class so I understand it is a little bit harder - we do it with each other. ... Like lunch time we would just sit there and say, "Oh, my goodness, what do we do here?" And then, you may start out being stuck on something but as you get ideas going and you find one answer and then the rest would be very easy because it's the same thing. As long as you know how to do one then the rest would be similar to it. [David, interview]

Working collaboratively on homework tasks with other students was another example of David's tendency to learn through socio-interactive participation practices.
Teacher as facilitator of peer collaboration

David felt that it was boring to have to listen to the teacher talk and explain for long periods of time. He elaborated further that, “instead of the [teacher] just explaining and the class just sits there and writes notes,” the teacher should “try to find ways to get the class participating.” He found working in groups much more “fascinating.”

...see, when it’s a group you get to find out things and argue about what’s wrong and what’s right instead of just doing it by yourself or looking at the board watching him [teacher] write notes.
[David, interview]

David’s view of the teacher as a facilitator of peer collaboration suggests that David preferred to learn through socio-interactive participation practices.

Social whole class interactions

David’s preference for learning through social interactions was consistently reflected in his participation practices during whole class activities. He often responded to teacher questions (47 times over 30 lessons) and he asked questions (7 times over 30 lessons). During teacher explanations and discussions, his face often reflected a lively interest and excitement. He responded to and laughed at teacher comments and jokes. David often shared his interest in the topic by communicating with his neighbour, Steve. David explained that he would ask Steve questions about the topic being discussed by the teacher. They would discuss what the possible explanations could be or if both were unsure then either David or Steve would ask the teacher questions.

Learning through social interactions with both teacher and peers during whole class lessons was a consistent practice throughout the research project.
Collaborative small group interactions

David enjoyed learning in small groups. He usually chose to work with his neighbour Steve or worked with Steve and a group of boys seated around him. During group work, David asked his peers questions about the task and collaborated with them to come to some shared understanding of the activity.

In the following lab, David dissects a grasshopper and interacts with Steve, his partner.

1. David: Look, the crop, right, then there’s the gizzard.
2. Steve: Yeah.
3. David: That’s the stomach and there is the colon. Isn’t the gizzard the stomach?
4. Steve: It’s connected to it.
5. David: That’s weird because in the worm the gizzard is the stomach.

In this excerpt, David collaborates with Steve about their observations of the internal organs of the grasshopper. He sought clarification from Steve about the use of the terms gizzard and stomach (line 3) and compared the parts of the grasshopper to the earthworm (line 5), (dissected in a previous lab). David’s social interactions during small group work were strongly socio-interactive in nature.

Overall, David’s social interactions with his peers and teacher during whole class activities and small group work, his view of the teacher as facilitator of peer collaboration
and his preference for learning through collaborative interactions during small group work indicate a student with strong socio-interactive participation practices.

**Steve’s Participation Profile**

**Background**

Steve was born in Canada. His parents came from Shangai, China. Steve attended ESL classes in kindergarten. While growing up, Steve spoke only Cantonese at home. English was spoken outside the home with his friends. When Steve was 13 years old he began to speak both English and Cantonese with his dad and younger sister.

From an early age, Steve loved to read science magazines and watch science related movies like the X-Files. His science teachers, primarily this biology teacher, had also fostered his interest in science. This biology teacher had also taught Steve science in grades 8 and 9. In his grade 11 year in school, Steve was taking chemistry and physics as well as biology.

**Learning orientation - visual and social**

Steve, like David, indicated a preference for learning through visual means rather than reading a text. Steve stated that:

> I don’t think the textbook actually helps a lot because your mind drifts away after a while but using the overhead you actually get all the information down. [Steve, interview]
Although Steve was not very direct about his preference for learning, his responses about learning tend to indicate a preference for learning through social interactions.

I just listen to the teacher, talk with friends, that sort of thing. ... whenever we have discussions throughout the classroom, we seem to wander off the subject but we learn more that way. [Steve, interview]

Steve’s preference to learn through class discussions that were not confined to the topic, suggest a student with a tendency for socio-interactive participation practices.

Teacher as facilitator of peer collaboration

Unlike David, Steve felt that the teacher should encourage students’ collaboration through oral presentations rather than leaving groups to share ideas on their own. He stated that when groups were unsupervised, students “just copy off each other” and “don’t really do any talking.”

Steve felt that a better strategy would be to:

have individual groups doing the work and then in the end we share information as a class so everybody has information together. [Steve, interview]

Steve’s view of the teacher as facilitator of peer collaboration suggests a tendency for learning through socio-interactive participation practices.

Social whole class interactions

Steve was the student who interacted with the teacher the most during whole class activities. Steve answered the teacher’s questions in every lesson - about 121 times over 30 lessons and he occasionally asked the teacher questions. Steve told me that he had always
been interested in science and he answered questions depending on the topic and his interest in it. The teacher told me that Steve did not score high marks on written tests but Steve’s oral responses to questions in class indicated that Steve understood many concepts.

Steve also interacted with his neighbour David during class lessons. Most of these peer interactions were about the topic under discussion, with Steve responding to David’s questions. Steve’s whole class interactions reflect a student with strong socio-interactive participation practices.

Collaborative small group interactions

Steve mostly worked with David and the group of boys seated around him. As illustrated in the excerpt with David, Steve asked questions and collaborated with his peers during small group interactions.

Overall, Steve’s social interactions during whole class and small group activities and his preference to learn through classroom discussions and collaborative oral presentations are reflective of strong socio-interactive participation practices.

Pete’s Participation Profile

Background

Pete is of Vietnamese origin. His childhood experiences include leaving Vietnam at an early age and spending time in a camp for refugees in Malaysia. Pete was eleven years old when he travelled, with an uncle, to Canada on a boat. Prior to his arrival in Canada, Pete’s exposure to English was minimal. Pete was therefore placed in the ESL program in elementary school. When Pete went to high school, he continued in the ESL program for
two more years. Part of the program included attending specially adapted science classes
(called transitional science) for ESL students. Pete spent six months in transitional science
after which he progressed to the regular grade nine science class. He completed grade 10
science and was now in the grade eleven biology honours class.

Learning orientation - social and listening

Pete expressed a preference for learning by asking questions and listening to others.
Pete’s comments to this effect were:

I don’t want to read books and stuff. I hang out
around friends and they tell me the answer and it
go to my head. ...Teacher, he keep talking -it go to
my head. [Pete, interview]

For Pete, "go to my head" referred primarily to memorizing or remembering the
answers. At both the initial and final interviews he indicated that he merely wanted to
explore the simple aspects of biology. He found the details and concepts too complicated.

Pete used social interactions with peers to elicit correct answers. His response to my
question: "Do you ask the students in class to explain things to you?" was a laughing, "No.
I just ask for the answer." Pete’s preference to learn through interactions with his peers and
teacher suggest a student with a tendency for socio-interactive participation practices.

Social whole class interactions

Pete's participation practices during whole class activities were social in nature. His
overall demeanour during class lessons was relaxed and alert for most of the period. He sat
upright, listened attentively to the teacher and responded (10 times over 30 lessons) and
asked questions related to the topic (23 times over 30 lessons) during class instruction time.
Pete's limited proficiency in the English language made the interpretation of oral discourse and written work a difficult task. There were times when Pete would appear to lose the thread of the teacher's explanations. These instances were noticeable by the blank or quizzical expression that appeared on his face. Pete confirmed these observations by stating in the interview that, "the way he [the teacher] talks out is too complicated. He use [sic] too complicated words and I cannot catch up most of it."

In spite of Pete's language limitations, he wanted to compete with other students and do well. His desire to do as well as other students often translated into anxiety about tests and quizzes. Pete would often ask the teacher to reiterate the questions and sections that he had to learn for tests and quizzes prior to instruction. He often met with the teacher at the end of lessons to inquire about his performance on the tests. Therefore, in addition to the 23 questions asked about the topic, he asked a further 13 questions that were logistical in nature (related to instructions about classroom tasks and performances on assignments, tests and exams).

Pete sometimes interacted with his neighbour during whole class instruction. These exchanges were often playful and provided a distraction during lengthy teacher explanations.

Social small group interactions

Pete regarded group work as a means to accomplish work more efficiently.

It's faster instead of one guy have [sic] to do everything. [Pete, interview]
As for learning, Pete felt that he did not learn much from his peers during these times.

All you do is show and now [sic] write down the answer and give it to the teacher. [Pete, interview]

During group work, Pete did not usually discuss concepts related to the task. He and his neighbour/partner carried out the task and focused on answering the questions. Pete usually asked his partner for answers to questions. Pete, however, often used the group work sessions (and our interview sessions) to ask the teacher or me to interpret questions and explain answers that he had difficulty comprehending. Specific examples highlighting these language difficulties are illustrated in the next chapter.

Overall, Pete’s preference to learn through social interactions and his actual participation - he asked and answered questions in most whole class discussions throughout the year - indicate that Pete's participation tended to be socio-interactive in nature.

**Mai’s Participation Profile**

**Background**

Mai was born in Cambodia in the early 1970’s, during a period of civil unrest. When Mai was two, she and her family moved to Thailand. Her family emigrated to Edmonton, Canada when she was about eight years old. Mai had not spoken English prior to coming to Canada so she was placed back three grades in elementary school. She attended ESL classes for three years and completed her junior high school in Edmonton. Thereafter, her family relocated to Vancouver. Mai had attended another high school in
Vancouver the previous year. She was a newcomer at this school and was in the hairdressing program. Although Mai’s parents only spoke Cambodian, Mai and her siblings, a sister in grade 8 and a brother in grade 5, spoke both English and Cambodian at home.

**Learning orientation – reflective listening and visual**

According to Mai, learning involved “listening to the teacher” and “trying to understand what you’re reading and make sure you can put it in your own words.” She felt that by writing down and summarizing what you read in your own words “helps you more to understand it than just memorizing it.”

Mai preferred to learn by listening to the teacher rather than reading the text.

> Like listening to the teacher explaining things makes me understand it. .... Cause sometimes when I read stuff in the book, I don’t really understand everything, but when I go to class and the teacher starts explaining things I understand it clear. [Mai, interview]

Mai was curious about nature and loved watching nature shows on television. She explained that she also preferred to learn through visual means such as films.

> When you see it you kind of like understand it clearer. [Mai, interview]

Mai’s preference to learn through reflective listening and visual means suggest a student with a tendency for personal-individual participation practices.
Individual whole class interactions

Mai’s demeanour during whole class activities was quiet and reserved. She appeared isolated and did not interact freely with other students in the class. Throughout the research project, Mai responded five times to the teacher’s questions and did not ask any questions. The solitary nature of her interactions during whole class activities suggests a tendency towards personal-individual participation practices.

Collaborative group interactions

In relation to group work, Mai felt that “group work helps a lot because like I don’t always know everything and you always get ideas from other people.” Mai used group work to collaborate with and elicit help from more knowledgeable peers. She preferred to “go in a smart group” where she could get “much ideas” from other students. She also used small group work as an opportunity to ask me or the teacher to explain concepts or language related difficulties to her.

Overall, Mai’s preference to learn by listening to the teacher and her solitary demeanour during whole class activities reflect a student with a tendency towards personal-individual participation practices.

IV. Summary of Participation Practices

The table on the next page provides the reader with a summary of the participation profiles of the six students discussed above.
Table 1. Summary of students' participation and learning interactions

<table>
<thead>
<tr>
<th>PERCEPTION OF ROLE OF TEACHER</th>
<th>WHOLE-CLASS INTERACTIONS</th>
<th>GROUP INTERACTIONS</th>
<th>LEARNING ORIENTATION</th>
<th>PARTICIPATION PRACTICE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sue</strong></td>
<td>Explainer of text facts</td>
<td>Solitary listener</td>
<td>Individual and Social – collaborates to elicit answers</td>
<td>Individual engagement</td>
</tr>
<tr>
<td><strong>Shen</strong></td>
<td>Extender of text facts</td>
<td>Personalized interactions with teacher</td>
<td>Social – initiator and leader</td>
<td>Individual engagement</td>
</tr>
<tr>
<td><strong>David</strong></td>
<td>Facilitator of student collaboration</td>
<td>Social. Very interactive</td>
<td>Social – collaborates to share ideas</td>
<td>Social and visual</td>
</tr>
<tr>
<td><strong>Steve</strong></td>
<td>Facilitator of student collaboration</td>
<td>Social. Very interactive</td>
<td>Social – collaborates to share ideas</td>
<td>Social and visual</td>
</tr>
<tr>
<td><strong>Pete</strong></td>
<td>Explainer of text facts</td>
<td>Social. Very interactive</td>
<td>Social – collaborates to elicit answers</td>
<td>Social and listening</td>
</tr>
<tr>
<td><strong>Mai</strong></td>
<td>Explainer and extender of text facts</td>
<td>Reflective listener</td>
<td>Social – collaborates to share ideas</td>
<td>Visual and listening</td>
</tr>
</tbody>
</table>
The analysis of data revealed that students' participation in this biology class tended to range along a continuum from personal-individual to socio-interactive in nature. There was considerable variability in the nature of and extent of engagement in different contexts.

The presence of a range of participation practices suggests that both group and individual based activities are significant for ESL students' learning in science. This finding raises questions about the assumption that learning science and language is enhanced by greater emphasis on collaborative small group work as suggested by the literature (Fathman & Kessler, 1993; Meyers, 1993; Nunan, 1999). The data in this study suggests that different instructional and learning strategies ranging from individual activities to group work were preferred by different students. For example, Sue and Shen preferred individual-based activities such as reading, quizzes and tests while Pete, Mai and Steve preferred to learn science in group-based activities. While the merits of group work from the sociocultural perspectives of learning are recognised, the assumption that more group work over individualised work will support all students' learning is a misleading notion. Students come from different sociocultural backgrounds, have different prior science classroom experiences and have different parental and personal expectations. The role of these latter factors on ESL students' preferred learning orientations and participation practices in the classroom are examined in the next section.
V. Factors Enhancing or Constraining Students' Engagement in Social Interactions

In the previous section, students' participation practices were inferred from their expressed preferences for learning and their actual participation during whole class and small group activities. In this section, factors enhancing or constraining students' social engagement in classroom interactions are identified. A factor was considered to enhance students' social engagement if it contributed to increased social interactions with peers and teacher. A factor was considered to constrain students' social engagement if it limited social interactions with peers and teacher. Transcript excerpts from both the study and pilot are used to support these assertions.

Socio-cultural Factors

The nature of students' engagement in classroom practices may be related in part to the cultural expectations communicated and perpetuated through overt and covert norms, customs, and practices in their previous classroom settings. All students experience some sort of "cultural norms." In this study, students responded in different ways to different sets of cultural norms and values.

For example, Shen and Nancy were recent immigrants from Hong Kong and India respectively. Shen's comments with regard to the participation practices of students in Hong Kong highlight the differences between the norms, customs and practices in this biology class in Canada and those in Hong Kong. The biology class in Canada was
characterized by students answering and asking questions, expressing opinions and becoming involved in discussions. Referring to student participation in Hong Kong classes, Shen commented, "We don't even talk in class." She went on to state that, "if we talk we get detention or something."

Nancy, also a Cantonese-speaking student, had been born in Calcutta, India and had been educated in English speaking schools. She had arrived in Canada the previous year. This was her first experience in a Canadian school. At our initial interview, she made the following observations about the cultural expectations in her previous schools in India, "You were expected to be quiet when the teacher was teaching."

The behavioural expectations in Shen's and Nancy's previous schools appear to be related to broader cultural expectations and traditions. In Chinese culture, teachers are accorded high status and "students show their respect by keeping quiet in class" (Cooper & Simonds, 1999, p. 23). Challenging the authority of elders is considered disrespectful. Similarly, in Indian culture, Jayalakshmi (1993) points out that the influence of the traditional Gurukala style of instruction and storytelling can be seen in secondary education in India. In Gurukala, the guru (storyteller) is regarded as the authority figure who explained texts to less knowledgeable students. The influence of this tradition can be seen in secondary schools where the teacher is regarded as the authority figure who transmits his superior knowledge to less knowledgeable students.

Institutions, like schools, perpetuate these cultural norms and traditions. Shen and Nancy were accustomed to passively accepting information without questioning the teacher. Their participation during whole class interactions reflected this pattern of behaviour to
different degrees. Shen had been in the Canadian school system for four years. She did respond to and question the teacher, but her whole class interactions were characterized by softly spoken responses and questions directed at the teacher only. Like Shen, Nancy's participation practices during whole class activities tended to be personal-individual in nature. She came across as quiet and unobtrusive. Nancy responded to the teacher's questions about seven times throughout the year and did not ask a single question during whole class discussions. Both students' experiences with a different set of cultural behavioural expectations may have constrained their social interactions in this biology class.

In contrast, Steve, David, and Pete (also Asian students) were brought up in Canada. They had been exposed to the cultural norms of both their family and North American society. In North American culture, the concept of respect and authority incorporates ideas of questioning information, mutual consent, agreements and disagreements, negotiation and choice.

Steve, David and Pete were socially active during all classroom activities. They responded to teacher questions and questioned the teacher. Their exposure to the cultural norms in North America may have enhanced their social interactions in classroom activities.

**Prior School Experiences**

The prior experiences of students in previous classrooms appeared to influence their engagement in classroom social interactions. The expectation of how students should behave in classrooms was communicated through expectations set up in previous science classes.
Sue had been born and educated in Canada. She preferred to use a textbook to learn rather than listen to elaborate explanations from the teacher. When I questioned her about her habit of using the text, she explained that:

[In] grade 10 and grade 9, we just used science text books and the teacher never did anything of this [elaborate beyond the text]. We always used the text book and I always thought that was most helpful. [Sue, interview]

Sue's comments suggest that her experiences in previous science classes contributed to her participation pattern in this biology class. During whole class interactions, she sat passively, listening to the teacher. During small group work she was mostly quiet. When she did engage socially with her peers, her social interactions were purposeful—to elicit answers to assignment or lab questions. Sue’ prior classroom experiences appeared to constrain her engagement in classroom social interactions.

Mai’s previous classroom experiences were in Canadian schools where teacher talk dominated the class. When asked what learning involves, Mai replied instantly: “Listening to the teacher”. Mai’s participation during whole class activities reflected her response - she sat passively and listened to the teacher. Mai’s social interactions during whole class activities appeared to be constrained by the behavioural expectations set up during prior classroom practice.

Nancy’s prior school practice in India was characterized by passively listening to lectures and copying notes. She was not accustomed to labs, field trips and co-operative group work - activities that encouraged socio-interactive participation practices.
In India, we get more notes. ... I think I prefer it here because of the activities and the labs we do. [Nancy, interview]

Nancy’s experiences in her previous science classes in India may have also contributed to her participation pattern of sitting quietly in this biology class and listening to the teacher during whole class interactions. There was also a noticeable difference in her participation in small group work at the beginning and at the end of the year. At the beginning of the year, she was quiet and her social contribution to the group was limited. Towards the latter part of the year, her social interactions within the group increased and she asked and responded to group member’s questions (as illustrated in the section on Peer Mediation of students’ learning in the next chapter). Prior school practices appeared to constrain Nancy’s social engagement during whole class and group interactions in this biology classroom.

Similarly, Shen’s participation practices appeared to be related to her previous classroom practices in Hong Kong. The behavioural expectations set up in Hong Kong classrooms (quietly listening) appeared to constrain her social interactions in this Biology class.

David, Steve and Pete’s prior school science experiences were in Canadian classrooms where the expectation regarding student participation was active engagement in whole class and small group activities. Whole class discussions, small group work, labs, and field trips were a regular part of their school practice. David, Steve and Pete expressed a preference for and exhibited strongly socio-interactive participation patterns in this biology
class (as explained in the previous section). Their prior school experiences appeared to enhance their social interactions in both whole class and small group activities.

**Teaching Practices**

A variety of teaching strategies appeared to increase students' social engagement in classroom interactions. During whole class explanations, the teacher directed questions to the whole class in an attempt to encourage all students to respond. For example, during a lesson on “Structure-Function Relationships”, the teacher asked questions such as “what’s the difference between you and a bat? and “what do you need to be a predator in water? Such questions were directed to the whole class and encouraged individual students to think about and volunteer responses about how their bodily structures were different from other organisms and/or how it should be adapted to perform a particular function.

This questioning strategy was used throughout the year and enhanced the social engagement of students like Steve, David, Pete and Shen. During the early part of the school year, this strategy was also used to assess the level of social engagement of students. It was the teacher’s intention to then direct questions to quieter students to enhance their participation. During the course of the year, the teacher occasionally singled out students by name - a strategy used to enhance the participation of more passive students like Sue, Nancy and Mai.

The teacher used illustrative examples related to students’ everyday lives to motivate and stimulate responses and questions about science topics. For example, during the introduction of the concept “homeostasis”, the teacher illustrated how organisms maintained
the range of conditions (e.g., temperature, acidity, amount of water) required for optimum biological and chemical functioning using examples related to students' everyday lives. He asked students what would happen to them if they drank too much water to illustrate how the kidneys maintained water balance. He illustrated how body temperature is controlled, by referring to the everyday example of sweating. Questions such as: “what makes you sweat?” and “what does your skin look like when you get cold?” were personal and motivated students to describe their everyday experiences such as “sweating when you run or live in a hot climate” and “getting goose bumps when you are cold”. Such questions triggered a lively discussion. The teacher then used these student responses as the basis for explaining how sweat glands and hairs on the skin maintain body temperature. The above episode suggests that illustrative examples related to students' everyday lives stimulated classroom discussion and enhanced students' social engagement during whole class interactions.

Another strategy that enhanced social interactions among all students was small group work where students had a choice in selecting partners or group members. For most small group activities in this class, students chose whom they worked with. The composition of groups or partnerships was fairly consistent throughout the year. Steve and David always worked together. Shen, Sue, and Nancy usually formed groups with each other and the other girls seated in the first row. Mai sat in the second row and tended to be the odd one out. She either joined the girls in the front row or grouped with students seated next to her in the second row. Pete mostly paired up with his neighbour. Joe worked with a group of four boys in the last row.
In this biology class, the teacher provided numerous opportunities for small group interactions through labs, collaborative assignments, and peer editing of assignments. David and Steve’s preference for communicating with peers was enhanced by the numerous opportunities to work in groups. For Sue and Nancy, who expressed a preference for personal individual participation practices, opportunities to work in small discussion groups of their choice, working on tasks such as lab or assignment questions (tasks to be handed in for assessment), tended to enhance their social interactions.

In the following small group activity Sue, Nancy and Kim collaborate with each other as they discuss questions related to the grasshopper lab.

1. Sue: What’s the advantage of the compound eye? What’s the advantage of its structure and shape?
2. Kim: gives better sight, okay.
3. Sue: What else?
4. Kim: I don’t know. Camouflage?
5. Sue: It’s green colour?
6. Kim: Shen [in another group], aren’t you going to share yours [answers] with us?
7. Shen: Wings for flying.
8. Kim: They don’t fly, do they?
10. Kim: They jump.
11. Sue: Do they fly like birds or do they just jump?
12. Nancy: They jump a great distance.
13. Sue: Where do grasshoppers live?

In the above excerpt, Sue engages in purposeful social interactions with her peers. She asks a series of questions to elicit answers or explanations (line 1,3,11,13). Kim and Nancy respond to Sue’s questions (line 2,9,10,12,14). The above excerpt suggests that small group work (pairs and threes) tended to enhance social interactions among students.

The size of groups appeared to play a role in the nature of student engagement. Social interactions in larger groups (four or more students) were often characterized by inequitable participation among group members. In larger groups, some students tended to be more socially dominant than others. For example, her peers regarded Shen as a high achiever. She dominated social interactions during group work.

In the following group activity, six students compared the specimens of the frog and the rat. The conversation below is with reference to the specimen of the rat.

1. Shen: These are the lungs.
2. Kim: Lungs?
3. Shen: Ya. It should be.
4. Nancy: But they are not connected. It’s either a separation.
5. Shen: That’s a diaphragm.
7. Tina: It should be. We cut it off.
8. Shen: No. I think this is the diaphragm.
9. Chorus: This? [pointing to specimen of rat]

10. Kim: Diaphragm is the respiratory system, right?

11. Shen: Ya, under the lung. [More talk about the appearance and size follow]

12. Sue: Can we say the lungs [of the rat] were detached and those [pointing to the frog] were detached.

In this excerpt, Shen (spoke 5 times) and Kim (spoke 3 times) dominate the talk while the other four students are mostly silent or interject occasionally (line 4,7). Shen points out and identifies the lungs and diaphragm is a very decisive manner (L. 1, 5). Kim’s explanation on Line 10 and Shen’s affirmation on line 11, suggest that these students are not sure what the respiratory system is comprised of. The diaphragm does play a role in breathing, but it is a muscle that separates the thoracic and abdominal cavity. Shen does indicate that she knows where the diaphragm is positioned (L. 11). The students are however, cooperating to carry out the objective of the group activity (L. 12) - to compare and contrast the internal organs of the rat and the frog.

In general, two or three students dominated talk in larger groups while the rest of the members interjected occasionally (L. 12) or acted as observers. When students worked in pairs or threes, participants contributed to the interaction on a more equitable basis. Social interactions of all group members appeared to be enhanced when students worked in pairs or threes rather than in larger groups.

Small group work also enhanced student-teacher interactions. Many students used this practice to ask the teacher to explain or clarify concepts.
In the following group activity, Shen and Tina are reading instructions from a lab worksheet as they examine a preserved crayfish specimen.

1. Shen: Read it out loud.
2. Tina: You read it.
3. Shen: Extending from many of the segments of the most primitive arthropods are two-branched appendages.
4. Tina: What do you mean by two branched appendages?
5. Shen: I don't know. Sir [yes] what does it mean by two-branched – how do you say that word-appendages?

In this segment, Shen calls out to the teacher to assist their group in understanding the meaning of two-branched appendages. The teacher immediately responds and begins to explain with reference to the crayfish specimen.

6. Teacher: OK. That’s what I meant – each one of these things is two branches - one branch is the leg coming out underneath and the other branch is the gill going up underneath the carapace. So each of these things when you look down at the swimmerets - look at them - each of them comes out as one and then branches into two parts.

Shen continues to interact with the teacher and ask for clarification while pointing to the parts on the specimen.

7. Shen: These are all the parts of the branch [pointing to specimen]?
8. Teacher: Each of these appendages. So there’s the main part of the body -
the abdomen and the cephalothorax and then anything that sticks out from that is called an appendage - something that hangs from the outside. In crustaceans, the appendages are always two- branched - they come out and then they split in two.

9. Shen: So does the antennae branch in two? [pointing to the visible appendage]

10. Teacher: No, this whole thing is in fact one. The other part of it is a gill that is up underneath the carapace.

In this group interaction involving the teacher, Shen asked the teacher to explain the meaning of two-branched appendages. She asked for explanations (Line 5) and clarification of explanations (line 7,9). Small group situations appeared to enhance interactions between students and teacher.

**Affective Factors and English Language Proficiency**

Students' self-esteem, self-concept, and perceptions of themselves as English language speakers seemed to constrain their social engagement in classroom practices in both the pilot and research study.

Although Pete's participation practices were socio-interactive in nature, Pete felt that his social engagement could be greater. Pete told me that he did not ask the teacher to repeat explanations that he did not follow during whole class discussions because he felt that, "the whole class is going to laugh at me." His belief seemed to stem from his image of what it
meant to be a biology honours student. Pete explained that he did not want people to say, "Pete, you don't know anything about this. Why you [sic] in 11H [honours] for? Why are you not in 11 instead or something like that."

English Language proficiency also appeared to play a role in constraining Pete's social engagement. Pete indicated that there were times when his pronunciation and lack of fluency in English bothered him. "Sometimes when you talk to teachers, [they say]: "I couldn't get you. I couldn't get you. What? Yeah, yeah. It kind of shy me away." Instead of persisting with his questions, Pete would respond: "Forget it. Nothing." For Pete, self-esteem, his belief of what was expected of an honours student and his limited proficiency in English were factors that appeared to constrain his social engagement in classroom activities.

Mai also appeared to lack confidence in herself as a learner in this honours class. During our informal conversations at the beginning of the school year, she told me that the students in this class were "more intelligent" than her. She stated that she felt embarrassed at giving incorrect answers and thought that "smarter" students would laugh at her. These sentiments expressed by Mai appeared to be based on prior experiences. During the entire research project, I did not observe any student laughing at Mai’s responses. Mai's social interactions during whole class activities therefore appeared to be constrained by her lack of self-esteem and self-confidence. Group interactions with peers of her choice appeared to give Mai more confidence. She was more willing to offer suggestions and explanations during small group work (as illustrated in the excerpt where Sue and Mai describe Bacteria plates).
Another example that illustrates how affective factors and language proficiency constrained students' social interactions is drawn from the pilot study. Sal, a native Spanish speaker, was born in Costa Rica. She and her family had emigrated to Canada five years earlier. On her arrival in Canada, Sal was placed in an elementary ESL program where she completed grades 5, 6, and 7. In secondary school, she completed the following ESL courses: modified English in grade 8, and transitional science in grade 8 and 9. Sal progressed to regular science courses in grade 10.

In this grade 11 biology class, Sal came across as a quiet, conscientious student who enjoyed learning. For the most part, she listened attentively to the teacher or diligently took down notes from the overhead. Sometimes, Sal would answer questions in response to the teacher's questions, or direct queries (e.g., about test schedules) to the teacher. A distinctive feature about her social interactions in these initial whole class discussions was its unobtrusive nature. Sal's responses were always mumbled or directed softly at the teacher only.

On being asked about this aspect of her participation in class, Sal responded:

I am embarrassed that it will be - I said it wrong or it will be the wrong answer so I just mumble.
[laugh] [Sal, interview]

For Sal, "saying it wrong" was not strongly linked to embarrassment at not knowing the right content. Rather, her embarrassment seemed to be strongly related to her belief about her proficiency in English, as illustrated in the next excerpt.

Interviewer: But don't other students also say it wrong sometimes.

Sal: But their English is perfect, I mean.
Sal believed that her English was "not up to standard" in comparison to her native English speaking peers, especially her pronunciation.

Interviewer: ... do you have difficulty in understanding [the teacher's] pronunciation or were you talking about your own pronunciation?

Sal: Oh, his I have no problem. Mine, when I talk. So I try to participate but it's really embarrassing.

In Sal's view, social interactions were an important component in learning. In spite of her belief that learning involved social interactions, Sal's participation was constrained by her perception of herself as a proficient language speaker.

Besides this perception of herself as a speaker, Sal felt that her participation was also linked to the nature of her personality. She stated, "I've always been shy, I guess. That's part of it too."

For Mai, Pete and Sal, their self-esteem and their perceptions of themselves as inadequate English language speakers seemed to be factors that constrained their social engagement in this biology class.

**Participation in the Research Project**

Of the ten participants in the research study, students who were confident about their academic grades (e.g., Shen and Sue) felt that their participation in the research project did not change their participation practices during biology. Students who were less confident about their academic grades (Pete, David, Mai) indicated that their participation in the
research had made a difference to their approach and attitude to learning. Overall, four of the research participants in the study and one student in the pilot study remarked that they had either reflected upon or changed their learning approaches and participation practices as a result of the interview sessions.

Pete commented that our interview/discussion sessions, where I explored his interpretation of questions on tests and assignments (see example in the next section), had made him reflect upon his approach to reading and interpreting questions. During these sessions, I would help Pete break down the question into parts and we would then explore his interpretation of concepts, words or phrases. Pete felt that our discussion sessions had made him realize that he should "read the question more slowly."

He elaborated further:

So instead of wasting time, you just go read [sic] slow, the way you [researcher] go through the sentence with me. You go slow and then you go back. So that's why I have to read slow and then go back again. [Pete, final interview]

Mai also expressed the following sentiments about the changes the research project had brought about in her approach to learning:

You're helping us to look at what we are doing. It's like can [sic] improve oneself. ... it just make [sic] me realize that I [can] study better. ...you kind of change your habit of studying. Before, I didn't read the thing [text], I memorized [the] thing ... now I'm trying to make myself understand it. ... Like if I read the chapter and there's a question at the end of the textbook, I try to answer some of them. When you answer some of them it's just like you understand. [Mai, final interview]
The presence of another adult also appeared to enhance the social interactions of Pete and Mai during class lessons. Both Pete and Mai were ESL students who experienced difficulties with the language aspects of the lessons. Rather than ask peers or the teacher for clarification of instructions or explanations, Pete and Mai would often come up to me for assistance. It may be that they saw me as non-threatening in terms of self-esteem and grades. When I asked Mai why she would rather ask me to explain than her teacher, she replied, "I see him busy and I don't want to interfere. Because he's helping other [sic] group, so I come to you. If he's not busy I come [sic] to him." Mai's reason for asking me for explanations may also have been related to politeness. She did not want to interrupt the teacher when he was engaged with another student. Mai may have also felt it easier to relate to me because of gender.

My presence in the class appeared to serve as a non-threatening resource for Pete and Mai. Their familiarity with me through interviews and constant informal interactions encouraged them to initiate conversations with me during whole class lessons, group work and field trips. It may be argued that the presence of another supportive adult, in this case the researcher/teacher assistant enhanced some students' participation and engagement during learning activities.

David was another student who indicated that he had changed by being a participant in the study. He knew that his participation practices had not changed but he felt that his attitude towards learning in this class and other classes had changed. He told me that our interviews had given him awareness about why and how he learnt. For example, our
discussions had made him aware of the importance of listening in class. Prior to our interviews, he would not pay much attention to the discussions in class.

Sal (the ESL student in the pilot study) was another student who seemed to change in her participation practices. By singling Sal out, making her the focus of attention during the six weeks, being interested in how she learned and what problems she was experiencing, the teacher and I observed that she became more self-confident about herself as an English speaker. During the course of the project, there was a noticeable change in the nature of her participation in class. She began to answer questions and ask questions more frequently in class. Her responses to questions were more loudly elucidated, although still not loud enough for the entire class to hear.

These examples suggest that for some students participation in the research project initiated a reflective awareness of the learning process that appeared to bring about changes in their attitudes and participation in class activities.

VI. Complex Interactions among Factors

I have described the participation patterns of students in terms of two extremes on a continuum and I have identified some factors that appeared to enhance and/or constrain students' social interactions in this Biology class. While the factors are examined separately, I would like to point out that the nature of students' interactions in the classroom is complex. Students are not isolated entities in the classroom. The student is involved in many social interactions inside and outside the classroom. As explained earlier in this
chapter, an understanding of students' participation and learning involves an examination of processes at three levels: the individual, the interpersonal and the community (Rogoff et al, 1995). These three levels of analysis are inseparable. From this socio-cultural perspective, the learning orientations and participation practices of students in classrooms is highly complex in nature and is most likely influenced by the complex interactions between a number of potentially competing factors at the three levels.

For example, all participants have experienced "cultural norms" in different ways. All students have prior classroom experiences. All students experienced the teacher's practices in different ways. All students exhibited varying degrees of self-esteem and self-confidence in themselves as learners for a variety of reasons. All students reacted differently to the presence of the researcher in the classroom. It is the complex interactions between a number of these potentially competing factors that most likely enhances or constrains students' social interactions.

VII. Summary

In this chapter, students' participation practices were inferred from an analysis of my interviews with the students and my field notes regarding classroom participation. The analysis revealed that students preferred and exhibited participation practices that ranged from personal-individual to socio-interactive in nature. These findings raise questions about the assumption that emphasising group work is the way to enhance the learning of science and language among ESL students. Thereafter, six factors that appeared to enhance
or constrain students' engagement in classroom social interactions were identified. These factors were socio-cultural factors, prior classroom practice, teaching practices, affective factors and English language proficiency, and participation in the research project.
CHAPTER SIX

Relationships between Language and Learning

I. Introduction

In this chapter, I analyse the data in terms of how language is used as a mediational means in ESL students’ learning of biology terms and concepts. I focus on two main areas:

- Teaching: how the teacher teaches and represents terms and concepts in biology
- Learning: how students interpret biology terms and concepts in the teacher’s written and oral questions.

Evidence used to support assertions throughout the chapter is illustrated through excerpts and vignettes.

I initially approached the analysis of data by looking for evidence of how the teacher and students mediated learning in the biology classroom using language. The data suggests that teacher, peers, and prior knowledge each played a significant role in ESL students’ learning of both language and biology terms and concepts. This level of analysis highlights the difficulties experienced by ESL students as they attempt to construct meanings in biology, and particular teaching and learning strategies that appear helpful in enhancing both language and science learning.

A closer examination of the data revealed that the same data could be analysed to reveal insights about how language is used to represent and construct scientific knowledge. I use the data in this chapter to support two assertions about the role of language in learning
science. My first argument is that the common-sense belief held by science teachers - that science teachers teach science concepts while language teachers teach English words - is a misleading notion as even the simplest model of language relates words to concepts. The data in this study indicates that science and language concepts are taught in biology and that both are integral to understanding and constructing biology knowledge.

My second argument is that the basic model of language signification based on the triad of word, concept, thing, which appears to be the general, unacknowledged theory that most teachers hold, is inadequate to explain the way language is used to construct meanings in biology. The data in this study points towards a more complex theory of language in the direction of Halliday’s (1998) model. Evidence in this study shows that learning science concepts involves more than learning the meaning of a mediating concept that signifies the thing. For example, the data will show that learning biology involves the use of language to construct taxonomies and ways of reasoning.

This chapter is thus organised in relation to the two focus areas: teacher’s teaching of terms and concepts, and students’ interpretation of terms and concepts. Within these two focus areas, the data provides evidence to support the main arguments being made in this chapter:

- biology teaching involves the teaching of both language and science concepts
- teaching and learning of biology terms and concepts is better explained by a more complex theory of language than that purported by the traditional triad model.
- teacher, peers and prior knowledge mediate ESL students’ learning of both
language and science concepts.

II. Teacher's Teaching of Terms and Concepts

Introduction

A traditional idea about biology teaching is that talking about language or teaching language is not part of the biology teacher's repertoire. This idea stems from the traditional belief that the learning of biology content is independent of language aspects. The data in this study shows that the teaching of language is integral to biology teaching because:

- various language aspects mediate students' learning of biology concepts
- the morphology of terms and concepts plays a significant role in the construction of biology knowledge.

Evidence in this study also indicates that teaching science involves more than teaching the meanings of words as labels for things or teaching concepts by pointing and describing (as implied by the traditional language model). The data suggests that teaching science is a complex process that can be explained by a model of language that includes the following language aspects:

1. Exploring the meaning and morphology of terms and concepts
2. Using multiple semiotic representations
3. Constructing taxonomies.
Exploring the Meaning and Morphology of Terms and Concepts.

In this section I use the data to support my assertion that the teaching and learning of biology terms and concepts involves more than the teaching and learning of "words"—teaching and learning biology concepts involves knowledge of morphemes or parts of words. I argue that knowledge of the meanings and morphology of terms and concepts plays a significant role in students' learning of biology terms and concepts. As well, knowledge of the morphology of terms and concepts is integral to understanding how biology knowledge is constructed.

To help students understand and explain scientific concepts, the teacher approached the teaching of terms and concepts by exploring the Greek and Latin morphology of terms and concepts. Many biology terms are derived from Greek and Latin words. To facilitate recognition of these Greek and Latin words, the teacher handed students a vocabulary worksheet containing the meanings of common Greek and Latin words used as suffixes and prefixes in science terms, at the beginning of the year. Thereafter, when introducing a new term or concept, the teacher explored the morphology of science terms by separating the term into its component parts or morphemes and linking the morphemes to the Greek or Latin words. The teacher repeated this strategy at different times to reinforce students' learning. This strategy is illustrated in the following vignette.

Deriving the meaning of "homeostasis"

At the beginning of the academic year (September) the teacher briefly introduced the term "homeostasis" by saying: "this is one of those words we need to take apart." He directed students to vocabulary sheets (which listed the meanings of Greek and Latin words)
and pointed out the meanings of the two component parts of the term (morphemes)—
“homeo” meaning the same and “stasis” meaning balance. The meanings of the two
component parts were then linked to convey the conceptual meaning of the scientific term
“homeostasis” - "staying in balance". Thereafter the teacher went on to explain the concept
“homeostasis” by using everyday examples of organisms using different systems to
maintain their internal balance. For example, he explained that if you drink too much water
your body gets rid of the excess by perspiring.

In a subsequent lesson in February, the teacher revisited the concept “homeostasis”
and once again explored the morphology of the term.

Teacher: What is homeostasis? What does homeo mean?

Students: The same.

Teacher: It's the same. What does stasis mean? [pause] It means not
moving, the same. So you say the same thing twice. Homeo means you
stay the same. Stasis means you stay the same - not moving. One of them
is Greek and one of them is Latin. ...[the teacher then compares
“homeostasis” to the word “automobile” and illustrates how the latter is
also derived from Greek and Latin words] It stays the same. Okay, what
stays the same?

Shen: [Inaudible]

Teacher: Shen says internal balance. Internal balance of what?

Students: [Mumblings]
The teacher then went on to provide other examples of homeostasis in other systems (e.g., circulation, immunity, getting rid of waste materials) to reinforce the concept.

Rather than presenting the term and stating the textbook definition, the teacher mediated students' learning of terms and concepts by exploring the morphology and meaning of the term. At one level, students' learning of the term "homeostasis" was mediated by the teacher's explicit exploration of the meanings of parts of the word or morphemes "homeo" and "stasis". Exploring the morphology of scientific terms (and knowing the meanings of Greek and Latinate words) was used to make an unfamiliar scientific term and its conceptual meaning more meaningful to students.

At another level, students' were being given an awareness of how biology terms evolved from classical Greek and Latin. Many scientific terms were created by reconstructing the grammar of the languages of the iron-age cultures of the Eurasian continent (Halliday, 1998).

Another way that the teacher explored the morphology of words was through the explicit teaching of parts of speech during science lessons. The excerpt that follows illustrates how the teacher mediated students' language and science learning by discussing how nouns are derived from verbs. More significantly, the excerpt shows how knowledge of morphology of terms and concepts is integral to the learning of biology terms and concepts and to understanding how scientific knowledge is constructed.

In the following vignette, exploring the morphology of words - in this case how grammatical suffixes change the meanings of words - was used to explain the term "adaptation" during a lesson on structure-function relationships.
Understanding "adaptation" as a noun

When introducing the scientific concept "adaptation" to students, the teacher stressed that in the scientific context, "adaptation" was used as a noun. Rather than assume that students knew what a noun was, the teacher went on to elicit a basic understanding of what a noun is.

Teacher: What is a noun?

Steve: It's a thing.

Teacher: Noun's are things you have or you don't. In Biology, "adaptation" means either you have it or not. [The teacher refers students to pictures of different birds in the text to illustrate the concept "adaptation".] For example, my beak is longer than yours.

The teacher then went on to explain the meanings of "adaptation" and "adapt" in terms of the differences between a noun and verb respectively.

Teacher: Adaptation is a noun - it is not a verb. It is something you have, not something you do. The English word "adapt" refers to what people do.

Rather than presenting and defining the scientific term "adaptation" in terms of the textbook definition, the teacher used grammar to mediate students' learning of both English language content and a scientific concept. With regard to English language learning, he attempted to explain the differences between a noun and a verb as illustrated in the excerpt above. With regard to science learning, he explained the differences between the way
"adapt" and "adaptation" were used as parts of speech to communicate the meaning of "adaptation". The conceptual meaning of "adaptation" is closely associated with the function of a noun. In biology "adaptation" refers to structures/features that organisms have that help them function/survive in a particular environment. These structures are fixed and do not change – similar to the characteristics of a noun.

Furthermore, differences between a noun and a verb were pointed out to emphasize the differences in the meanings of the two terms "adaptation" and "adapt". In everyday contexts, "adapt" is used as a verb and refers to how objects, people or entities change. The possibility exists that students could interpret "adapt" and "adaptation" in the same way. Therefore, instead of explaining the term "adaptation" in isolation, the teacher recognized the need to link the term to other familiar words such as "adapt". This was done to show students the differences in the morphology and meaning of the words "adaptation" and "adapt" and to prevent students using both terms in a similar way.

The comparison of "adaptation" and "adapt" also illustrates how scientific terms are constructed. Many scientific terms evolved as a result of nominalization - that is, changing verbs and/or adjectives into nouns (Halliday (1998). In this example, the term "adaptation" is formed by changing the verb "adapt" into a noun. "Adaptation" now functions as an entity that exists as part of a theory on "Living Things". Although not explicitly taught, the teacher, in the above excerpt, explores how scientific language evolved. He contrasts the two terms within a morphological and a semantic taxonomy - that is, he compares the terms "adapt" and "adaptation" at two levels - its function as a part of speech and its meanings (as illustrated in figure 7).
A teaching strategy that incorporates the exploration of the morphology and meanings of terms appears to support both language and biology learning. The teacher’s success at helping some students gain a better understanding of the concept “adaptation” by using this teaching strategy is illustrated in the next excerpt. During an interview session, Shen explained her understanding of “adaptation” in terms of the differences in meaning of a noun and a verb.

... when he [teacher] says that it is “adaptation” right, it’s like the structure of something. Giving you an example is like long legs, not like how the organism changes. Like they don’t change their legs because they try to adapt to the environment. So it is the long legs that is an adaptation, not the changing [Shen, Interview]
Shen was able to communicate the scientific interpretation of “adaptation” by using an example and highlighting the differences between the ways “adapt” and “adaptation” are used.

**Using Multiple Semiotic Representations**

In this section, I argue that teaching science concepts involves more than pointing to the thing and describing. Teaching science involves the use of multiple semiotic representations, together and in relation to one another to communicate the meanings of concepts. Further, the data suggests that the use of multiple semiotic representations supported students in constructing meanings of concepts.

As argued in chapter three, different forms of semiotic representation (verbal texts, mathematical graphs, pictures) communicate related but not identical meanings. For example, a verbal description does not make exactly the same sense as a physical performance.

**Teaching the concepts “bilateral” and “radial” symmetry**

The excerpt that follows illustrates how the teacher used multiple semiotic representations to explain the concepts “bilateral” and “radial” symmetry. In the lesson prior to this, students had been on a fieldtrip to the aquarium and seen a variety of jellyfish. In this follow-up lesson, the teacher begins his explanation by referring students to a picture of the jellyfish in the text and illustrating his lesson with a prop.
Teacher: If you can please find ...a picture of a free-swimming medusa - it's a jellyfish. [The teacher then holds up a plastic dome shaped container]. Let's just pretend that this is a medusa. [He points out a limitation of the demonstration] What I don't have is tentacles round the rim. If I got very upset and I took that jellyfish and sliced it in half, would you be able to tell which side was which?

Steve: No.

Teacher: Each side would have the same stuff. If I turned it a little bit and sliced it in half that way, would it make any difference?

Class: No.

Teacher: No matter which way I slice it, it's the same. It's a circle and I can cut across the circle any way and I get two halves that will hold half circles. This means that these things are organized as circles. They radiate out from some sort of centre and it does not matter which route you take from the centre to the end, you can go through the same thing. Bicycle wheels - the same sort of round thing. These have radial symmetry. ...What does bilateral mean?

Student: [inaudible]

Teacher: How many sides do they have?

Student: Two.

Teacher: Two. So if I took somebody, Kim - now if I was to take Kim and - pretend that this metre rule was a samurai sword - and go right down the middle [points to student's body], would I get two halves that are basically
the same?

Steve: No.

Teacher: If I did it right down the middle, each side would have an eye, each side would have half a brain, each side would have a nostril. A little bit of a zig here and each side would have both an atrium and a ventricle, each side would have lungs. I'm slicing right down the gut and unfortunately the gut wriggles, but each side would have basically one of everything. Now you only have one liver but it has some tissue on the other side and one spleen. But for the most part, each side has an arm, and each side has a leg.

The teacher elaborated further on the differences in bilateral and bilateral symmetry in terms of mirror planes.

In the above excerpt, there is evidence of the use of multiple modes of semiotic representations such as pictures, demonstrations, and verbal descriptions. These different representations mediated ESL students' learning of both English and biology concepts by acting together and in relation to each other to help some students construct some intended meaning of the concept "bilateral symmetry".

The way multiple semiotic representations helped some students attempt to construct the scientific way of explaining concepts is illustrated in the next two vignettes. In these two vignettes, two students, Sue and Joe explained their understandings of the concepts "bilateral" and "radial" symmetry. The two vignettes emphasize the ways in which visual and verbal representations assisted these students' in their construction of meanings.
Learning from visual and verbal representations

During an interview, Joe explained his understanding of bilateral and radial symmetry by doing a demonstration similar to that done by the teacher. Holding up a spherical object (the object had been lying on the table), Joe told me that he remembered the teacher using a similar object to explain radial symmetry.

Joe then used the object to demonstrate and explain his understanding of radial symmetry.

He [teacher] used a cup. So pretend it's a cup. Radial symmetry is, [it] doesn't matter where you cut it, ... everything is like the same, same all round. But for bilateral symmetry, it only has two things, like us. Like only one plane mirror. When you look in a mirror, it's not all round
[Joe, interview]

His written explanation on a test was consistent with his oral explanation.

Radial symmetry had the same shape 360 all around. eg. a cup without a handle for ex. [sic] has radial symmetry because no matter which way around you look at it will have the same shape.
[Joe, test answer]

Bilateral symmetry has a plane mirror outcome. If you split it right through the line of symmetry, it will have parallel resemblance. [Joe, test answer]
The written and verbal explanations above suggest that Joe did not try to memorize the definitions from the text. Joe confirmed that he did not learn these concepts from the textbook. He had gone through his notebook prior to the test. Joe’s oral and written explanations suggest that he attempted to construct meanings by integrating visual and verbal semiotic explanations.

Sue explained during an interview that the way she had understood the concept of bilateral and radial symmetry was by picturing "examples that had that kind of symmetry". The two examples that appeared to help her to understand bilateral and radial symmetry were the illustrative examples of the human body and the jellyfish (both representations were used by the teacher).

Sue: The way I understood that was I just pictured examples that had that kind of symmetry. Like...

Interviewer: Could you elaborate a little?

Sue: Like bilateral. Like a human is bilateral right so ... I would say if you're looking at some organism and if there's only one line that splits it up to make it equal then it's bilateral. But radial would be like if you separate it into different parts it would still be equal but like [pause] I forgot. What's an example of radial symmetry? [pause]. Oh, a jellyfish. Like if you just picture it I can kind of put it in with symmetry ...that's how I know it.
Sue's explanation suggests that the teacher's verbal explanation and visual examples were helpful in assisting her in her attempts at constructing the concepts “bilateral” and “radial” symmetry.

Joe and Sue’s explanations of how they arrived at some understanding of these two concepts support Lemke’s (1998) assertion that it is the union of meanings constructed from multiple semiotic representations that contribute to the meaning of a concept.

**Using everyday narrative examples**

Another semiotic representation that mediated students’ learning of science concepts was the creation of a narrative with reference to everyday examples. In the lesson excerpt below, the teacher uses illustrative examples from the everyday world to create a narrative to explain the meaning of “natural selection.”

Teacher: If a family of wolves, and they generally hunt as families, if they are hunting a herd of horses, and all of the horses start running, what's going to happen? [pause] The fast horses will get away and the ones that are old or sick won't be able to keep up and those will be the first ones taken by the wolves. So who is this good for? It's good for the wolves because they get lunch. Is it good for the rest of the horses? [pause] It might be. Do they know that? [Student: No.] But every time this happens they get sorted out and only the most physically fit make it.

[Teacher, lesson excerpt]
Rather than give students the textbook scientific definition of natural selection - the process that results in the survival of those organisms best suited to their environment - the teacher explained the concept in narrative form using the example of wolves hunting horses. The everyday narrative example is another semiotic representation that appeared to assist some students construct meanings of concepts. David cited how the teacher’s use of everyday narrative examples assisted him in constructing meanings.

He [teacher] put's it [new concepts] in everyday life - what it means today and it is easier. Most science teachers just get it straight out of the textbook and tell you, "that's what it is," and you don't understand. ... even though you know the meaning you still don't understand because the meanings are in scientific terms. So if you put it in everyday life it's much easier. [David, interview]

In the preceding vignettes, visual, verbal and narrative representations were jointly used to construct meanings of concepts. These vignettes show that multiple semiotic representations mediated students’ learning of scientific concepts.

**Constructing Taxonomies**

In this section I argue that the teaching and learning of biology terms and concepts cannot be explained by the traditional theory that words/terms are labels for things via a concept (or meaning). From this traditional viewpoint, a word is taught by showing the “thing” or by explaining the meaning. Evidence in this study shows that biology terms and concepts are not taught and learnt in isolation - biology terms and concepts are taught by contrasting within taxonomies. In the vignette described in the previous section, there is
evidence that the teacher worked to help learners construct taxonomies of biological concepts. Such taxonomies then become ways of interpreting “things” from a biological perspective. The teacher’s explanation of the term “bilateral symmetry” may be interpreted as contrasting the concepts “bilateral” and “radial” within a taxonomy (as illustrated in figure 8).

![Symmetry Taxonomy]

Figure 8. Contrasting “bilateral” and “radial”

Another example of the teacher mediating students’ learning of scientific concepts by contrasting terms within taxonomies is illustrated in figure 9. In this second example, the teacher attempts to assist students construct the meaning of the concept “heterogeneous”.

Instead of explaining and describing the term in isolation, he contrasts the term with “homogeneous” and uses an analogy (e.g., properties of candies in a “Smarties” box) to illustrate the differences in the meanings of the two terms.

![Diagram contrasting heterogeneous and homogeneous properties](image)

**Figure 9.** Contrasting the terms “homogeneous” and “heterogeneous”

Figure 8 and 9 illustrate that teaching biology terms and concepts involves more than describing and illustrating concepts in isolation - it involves showing relationships by comparing and contrasting terms and concepts within taxonomies. As well, these relationships are illustrated by multiple semiotic representations such as verbal explanations.
and comparative analogies, physical demonstrations and visual graphics that jointly contribute to the meaning of the concept.

III. ESL Students' Interpretation of Terms and Concepts

Introduction

Often, students misinterpret written and oral questions about science concepts and phenomena. That is, students interpret questions in different ways. For example, their interpretation of specific words as they appear in a written question may be different from what the teacher intends. Students may therefore convey meanings (in oral or written form) about science concepts that are different from scientific meanings. ESL students are most vulnerable because: 1) they have a limited English vocabulary, and 2) they are often unfamiliar with the multiple meanings associated with terms and concepts in everyday and scientific situations.

Two traditional notions about language learning are:

1. if a learner knows a concept in his/her first language (L1), then learning the concept in the second language (L2) is merely a matter of learning a new label for the concept,

2. if a learner knows the general or everyday meanings of English words, then she/he should not have any difficulty understanding the word in written or oral questions.
In the sections that follow, I argue that the data suggests that ESL students' interpretation of written and oral questions is mediated by prior knowledge of words and concepts in more complex and subtle ways than listed above.

These complexities are explored in relation to:

1. Concept transfer from L1 to L2
2. Using everyday language in formal style
3. Re-labelling everyday words
4. Morphological structures
5. Everyday language used to construct scientific ways of reasoning.

**Concept Transfer from L1 to L2**

In this section I argue that learning concepts in a second language is not simply a matter of transferring meanings from one label to another. Learning science terms and concepts involves more than learning new labels for concepts already learnt in L1. For example, the data in this study shows that labels or terms in the second language may refer to a different set of features than the features associated with the concept label in the first language.

The following vignette illustrates the ways in which ESL students' prior knowledge of concepts in their first language interacts with their learning of science concepts in English, their second language. The vignette begins with an excerpt from a lesson where the teacher is attempting to illustrate the shape of the leaf associated with the plant species *Gingko biloba*. Thereafter, excerpts from interviews are used to show how a Spanish -
speaking student had difficulty linking the meaning of the term ‘earlobe’ to the shape of the leaf.

Sal's understanding of lobes

During this lesson episode the teacher introduces a new species of plants by the name *Gingko biloba*. To get students to learn the word as more than a label for a species of plant, the teacher tries to communicate the meaning behind the label, “biloba”. He highlights the meanings of the morphemes, “bi” and “loba” to illustrate how a distinguishing characteristic of the plant species (i.e., having two-lobed leaves) can be inferred, as illustrated in the following excerpt.

Teacher: The one that we see a lot of including quite a few in Vancouver is a species called *Gingko biloba*. ... biloba -let me take this first. What does bi mean?
Sal: Two
Teacher: Loba? Means lobes. This is my earlobe [.touches ear], these are the dangling parts that stick out. The leaves of the *Gingko biloba* are wide, but [the leaves] have got two big lobes, like that [draws picture of leaf on blackboard].

Sal, whose first language is Spanish, spontaneously turned to me at the conclusion of this episode (I was sitting next to her during the lesson) and said that she had not understood the meaning of the English word “lobe” and how it related to “earlobe”.
At the end of the lesson I asked her to explain why she had difficulties understanding the meaning of the word lobe.

Interviewer: Had you heard of the word lobe before?
Sal: I have but not paid that much attention to it ... [and] I've never actually looked at it in the dictionary. But earlobe I didn't link it to ...

[long pause]

Interviewer: You hadn't linked the lobe of the plant with earlobe?
Sal: No.

[lesson recall interview]

In this interview excerpt we see that Sal was not familiar with the use of the term “lobe” to refer to a part of the ear. For most native English speakers, their everyday experiences using the word “lobe” in situations such as piercing earlobes conveys both a concrete and visual sense of the meaning of the word lobe. For example, “lobe” refers to an object with a particular shape such as an earlobe. Sal did not make the connection to both the object and the shape.

Sal: If he wouldn't, like if he wouldn't have drawn it or twist his ear I wouldn't understood. I didn't link earlobe.

Even if she attempted to translate the word “earlobe” into Spanish, the Spanish word would have elicited a different set of associations.

Interviewer: What would you call this [pointing to earlobe] in Spanish?
Sal: Ear, like ...
Interviewer: Does it have a word?

Sal: Yeah, but it doesn't link to the English one at all.

Interviewer: That's what I want to know. What's the word in Spanish?

Sal: Guindar - like hanging.

Interviewer: So if you were to learn this word by translating it you'd have a problem because it means hanging?

Sal: Yeah, yeah.

Learning the meaning of the word “earlobe” by translating it into Spanish was not a problem for Sal in this instance because she had realized the lack of association between the meanings of the English word and its corresponding label in Costa Rican Spanish. The above excerpt, however, illustrates the potential problems involved in learning words by simply transferring meanings learnt in the first language to new labels in the second language. Sometimes the label in the first language is associated with a different set of meanings and could hinder rather than encourage construction of meanings in the second language (McNaught, 1993). In this example the translated label, “guindar” highlighted the hanging feature of the ear rather than the property of a lobe-like shape (refer to Figure 10).
In this example there is partial overlap of meaning. The label in L1 (Spanish) and L2 (English) refer to the same thing (earlobe) but emphasize different features. This example highlights the notion that translation of words from the first language into the second language does not necessarily convey the conceptual meanings underlying the new term. This example thus highlights a limitation of Cummin’s “dual iceberg” model - that if the concept is known in the first language, then one needs only to learn the new label in the second language. The vignette with Sal illustrates that learning a concept in the second language is complex and does not involve the simple transfer of a common underlying meaning to another label in the second language. The meanings of concepts in the second language often differ from meanings in the first language. Thus there is need to explore both the new labels and its underlying meanings in the second language.
Cummin’s model also does not account for other complexities arising during ESL
students’ learning of science concepts in a second language. For example, this study
highlights another complexity arising when ESL students’ prior learning of science is in
English medium classes where a mixture of English and the first language is used to explain
science concepts. Often, in these situations, teachers explain science concepts using the first
language and use labels in the first language to refer to the concepts. In these situations,
students know the meaning/concept and its label in the first language but do not know the
label in the second language. The vignette below highlights how an ESL students’
unfamiliarity with the English label hindered her initial learning of the concept “dentine”.

Shen’s understanding of “dentine”

Shen, a student from Hong Kong, felt that native English speakers were sometimes
at an advantage with regard to learning scientific vocabulary.

Scientific vocabulary. Like you don't know it right. People who were born here that may know it like a
long time ago because they have been using the word for a long time. ...sort of like simple
scientific vocabulary, not really hard ones. The really hard ones, I guess they don't know it either.
[Shen, Interview]

Shen felt that native English speakers were likely to have heard of many scientific
terms and would have some understanding of these terms because of their familiarity with
and use of these terms in previous situations.
Shen explained why she was unfamiliar with some scientific terms by describing her science classes in Hong Kong:

Normally they don't use English vocabulary. They [teachers] explain it in Chinese but not in English. So I know the word in Chinese but not in English. [Shen, Interview]

Science terms were often translated into Chinese and explained in Chinese in her previous English medium science classes. It was Shen's unfamiliarity with the English labels for the scientific term and not the conceptual meanings underlying the term that presented her with problems. Shen explained that when she had first heard the word “dentine” used in a Canadian biology class, she did not know what it referred to.

There's a word like dentine or something, d.e.n.t.i.n.e. [Interviewer: dentine?] Yeah, dentine. ....if you told me what it is in Chinese I know there's such a thing. I heard of that in Chinese. I know there's such a thing. [Shen, Interview]

Shen had already known that the concept of dentine was associated with teeth, but that was in the Chinese language. She was not familiar with the English label for the scientific term. Hence, when Shen had first heard the term “dentine” used, she had thought that “dentine” was a concept that she did not know. In other words, she did not just need to learn a new label. She also needed to identify what the label was a label for. This example highlights another of the subtle complexities involved during ESL students’ learning of biology terms and concepts in mainstream science classes. It shows that one cannot assume that ESL students, who have studied science concepts in their native countries, know the English labels associated with science concepts or which concepts the English labels are
associated with. Learning a concept in L2 is therefore more complex than portrayed by Cummin's (1992) model of learning labels for an existing concept. In cases where ESL students have learnt science concepts in English medium classes, scientific labels/terms in L2 and their associated meanings/concepts need to be explored to help ESL students make connections with their prior knowledge of terms and concepts in L1.

**Using Everyday Language in Formal Style**

In this section I argue that ESL students' general, prior knowledge of everyday English words does not necessarily help them interpret these everyday words when these words are used in a formal style. The use of everyday language in formal style is typical of academic English and in the classroom such formal style often appears on written test and exam questions. The data shows that ESL students were not familiar with how everyday language was used in a formal style in oral and written biology questions. While this hinders ESL students' interpretation of questions, it is not necessarily a scientific difficulty. However, evidence shows that the multiple meanings associated with terms and concepts in everyday and scientific contexts, exacerbates the situation and does cause problems in understanding the scientific concept. In the review of literature, I pointed out how the traditional 'word and thing' model of language signification fails to deal with the problem of multiple meanings.

Pete and Mai were two ESL students in the present study whose verbal and written English language skills were noticeably limited. Both students told me they had difficulty interpreting written questions. The two vignettes that follow illustrate how these students'
prior knowledge of the general meanings of English words did not assist them in interpreting these words when used in a formal way in written questions about biology. The vignettes also highlight other language problems experienced by ESL students - specifically ESL students' unfamiliarity with the multiple meanings associated with words and concepts in scientific and everyday contexts.

**Pete's interpretation of "arisen"**

During an interview session, Pete and I explored his interpretation of a question on a quiz about viruses. The question required a paragraph explanation response.

**Interviewer:** It says: "Explain how viruses may have arisen?"

**Pete:** Arisen, arise right?

**Interviewer:** Yeah.

In the above excerpt Pete seeks affirmation that the word "arisen" originates from the "word" arise - an indication that he is attempting to associate the formal word "arisen" to a familiar everyday word that he has come across before. I then proceeded to explore Pete's interpretation of "arise."

**Pete:** It from "arise" right?

**Interviewer:** What does "arise" mean?

**Pete:** Going up.

**Interviewer:** Going up?

**Pete:** Yeah.

**Interviewer:** Okay, arise - going up, so what do you, just in your own words tell me what you understand by, "explain how viruses may have
arisen?"

Pete: How viruses reproduce?

Interviewer: How they are reproduced?

Pete: Yeah, how did they become like so large and how did they become - produce a lot and how they burst out a lot, those thing [sic].

In Pete's case he translated arise as "going up" and interpreted this to mean "reproduce" and grow in numbers. He therefore gave a written scientific response that suited his interpretation of the question.

His written response was:

Virus has attach to other blood cell. Then eject their DNA. When DNA inside the blood cell. It's start to reproduce within a blood cell. Then as it full and no more to produce it burst the blood cell and trying to attack other blood cell. [written test]

Pete had couched his explanation in terms of how viruses reproduce. The question as given on the quiz was intended to explore students' understanding of the origin of viruses. I explained the alternative interpretation of the question to Pete.

Interviewer: There are many ideas about where viruses come from. That's what arisen means, where do they come from.

Pete: Oh. I see.

Interviewer: Right. So where they arise means where do they come from, rather than what you were looking at, how they are [reproduced]. And according to this, what they were looking for was the origin of life, like
some scientists feel that viruses have cellular ancestors who are adapted.

Another view is that they are simply fragments of cells.

Pete: Yes.

Interviewer: ... And what did you actually think it was?

Pete reaffirmed his interpretation of the question.

Pete: How they have a lot of them.

Pete’s difficulty in answering the question could be attributed to his not knowing the different meanings associated with the word “arisen” and to his unfamiliarity with the use of “arisen” in formal style. According to the Oxford dictionary, “arise” has many meanings associated with it - “to occur” or “crop up”, “to appear” or “evolve”, “to rise up”, “to come from”. These multiple meanings increase the possibility of alternative interpretations of questions. The above example shows that Pete was aware of how the term “arisen” was used in one sense in the everyday context but this general understanding did not help him interpret the term when it was used in formal style.

Mai’s interpretation of “concentrated”

The following discussion question appeared at the end of a vertebrate dissection lab:

At which part of the frog’s body are the sense organs and food-getting organs concentrated?

In this worksheet question, the word “concentrated” is used in a formal way to elicit a biology explanation.

During an interview session, Mai and I explored her interpretation of this question. On first reading the question, Mai commented: "I really don't know what concentrate is."
In the following excerpt I probed her understanding of concentrated.

Interviewer: Have you heard of the word concentrated?
Mai: Yeah.

Interviewer: In what sense? Where about?
Mai: Sometimes I think of a solution that is concentrated.

Mai's first response to my probing elicited the scientific association. This initial association suggests that Mai probably expected the meaning of "concentrated" in the lab question to be related to the scientific meaning.

When I questioned her about her understanding of concentrated, she replied in relation to the lab question: "I was thinking like how their body organs function. What is the use for it." Further probing revealed that Mai did not know the meaning of concentrated in the scientific context involving solutions.

I really don't know what the term concentrated is. I just remember from doing experiments.

Mai's response suggests that one cannot infer that a student who associates terms in linguistically or scientifically accepted ways (e.g., a solution that is concentrated) understands the conceptual meanings underlying the terms. I continued to probe Mai's understanding of concentrated and asked her if she had heard or used the word in any everyday situation.

Yeah, Like you concentrates [sic] on your homework. Is that a different meaning or...?
Mai's response indicates that she was familiar with using the term "concentrated" in an everyday context. Her tentative question at the end of her reply, however, indicates that she was not familiar with the multiple meanings associated with "concentrated" in different contexts. Mai then went on to elaborate on her understanding of the meaning of concentrate in the everyday context.

You're studying. You're thinking.

Mai's interpretation of "concentrate" represents a meaningful association - linking concentrate with thinking. In the everyday context, to concentrate on your homework is to focus on or spend a lot of time and effort on it. In the scientific sense, a concentrated solution is one that has more solute in a fixed amount of solvent. While the scientific and everyday meanings of "concentrated" are different, they are similar in that in both instances one is putting more effort/solute in a fixed amount of time/solvent.

In the above excerpt, Mai appeared to have difficulty interpreting the term "concentrated" when used in a formal way in scientific discourse. One possible explanation for this difficulty could be her unfamiliarity with the use of everyday language in formal style in scientific discourse. Although Mai was familiar with how the term concentrated was used in the everyday context and had a general understanding of the meaning of the term, she was unable to interpret the term when it was used in a formal way in scientific discourse. It is likely that many native English speakers may also have a limited awareness of how everyday language is used in a formal way to talk about and construct biology knowledge.
A second explanation for Mai's difficulty with the question could be that she was unable to extend the scientific meaning of "concentrated" from a liquid to the frog's body. These difficulties may be exacerbated when a scientific concept is used in the scientific context in an everyday sense, as was the case in the lab question. The use of concentrated as it appeared in the lab question was similar to the way it is used in the everyday context - that is at which part of the frog are the food-getting organs concentrated or focused? While many students can distinguish between the different meanings of a single scientific concept and use them in both the everyday and scientific contexts, Mai was unable to see the similarity in the way concentrated was used in both the homework example and the lab question. Furthermore, the inclusion of food-getting organs in the lab question, another unfamiliar word, appeared to add to her confusion.

Mai explained to me that for her written response she had interpreted the lab question as:

How did the frog hunt for food. Sort of how did it gets [sic] the food.

The key concept that Mai was using to interpret the question and make associations to other concepts was food. For Mai, food conjured up images of stomach.

I was thinking of stomach. Like you eat the food and then you swallow it. It goes through the stomach. I was thinking the question ask like that [sic].
Everyday terms used in formal style in biology questions and Mai's limited knowledge of the multiple meanings of concepts in the scientific and everyday contexts appeared to contribute to her alternative interpretation of the question.

The example of “arisen” and “concentrated” illustrate problems of formal style likely to occur in written academic discourses in all subjects. It should also be noted that the issue of multiple meanings associated with words in scientific and everyday contexts is a problem for all students but it is more problematic for ESL students because of their limited English language experiences. Of course, there are two different problem areas here (everyday words in formal style; knowledge of multiple meanings of words). But for these students the two problems are correlated.

**Re-labelling Everyday Words and Concepts**

In this section, I provide evidence to show that the re-labelling of everyday words with technical terms often hinders ESL students’ interpretation of written and oral questions.

Scientific discourse is characterised by a pattern of re-labelling of everyday/common-sense words. The excerpt below illustrates how the use of technical terms to describe familiar everyday “things” or concepts often hinders ESL students’ understanding of explanations to written questions. Also, the excerpt indicates that peer mediation during small group work supported language and science learning.

**Learning the scientific label “anus”**

As part of the section on animal biology, students had to compare and contrast the seven classes of invertebrates with respect to body plan (as stated in the Curriculum). The
teacher approached this task by giving students a worksheet with questions related to the seven classes of invertebrates. Students were divided into groups of five and each student in the group was assigned a number corresponding to a different animal phyla. After working individually or in groups (with other students working on the same phyla), the five students regroup to discuss their answers. During a small group discussion about the animal phylum, Annelida, Mai, Ray, Nancy, Kim and Sue discuss their explanations to the question: How are Annelids segmented?

1. Nancy: I wanted to say that it [annelids] is like segmented from the mouth to the anus.
2. Mai: What’s an anus?
3. Ray: [continuing] It asks how not why.
4. Nancy: [responding to Mai] Heh?
5. Mai: [repeats, pronouncing as arnus] Anus, what’s an anus?
7. Mai: [correctly pronouncing the word] Anus. What is that?
8. Ray: [continuing with worksheet question] they are segmented [Nancy and Sue laugh at Mai’s question] in a coelum or whatever that’s called.
10. Sue: that’s where your faeces comes out from you know when you...[Mai laughs].
In the above excerpt, Nancy's explanation of the worksheet question includes the technical term “anus” (line 1). Mai, however, does not know what the term “anus” means and she quickly asks her peers for an explanation (line 2). Both Nancy and Sue respond with different yet acceptable explanations (L. 9,10). It is interesting to note that Sue uses the technical term “faeces” to refer to “waste products” - another example of re-labelling an everyday, familiar concept with a technical term. Mai’s laughing response (line 10) suggests that she was able to link the term “anus” to a known concept in everyday life. The use of the technical term “coelum” on line 8 also appears to cause problems. Ray’s response suggests that he is not sure what the “coelum” is.

The vignette illustrates that the use of technical terms (often replacing everyday familiar terms) in written questions, often hinders ESL students’ interpretation of questions and also hinders most students’ understanding of scientific concepts (line 8). In particular, the vignette illustrates the learning problems associated with this feature of scientific language (the replacement of everyday terms with technical terms).

**Knowledge of Morphology**

In this section I argue that ESL students’ limited knowledge of morphology hinders their interpretation of written questions. Most students have a limited knowledge of how words are derived from Greek and Latin words and how words are transformed into verbs, nouns, or adjectives. The following vignette illustrates how Pete's unfamiliarity with the morphology associated with the word “anus” interacted with his interpretation and construction of meanings.
Pete: relating “anal” and “anus”

During the group activity on invertebrates described in the previous section, Pete was assigned the phylum Platyhelminthes (flatworms). One of the questions on the worksheet was: Do they (flatworms) have an anal opening?

During the lesson, Pete came up to me and asked me what “anal” meant. I was surprised that he had difficulty understanding this term. When I asked him if he had heard of the term “anus”, Pete replied that he knew that “anus” was the opening through which waste products left the body. It seemed that Pete had not associated “anus” with “anal”. He had not realized that the words “anus” and “anal” had the same conceptual meaning but were being used in different morphological forms. I then explained the different forms to Pete - that “anus” was being used as a noun whereas “anal” was being used as an adjective. After this explanation Pete appeared to make the association between the two words and was able to interpret and answer the worksheet question.

This example suggests that knowledge of morphology of terms supports ESL students’ interpretation of questions and their learning of biology concepts.

Using Everyday Language to Construct Ways of Scientific Reasoning

In this section I present three vignettes to support my contention that the use of everyday language such as “essential” in written and oral questions, though causing difficulties to students, is necessary to direct students to construct ways of reasoning about biology concepts. Evidence suggests that such everyday language is used in written biology questions to trigger a technical kind of explanation. Also, while many ESL students are not
familiar with these words, evidence suggests that peer mediation during small group work supports ESL students’ interpretation of questions and construction of ways of reasoning.

Using “essential” to elicit functional explanations

This vignette is also based on the group activity where each student in a group had to answer questions related to a different invertebrate phyla.

In the excerpt that follows, Ray, Mai, Nancy, Kim and Sue are discussing their answers to questions pertaining to the animal phyla, Porifera (sponges). The teacher joins the group during their discussion.

1. Ray: what was the answer for why is water [flow] essential to all sponges?
2. Mai: What is essential?
5. Teacher: Sponges have flagella that filter out plankton. Water comes in through outside little pores and comes out through a larger opening, the osculum.
6. Ray: So the whole sponge is creating it’s own water current inside.
7. Teacher: More advanced sponges have more complex structures that channel water out than simple sponges but the goal is to allow water to filter out stuff with water.
In the above excerpt, the use of the word “essential” in a worksheet question posed difficulties for Mai. She uses this group interaction to ask her peers to explain the meaning of the word essential (line 2). Kim responds to her in line 3 and explains “essential” as “necessary”. At this point Mai does not ask for further clarification so one could assume that she was familiar with the use of the term “necessary” in the everyday context.

What is significant here is that the everyday terms “essential” and “necessary” are used in scientific discourse to elicit functional explanations. Students are being asked to construct ways of reasoning about features of living things in terms of structure-function relationships. The teacher tries to direct students to think in terms of structure-function relationships by highlighting flagella as a significant structure (line 5). Ray’s response about the water currents indicates that he is reasoning about why water is a “necessary” condition for “Sponges” (line 6). Hence, words like “essential” and “necessary” are used to talk about the conditions of living creatures in Biology and become part of constructing ways of reasoning in Biology— in this case relating structures to functions. Such everyday words therefore become conceptually central to constructing biology knowledge. They seem to be used to signal that a functional explanation is required.

Using “advantage” to elicit functional explanations

In this vignette, students are engaged in small group work to discuss the questions on the grasshopper dissection lab which they have just completed. Sue, Nancy, Kim, Shen and Ray discuss a question related to the grasshopper’s eyes.
1. Sue: What is the advantage of the structure and shape of the compound eye? Nancy, do you know?

2. Nancy: [inaudible]

3. Sue: They’re green - are they green?

4. Nancy: Yah, usually they are green. What’s the function of the simple eye?

5. Kim: I don’t know. Hey, Shen, What’s the function of the simple eye?

6. Shen: Don’t you think the simple eye detects light from dark and the compound eye actually sees things?

7. Sue: Really? What about the advantage of the simple eye and what does the compound eye do?

8. Ray: What is the advantage of the structure and shape of the compound eye? Oh, because you see in the grasshopper, the compound shape, uh, lets - it helps it [grasshopper] be better suited for the environment - its environment is light - all it does is jump around so…

9. Kim: What are you saying?

10. Ray: So what you could say is that the compound eyes adjusts, enables it [grasshopper] to better suit its environment because of its shape. What did you put?

11. Kim: there is a greater area of ….

12. Nancy: What?
13. Mai: Don’t we see clearly, we only have one [kind of eye]. We can see further.

14. Ray: Yeah, but their eyes are further out like here and here [points to picture of grasshopper]


In this excerpt, students are once again trying to construct scientific explanations. The use of the everyday word “advantage” directs students to think in terms of structure-function relationships. While not conclusively arriving at the scientifically “correct” explanation, students try to relate structure to function (L 8,10,13,14, 15). “Advantage” also directs students to compare and contrast compound and simple eyes (line 4-7). Rather than looking at the function of compound eyes in isolation, students try to compare compound and simple eyes to find out what the function of each eye is in relation to its structure. This comparison also supports the idea that students learn biology concepts by contrasting concepts within taxonomies.

Using “appropriate” to elicit functional explanations

In the next example, the everyday word “appropriate” is used to once again elicit a functional explanation in terms of structure-function relationships.
Nancy describes how peer mediation outside the classroom assisted her in understanding a question related to the frog dissection lab: How are the positions of eyes and external nostrils appropriate for life in the water?

Well, I had problem with number two. Like I didn't get any information from the textbook. So I asked Shen. I asked her about it then she told me. Like a frog is immersed in water so the position of the eyes is on top. So it could [pause] could be partly submerged in the water and the eyes could keep them aware of, aware of it's enemies. Then after what she told me, then I went to a text book, then I read it and like it was there. It was not quite specific but ... [Nancy, Interview]

The scientific explanation to the question was in the first paragraph of the textbook. Although Nancy had read the textbook, she could not link this information to the question. It is possible that she was confused by the everyday word “appropriate” as used in the scientific context. It is also possible that a similar but more familiar word such as “suitable” may have aided her in interpreting the question. Nevertheless, the word “appropriate” was used in the question to get students to reason in a particular way - in terms of structure-function relationships.

In the three worksheet-questions discussed above, the teacher uses everyday language such as “essential”, “necessary”, and “appropriate” to build up a framework of functional explanation. The three examples discussed above indicate that the use of everyday language in questions supports students’ construction of particular ways of reasoning in biology. As well, these examples indicate that for ESL students who have
difficulty interpreting everyday language in questions, peers play a significant role in helping them interpret everyday language and construct scientific ways of reasoning.

The three preceding vignettes also indicate that learning science is not as simple as portrayed by the traditional triad model. Learning science involves constructing ways of reasoning to illustrate particular relationships such as structure-function relationships. It does not involve the study of concepts in isolation but also involves comparing and contrasting concepts within taxonomies.

IV. Summary

In this chapter, relationships between language and students' learning in biology were examined in relation to two areas: teacher's teaching of biology terms and concepts and students' interpretations of written and oral biology questions. Within these two areas, the data was interpreted in two ways to highlight: 1) the role of language in the construction of biology knowledge and 2) the mediational role of teacher, peers and prior knowledge on ESL student's learning of biology terms and concepts.

With regard to the mediational role of language, the data shows:

- The teaching and learning of language concepts is integral to understanding and constructing biology knowledge.
- The traditional model of language signification is limited in explaining the learning and teaching of biology terms and concepts.
The findings of this study suggest that the learning and teaching of terms and concepts should be explained by a more complex model of language than the traditional triad model of word-concept-thing. Some of the differences are illustrated below between the traditional model and a functional model suggested by the data and informing the work of Halliday and other systemic functional linguists studying scientific discourse and its role in learning.

Table 2. Some differences between the traditional model of language signification and a functional model of language

<table>
<thead>
<tr>
<th>Traditional Model of Language Signification</th>
<th>Functional Model of Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word – signifies the thing.</td>
<td>Words and morphemes construct meanings which in the context of discourse refer to things.</td>
</tr>
<tr>
<td>Thing – teach meanings by pointing to and describing thing.</td>
<td>Teach meanings by using multiple semiotic representations to illustrate/refer to thing/process.</td>
</tr>
<tr>
<td>Concept – learn meanings in isolation.</td>
<td>Learn meanings by contrasting concepts within taxonomies and by constructing ways of reasoning.</td>
</tr>
</tbody>
</table>
With respect to the mediational role of peers, teacher and prior knowledge, evidence shows that teacher, peers and prior knowledge played a significant role in ESL students’ learning of both science and language concepts.

The findings indicate that the teacher supported ESL students’ language and science learning by incorporating the following language aspects during biology teaching:

1. Exploring the meaning and morphology of terms and concepts
2. Using multiple semiotic representations
3. Contrasting concepts within taxonomies

The findings reveal that peers assisted ESL students in interpreting worksheet questions and constructing biology explanations by:

1. Explaining the meanings of everyday words when used in formal style on worksheet questions
2. Providing everyday words and explanations for technical terms
3. Correcting pronunciations of words
4. Discussing and sharing explanations and answers to worksheet questions.
ESL students' interpretation of biology worksheet questions was also mediated by prior knowledge of:

1. Terms and concepts in L1
2. Everyday words used in formal style
3. Technical terms and morphology
4. Everyday language used to construct ways of scientific reasoning.

The findings summarised above raise some interesting issues and dilemmas such as:

- How can we raise awareness of the skillful language teaching that mainstream science teachers do?
- What strategies can be used to support the learning of science concepts in the second language, English?
- How do the processes of learning and teaching science reflect the nature of scientific discourse and language?

These issues will be explored in the discussion and implications sections in the next chapter.
CHAPTER SEVEN

Conclusions, Discussion and Implications

The conclusions, discussion, and implications for practice in this chapter are based on the interactions of ten grade 11 biology students as they engaged in classroom social interactions. This chapter is divided into five sections: conclusions, discussion in terms of sociocultural perspectives, implications for practice, implications for teacher education and future research.

I. Conclusions

In this section I will provide a summary of the conclusions that can be drawn from the analyses presented in chapter 5 and 6. These conclusions will be organized around the three research questions, which provided the frame for the study.

What is the Nature of ESL Students' Participation during Biology Instruction?

The purpose of this question was to gain insights into the nature of ESL students' participation in mainstream science classrooms. The premise that social interactions are intrinsic to the learning process (Lave & Wenger, 1991; Rogoff, 1993, Vygotsky, 1987, Wertsch, 1991) makes the nature of students' participation a significant factor in the learning process. Furthermore, the premise, that it is through talk that people construct knowledge (Mercer, 1995), highlights the importance of examining ESL students' participation in classroom social interactions.
The analysis of ESL students’ participation in classroom activities revealed that students’ participation tended to range from a primarily individual engagement (personal-individual participation practices) to a highly social form of engagement (socio-interactive participation practices). Students’ actual participation practices during whole class interactions were consistent with their preferred learning orientations, which ranged from individual engagement in activities to social interactions with peers and teacher (refer to figure 11).

![Diagram showing the continuum of individual engagement to social interactions with examples of students: Sue, Shen, Mai, Pete, Steve, David.](image)

Figure 11: ESL students’ preferred learning orientations

Students exhibited considerable variability in their participation in terms of the context being considered. Figures 12 and 13 illustrate the variability in students’ participation practices during whole class and small group interactions respectively. Students’ participation is illustrated along a continuum from strongly personal-individual to strongly socio-interactive.
A comparison of the two diagrams reveals that all participants tended to exhibit more social forms of engagement during small group activities. This is not unexpected as small group work provided students with greater access to face-to-face social interactions.
Small group work enabled students to engage in talk with peers and teacher about language and science concepts and activities. While these conclusions about group work are not new, they reinforce the importance of small group work for classroom learning. As Mercer (1995, p. 89) points out:

Traditionally, talk between learners in classrooms has been discouraged and treated as disruptive and subversive. Although ideas may have changed to some extent in recent years, pupil-pupil talk is still regarded suspiciously by many teachers.

On the other hand, the findings also indicate that group work is not the dominant form of classroom activity supporting ESL students' learning of language and science concepts. The findings show that students like Shen and Sue preferred individual engagement in activities, and these personal-individual participation practices supported both language and science learning (as evidenced by these students' responses during interviews and their performances on assignments, tests and exams).

**What Factors Enhance or Constrain ESL Students' Engagement in Classroom Social Interactions?**

The nature of ESL students' social interactions was examined to gain an understanding of why they exhibited certain participation patterns. A number of factors that enhanced and constrained ESL students' classroom social interactions during science learning were identified. While these factors are discussed individually, students' participation patterns are most likely influenced by the complex interactions between a number of these competing factors (as discussed
in the previous chapter).

Socio-cultural factors

The nature of student’s engagement during classroom social interactions appeared to be related to students’ cultural norms, values and traditions. For example, Nancy’s lack of questions in whole class discussions appeared to be related to the cultural expectation of respecting the authority of the teacher. The role of social and cultural values and traditions on students’ participation in classrooms has been reported by other studies (B.C. Ministry of Education, 1999; Mercer, 1995; Peregoy & Boyle, 1997). With regard to ESL students, the B.C. Ministry of Education (1999) has identified possible cultural explanations for behaviours that ESL students sometimes exhibit. For example, when a student avoids eye contact, a possible cultural explanation may be that direct eye contact with a teacher is considered disrespectful and is a challenge to the teacher’s authority. Similarly, in this study, the nature of students’ social interactions appeared to be related to possible cultural explanations.

Prior school practices

Closely related to cultural norms are prior school practices. All students experienced prior school practices. The participation patterns of students in this study appeared to be related to their prior school practices.

Shen, Nancy and Sue were accustomed to classroom settings (teacher dominated classrooms in Hong Kong and India and a text-dominated Canadian classroom) that perpetuated personal-individual participation practices. Their participation practices reflected this pattern. Steve, David and Pete were accustomed to classrooms where students
answered and asked questions and participated in co-operative group work. Their participation reflected this pattern of social interactions. The nature of students’ prior school practices appeared to enhance and constrain social interactions.

**Teaching practices**

Different teaching practices appeared to enhance students’ social interactions during whole class and small group activities.

**Questioning techniques**

The use of questions directed to the whole class was a technique used by the teacher to initially assess different students social engagement during whole class discussions. This technique was non-threatening and gave all students the choice to participate in classroom discussions. The continued use of this technique, however, had the effect of allowing certain students like David and Steve to dominate whole class discussions. Students like Sue and Nancy were silent when this questioning technique was used. Hence, the continued use of questions directed to the whole class constrained some students’ social interactions. The use of questions directed to individual students was a technique used to enhance the social interactions of students. This technique however, was not used very frequently.

**Use of examples related to everyday life**

The use of examples and topics related to everyday life appeared to enhance social interactions among students during whole class discussions and small group work. Students were motivated and drew on personal experiences (e.g., sweating to maintain a constant body temperature) to contribute to whole class discussions and collaborative group work. This result is supported by the findings of Crawford and Marx (1999). They report that
tasks related to real-world questions “generated more collaborative interactions than topic-bound tasks” (p. 712).

*Frequency of small group interactions*

As illustrated under research question 1, small group activities promoted socio-interactive participation practices among all students. For example, Sue and Mai were passive listeners during whole class interactions. Small group work encouraged both students to engage in social interactions with peers and teacher. Hence, more small group activities (in comparison to whole class activities) enhanced students' engagement in social interactions.

*Choice of members in group interactions*

A factor that appeared to enhance social interactions among students was choice of group members. In this class, students chose their own partners and groups to work with. The assertion that allowing students to choose their own group members enhances social collaboration is supported by other studies on student participation in groups (Hogan, 1999, Zajac & Hartup, 1997). Studies also show that when students are paired with friends, the quality of discussion and consequently problem solving is enhanced (Azmitia & Montgommery, 1993).

*Composition and size of groups*

In this study, small groups with two students tended to exhibit greater social collaboration than larger groups with three or more students. Various studies (Bianchini, 1999; Cohen, 1994; Hogan, 1999) have shown that the inequitable participation of group
members in larger groups may be attributed to many factors such as race, gender, and social status. In the present study, students like Shen were perceived to be “smart” and were accorded higher social status. These students tended to dominate the group in terms of talk and activity. Many students in larger groups were often silent observers. When students like Shen worked in pairs, they tended to work more collaboratively with their partners.

**Affective factors and English language proficiency**

In this study, ESL students’ (Mai, Pete and Sal) self-esteem and perceptions of themselves as adequate English language speakers appeared to constrain their social engagement in classroom interactions. This inference is supported by Kohonen’s (1992) assertions that ESL students’ views of themselves as language learners, their self-concept and their self-esteem are important for successful language learning.

**Participation in the research project**

For some participants, participation in the research project appeared to enhance their social engagement during classroom interactions. There was an observable increase in Pete and Mai’s social interactions during whole class and group activities over the course of the project. The presence of an additional supportive adult, the researcher, appeared to provide an additional resource for them. Both Mai and Pete initiated many social interactions with me during classroom activities. There was also a marked increase in their interactions with other students and the teacher over the course of time.
What are Some Relationships between Language and Students' Learning Science?

The purpose of this question was to gain insights into the mediational role of language as ESL students learnt biology terms and concepts in a mainstream science classroom. Two major categories of analysis emerged:

1. the mediational role of language in the construction of biology knowledge
2. the mediational role of teacher, peers and prior knowledge during ESL students' learning of biology terms and concepts.

Mediational role of language

The mediational role of language in science learning was examined by using the triad model of language signification to explain how biology terms and concepts were taught and learnt in this classroom. The data revealed that the triad model of language signification where the word signifies the thing via a concept is limited in explaining the learning of science terms and concepts.

The findings of this study reveal that the learning of science terms and concepts can be more adequately explained by a model of language that includes:

1. the use of words and morphemes to construct meanings that signify the thing/process
2. multiple semiotic representations of the thing/process
3. contrasting concepts in taxonomies and constructing ways of reasoning.
A functional model of language incorporating the three aspects above is illustrated below:

![Diagram of language model](image)

Figure 14. A functional model of language

The data also shows that Cummin’s “dual iceberg” model is limited in explaining the learning of concepts in a second language. Cummin’s model does not account for situations where the meanings of concepts in L1 are not the same as the meanings of concepts in L2 as illustrated in the vignette “Sal’s understanding of lobes”.

The main findings about the relationships between language and science learning are summarized in table 3.
Table 3. Summary of findings about language and science learning

<table>
<thead>
<tr>
<th>Traditional Views about Teaching and Learning Language and Science</th>
<th>Findings of the Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talking about language is not a part of biology teaching.</td>
<td>Talking about language is integral to biology teaching and learning. Scientific terms evolved from the nominalization of verbs and adjectives. Exploring the morphology of terms and concepts supports ESL students in their learning of science terms and concepts.</td>
</tr>
<tr>
<td>Words are labels for things. Concepts are taught by showing the thing and/or by describing what the meaning is.</td>
<td>Teaching involves more than showing and/or describing concepts in isolation – it includes using multiple semiotic representations, contrasting concepts within taxonomies, and constructing ways of reasoning.</td>
</tr>
<tr>
<td>If the learner knows the general meaning of English words, then she/he should be able to interpret these words in written and oral biology questions.</td>
<td>ESL students’ prior knowledge of the meanings of everyday words does not help them in their interpretation of questions when everyday words are used in formal style on worksheet questions.</td>
</tr>
<tr>
<td>If students already know a concept in L1, then learning a concept in L2 simply involves learning a new label.</td>
<td>Learning concepts in L2 is complex. Prior knowledge of concepts in L1 does not necessarily support concept learning in L2. Labels in L2 often refer to different features of a concept.</td>
</tr>
</tbody>
</table>
Teacher mediation of learning

As discussed in the literature review, learning a second language and learning science concepts involve deliberate intervention by more knowledgeable persons (McGroarty, 1992; Ochs, 1988; Vygotsky, 1987, Wertsch, 1991). In the science classroom, the more knowledgeable person is usually the teacher (Driver et al, 1994; Lemke, 1990). Driver et al (1994) stress the importance of teacher mediation in the construction of scientific understandings in the classroom. All participants in this study intimated that social mediation by the teacher was a significant contributor in their construction of meanings.

In this study, the teacher mediated students’ learning of science and English language concepts through the use of the following teaching strategies:

*Exploring the morphology and meanings of words and concepts*

Many science concepts are derived from Greek and Latin words. The explicit teaching of Greek and Latin morphology by exploring the meanings of component parts of words (morphemes) making up science terms emerged as an important factor in all students’ learning of biology concepts. The teaching of morphology during science teaching is illustrated in the vignette “Deriving the meaning of homeostasis.”

The results of this study also indicated that ESL students with limited proficiency in English had a limited knowledge of the morphology of words as illustrated in the vignette “Pete: relating anal and anus”. Highlighting the morphological differences in the ways in which words such as anus and anal are used appeared to assist ESL students in their understanding of oral explanations and written texts. This finding is supported by
Vygotsky's (1987) studies on the relationship between instruction in grammar and linguistic development. The results of his studies indicate that grammar helps the child rise to a higher level of speech development.

Another example of teaching morphology is illustrated in the vignette, “Understanding adaptation as a noun.” In this vignette, the difference between a noun and a verb was used to illustrate the conceptual meaning of adaptation. This strategy supported ESL and non-ESL students' in their understanding of both language and scientific concepts.

*Using multiple semiotic representations to provide situational and linguistic cues to meaning*

The vignette “Learning from visual and verbal representations” supports Lemke’s (1998) assertion that the meanings communicated by multiple semiotic representations contributes to the overall meaning of the concept. Multiple semiotic representations could also allow different students to connect to various meanings highlighted by each of the representations. Semiotic representations such as demonstrations, analogies, pictures, and summaries on the overhead appeared to engage and assist different students in their construction of meanings.

Verbal explanations and demonstrations that were supplemented by written summaries and visual illustrations appeared particularly helpful to ESL students. For example, Sal was questioned about what helped her gain some understanding of the meaning of the word lobe during the lesson on *Gingko biloba.*
Interviewer: And so you did not have any idea what lobe meant [Sal: no, no.] until your teacher pointed to his ears [Sal: yeah, yeah.] and showed you ...

Sal: and the drawing.

Interviewer: and the drawing of the actual plant.

Sal: Yeah.

The use of concrete and visual representations to illustrate the meaning associated with the word “biloba” seemed to give Sal some understanding of the shape associated with the word lobe. This finding is consistent with the findings of another study on LEP students’ learning in Biology. Duran at al. (1998) illustrated the importance of using diagrams as visual explanatory texts when teaching biology concepts to ESL students. This teaching strategy is consistent with Cummins (1992) notion of context-embedded communication - where ESL students are supported in their learning of content by a wide range of linguistic and situational cues.

The use of everyday narrative examples (e.g., the teacher’s explanation of natural selection) also appeared to enhance some students’ learning of science concepts. Using analogies, metaphors, examples and demonstrations from everyday life offers a greater number of students the opportunity to make connections between their prior experiences and the new science concept (Jaipal, 1993).


Relationships between concepts in taxonomies

The findings of this study indicate the ESL students’ learning of science terms and concepts is supported by comparing and contrasting terms and concepts in taxonomies. For example, the teacher’s comparison of “bilateral” and “radial” symmetry and “homogeneous” and “heterogeneous”, appeared to support students’ construction of the meanings of the concepts “bilateral” and “heterogeneous”. The notion that science concepts are learnt by contrasting concepts in taxonomies is consistent with current views in the literature about the nature of and construction of scientific knowledge (Halliday, 1998). Many science concepts do not exist in isolation, but are related to other concepts in categories and classes. Hence, the learning of science concepts is supported by teaching concepts in relation to other concepts within taxonomies.

While many of the biological concepts that were introduced in the classroom during the time of this study could be embedded in a taxonomy, not all of the relationships between scientific concepts, particularly in the physical sciences, are taxonomic in nature.

Using everyday language to construct ways of reasoning

The findings indicate that the teacher mediated ESL and non-ESL students’ learning of science concepts by using everyday language in written and oral questions to direct students to construct ways of scientific reasoning. Everyday words such as “appropriate” and “essential” were useful in triggering scientific reasoning in terms of structure-function relationships. The construction of scientific ways of reasoning during science learning is consistent with Hallidays (1998) views about the nature of scientific knowledge.
Peer mediation of students' learning

Social interactions among learners have been shown to support the construction of knowledge (Cohen, 1984; Cohen & Lotan, 1995; Lumpe & Staver, 1995; Mason, 1998; Mercer, 1995; Rivard & Straw, 2000). In this study, peers played a significant role in mediating ESL students' interpretation of everyday words and technical terms used in written worksheet questions. Peers supported ESL students in their learning of both language and science content in the following ways.

*Explaining meanings of everyday words used in formal style*

During small group activities, students who were more proficient in English assisted LEP students in their interpretation of worksheet questions by explaining the meanings of everyday words (e.g., essential) used in formal style. The positive role of peer mediation on linguistic development has been reported by other studies (B.C. Ministry of Education, 1999; Fathman & Kessler, 1993; McGroarty, 1992; Myers, 1993; Wong-Filmore, 1982).

*Providing everyday explanations, labels and pronunciations for technical terms*

Peers mediated students' learning of science terms and concepts by providing the everyday explanations, labels and pronunciations for technical terms as illustrated in the vignette "Learning the scientific label anus." Most of these explanations occurred during small group activities. The significant role of peer interaction in science learning has also been highlighted in other studies on science learning (Basili & Sanford, 1991; Lumpe & Staver, 1995; Mason, 1998). As well, enhancing learning by interacting with more knowledgeable peers is consistent with assertions in the literature that changes in students'
understanding occur as students participate in social interactions where they are assisted by more knowledgeable peers (Brown, Collins & Duiguid, 1989; Rogoff, 1993).

**Students’ prior knowledge mediating learning**

According to Vygotsky (1987), learning a second language and learning science are similar. The students’ prior knowledge of the meaning of words in the first language mediates learning a word in a second language. In a similar manner, the students’ knowledge of prior science concepts mediates the learning of new science concepts. The results of this study show that students’ prior knowledge mediated science learning in the following ways:

*Prior knowledge of everyday words used in formal style*

Many everyday words are often used to talk about science concepts in the science classrooms. These words are however often used in formal style in science discourse. The vignettes, “Mai’s interpretation of concentrated” and “Pete’s interpretation of arisen” illustrate how ESL students’ unfamiliarity with the use of everyday words in formal style give rise to interpretations that are not consistent with scientific explanations.

*Prior knowledge of multiple meanings of everyday words and scientific terms*

Most science terms (e.g., frequency) and everyday words (e.g., arisen) have multiple meanings. These multiple meanings tend to complicate ESL students’ interpretation of science discourse and problems are exacerbated when the same term/label (e.g., frequency, concentrated) are used to denote both an everyday and a scientific concept. This result is consistent with findings of other studies investigating the role of students’ prior knowledge

Prior knowledge of terms and concepts in the first language

Relating terms and concepts in English to terms and concepts in the first language appeared to be both advantageous and disadvantageous to ESL students’ learning of biology. For example, Shen's understanding of the concept dentine was supported by her translation of dentine into her first language, Cantonese. This finding is consistent with findings reported by Lai, Lucas and Burke (1995). There was evidence in their study that Chinese students were explaining biology concepts in English by translating prior knowledge from Chinese. Also, there were numerous occasions when students in their study failed to recognize a concept label in English (as Shen had failed to recognize the label dentine) and asked for the Chinese translation. In the current study and Lai et al’s study, students were learning new labels for already existing concepts (Cummins, 1992). Prior knowledge of science concepts in the first language mediated learning of science in the second language.

However, in the vignette, “Sal's understanding of lobes”, the translation of lobe into the first language, Spanish, elicited an association to a different feature of the concept “lobe”. Translation of the English word into her first language did not support Sal in her construction of the scientific meaning. This finding is similar to the findings reported by McNaught (1993). She cites the example of how classification of animals in Shona (a language spoken in Zimbabwe) is based on mythology. For example, in Shona, a bird, a locust and a fly are grouped together whereas in science, birds and locusts are classified into
separate groups. Hence, when direct translations are made into the first language, the possibility exists that it may elicit relationships and meanings that are different from relationships and meanings in the second language.

The findings above suggest that one cannot assume that concepts already acquired in the first language (as illustrated by Cummins’ “dual iceberg” model), enhance concept learning in the second language.

_Prior knowledge of technical terms and morphology_

The findings show that ESL students had problems interpreting technical terms that were used to re-label familiar everyday concepts. For example most native and proficient English speakers may be familiar with the technical term “anus” because of their familiarity with the use of the term in previous science classes or they may have encountered the term in other everyday situations such as a program on television. Limited English proficient students such as Pete and Mai were not familiar with the technical term “anus” even though they knew what the concept referred to. Re-labelling everyday concepts with technical terms hindered ESL students’ interpretation of written texts.

ESL students’ prior knowledge of morphology also played a significant role in their understanding of science concepts. For example, Pete’s lack of prior knowledge of how the word anus is transformed from a noun into an adjective hindered his interpretation of a written question and his subsequent construction of meanings in science. The vignette “Learning from visual and verbal representations” also illustrates how students are aided in constructing meanings by their knowledge of the morphology of Latin and Greek words.
Prior knowledge of Latin and Greek morphology assisted both ESL and non-ESL students in learning science concepts.

II. Discussion of Results

In this section, the results of this study are explicated in terms of the assumptions derived from sociocultural perspectives - as outlined in the first section of Chapter two. Assertions are situated within and supported by the Science Education and Second Language literature reviewed in chapters two and three. The discussion also includes an examination of the ways in which power and authority relations played out in this study. Finally, the discussion concludes with a summary of the study’s major contributions to the literature.

This study explored ESL students’ participation and learning in a grade 11 biology classroom - specifically the nature of students’ social interactions and the relationships between language and ESL students’ learning in science. Learning classroom science was viewed as the personal construction of knowledge during classroom social interactions (Dewey, 1938; Vygotsky, 1978). As such, ESL students’ learning was examined in relation to whole class and small group classroom activities. Furthermore, students’ participation and learning were not analysed as isolated classroom events but were analysed in relation to participants’ past and present cultural, institutional and historical settings. This approach is consistent with the notion that learning is socially and socioculturally situated (Vygotsky, 1978; Wertsch, 1998).
The notion that learning is socially situated has resulted in many educators advocating participation in group work as the way to enhance academic learning. The findings of this study indicate that some students preferred and found individual engagement in activities beneficial to their learning. These findings raise questions about the simple inference made from sociocultural approaches that group work is the way to enhance learning of academic concepts for all students. The findings of this study show that different students have different learning orientations ranging from individual engagement to social interactions. Both individual and group activities appeared to support ESL students’ learning of language and science concepts. These findings suggest that educators should be cautious about advocating and emphasizing the exclusive use of sociocultural learning approaches as the way to enhance learning for all students.

With regard to the nature of social interactions, the analysis of data revealed that ESL students’ participation practices were influenced by the complex interactions between a number of factors at the community, interpersonal and individual levels. The factors identified in this study were cultural norms and traditions (e.g., views on respect and authority), prior school experiences and expectations (e.g., acceptable classroom behaviour), teaching practices (e.g., use of everyday examples) and affective and linguistic factors (e.g., self-esteem and English language proficiency). These findings are similar to the results reported by other studies in the literature (Mercer, 1995; Nunan, 1999; Peregoy & Boyle, 1997) and they support assertions about the sociocultural nature of learning (Rogoff et al., 1995; Wertsch, 1991, 1998). As well, these findings extend the literature by providing particular insights about the nature of the social interactions of a particular group of ESL
students. Further, these findings indicate that students' participation in the research project, particularly social interactions with the researcher, appeared to enhance their participation and learning. This suggests that interventions involving face-to-face interactions with an adult other than the teacher may be a means of providing additional support for ESL students in mainstream classrooms.

A significant characteristic of ESL students' participation practices was how language was used during social interactions. Vygotsky (1978) emphasised learning as a communicative process where more knowledgeable persons provide cognitive support. These social interactions are characterised by a dialogic give and take that support the internalisation of science concepts (Wertsch, 1991). In a recent study on the role of talk and writing in learning science, Rivard and Straw (2000) also found that peer talk combined with writing appeared to enhance the learning of science over time. These findings from the literature suggest that verbal communication during social interactions plays a significant role in the personal construction of science concepts.

In this study, the nature of language usage during classroom interactions depended on students' prior experiences with language in past cultural, institutional and historical settings. For some ESL students in the study, past institutional settings such as prior classrooms emphasised teacher talk and the text as authorities of knowledge. This prior experience with language manifested itself in the present setting by some ESL students listening to teacher talk and not questioning the authority of the teacher. The findings of this study lend credence to the assertion that sociocultural factors play a significant role in ESL student's engagement in classroom social interactions.
With regard to the relationships between language and students' learning in science, the commonly held belief that teaching and learning science concepts involves teaching and learning a label for a thing/process does not describe how biology concepts were taught and learnt in this classroom. The results of this study indicate that the teaching and learning of science terms and concepts can be explained by a model of language that goes beyond the traditional triad model of language signification. Evidence suggests that the teaching and learning of biology concepts is complex and involves constructing taxonomies and ways of reasoning and using multiple semiotic representations. These findings are consistent with current notions about the nature of scientific knowledge, specifically Halliday's (1998) argument that scientific language is created by constructing taxonomies and discourses of reasoning (a flow of argument such as cause and effect) and Lemke's (1998) argument that scientific meanings are constructed by the union of meanings implied by multiple semiotic representations. This study extends the literature by proposing a theoretical model of language to explain the teaching and learning of scientific concepts. This functional model of language appears to offer a more adequate explanation of the types of teaching and learning of science terms and concepts that were observed in the present study.

At another level, this study examined ESL students acting with mediational means in a sociocultural setting (Vygotsky, 1978; Wertsch,1992,1998). The findings showed that in this biology classroom, three types of mediators influenced ESL students' science learning: signs and symbols (e.g., language and diagrams), prior knowledge (e.g., words, concepts and morphology) and interpersonal relations (e.g., teacher-student and peer-peer relations). Wertsch (1998) argues that mediational means constrain as well as enable higher order
mental functions. In this study, there was evidence that three types of mediational means enabled and constrained ESL students’ learning of science concepts.

Firstly, language was the dominant mediator of classroom learning. Language was used during social interactions to mediate learning at the interpersonal (social) and intrapersonal (individual) levels (Vygotsky, 1978). For example, the teacher’s use of an everyday narrative example to explain the concept natural selection aided some students in their understanding of the concept. This process can be explained in terms of students comprehending the teacher’s verbal explanation at the interpersonal level, and then internalising that information by relating it to their prior knowledge of concepts (intrapersonal level). In this instance, there was evidence of the enabling potential of language at the social and individual levels (Wertsch, 1998). On the other hand, language, particularly English language proficiency, constrained ESL students in their attempts to construct scientific understandings at the interpersonal and intrapersonal levels. For example, Pete’s and Mai’s unfamiliarity with morphology and their unfamiliarity with the use of everyday words in formal style constrained them in their attempts to comprehend teacher explanations (interpersonal level) and construct scientific understandings (intrapersonal level).

Other signs identified by Vygotsky (1978) also mediated ESL students’ learning. In particular, multiple semiotic representations served as situational cues and supported the teachers’ linguistic cues to meaning. For example, the teacher used a picture and a dome-shaped container to illustrate the concept of radial symmetry. His verbal explanation was supported by situational cues to meaning. The findings of this study are consistent with the
findings of Duran et al’s. (1998) study. Their study showed that for students with limited 
English proficiency, “it is important to scaffold teacher lecture by pairing visual and 
auditory presentation of content” (p. 337). These findings reaffirm calls in the literature to 
provide more context-embedded communication for ESL students’ learning of academic 
content (Cummins, 1992).

Secondly, the use of prior knowledge by students as a mediational means can be 
explained in terms of Vygotsky’s (1987) notion of the development of higher scientific 
concepts. Vygotsky (1987, p. 197) maintains “a scientific concept relates to its object only in 
a mediated way, through previously established concepts.” For ESL students in this study, 
prior knowledge of the multiple meanings of everyday words and technical labels, 
morphology, and concepts learned in their first language enhanced and constrained their 
learning of science concepts (as elaborated in the summary of results section). These 
findings support the literature by highlighting the importance of prior knowledge of 
everyday words and science concepts as a mediational means. As well, these findings 
extend the literature by: 1) illustrating how students’ knowledge of morphology constrain 
and enhance their learning of biology concepts and 2) showing that ESL students’ prior 
knowledge of concepts in L1 can also constrain their learning of science concepts.

Thirdly, teacher-student and peer-peer relations played a significant mediational role 
in the learning of science concepts. These interactions were characterised by the teacher or 
more knowledgeable peer assisting ESL students in constructing word meanings and 
concepts. According to Vygotsky (in Wertsch, 1985, p. 107), “children do not select the 
meaning for a word, it is given to them in the process of verbal social interaction with
adults.” By interacting with more knowledgeable persons, students infer the structure of concepts and word meanings that lie behind adults’ speech (Wertsch, 1985). The findings of this study contribute to the literature by providing illustrative examples of how the teacher and peers assisted ESL students in constructing scientific meanings of concepts by: 1) contrasting concepts within taxonomies (e.g., bilateral and radial) and 2) using everyday words to construct ways of scientific reasoning (e.g., structure-function relationships).

The three types of mediational means discussed above are not “neutral cognitive and communicative instruments” (Wertsch, 1998, p.64). Since mediational means are part of the sociocultural setting, mediational means are associated with power and authority. Notions of power and authority were reflected in this study in two ways. Firstly, the use of a specialised scientific register involving specific ways of talking about concepts and their relationships (Lemke, 1990) placed the teacher in a position of power and authority. Power differences between the voices of the teacher and students manifested itself in the large amount of teacher talk as compared to student talk. Also the teacher’s use of words and concepts in accordance with classroom scientific ways of talking placed the teacher is a privileged position. The teacher had access to the language of communication and to the scientific register used to construct scientific knowledge. This is not unusual in a classroom setting. As Mercer (1995, p. 20) points out, “power and responsibility are formally vested in the teacher” because “teachers are usually expected to teach a set curriculum, a given body of knowledge.” Secondly, ESL students in this study, by virtue of having limited English proficiency, did not have equitable access to the languages used for both communicative and cognitive functions in the science classroom. Evidence of this appeared
during small group interactions when ESL students' limited knowledge of everyday and technical words such as "arisen" and "anus" hindered their communication and construction of science concepts.

In summary, this study firstly highlights the sociocultural situatedness of ESL students' learning in a science classroom by providing evidence of the complex interactions between cultural, institutional and historical factors at the community, interpersonal and individual levels of analysis. Secondly, this study cautions against advocating sociocultural learning approaches such as group work as the way to enhance learning for all students. Thirdly, this study proposes a functional model of language to explain the learning and teaching of science terms and concepts. Fourthly, this study provides specific examples of how three types of mediators influenced ESL students learning of science and language: signs and symbols, interpersonal relations and prior knowledge. Fifthly, the notion of learning as involving both interpersonal and intrapersonal processes - verbal communication during social interactions providing cognitive support - suggests that promoting the development of and use of language during social interactions supports ESL students' learning of science concepts.
III. Implications for Classroom Practice

Enhancing Student Participation in Classroom Activities

The results of this study indicate that a number of factors at the individual, interpersonal and community levels most likely interact in complex ways to influence the nature of students' participation in classroom social interactions. The findings of this study show that students enter the classroom with prior classroom and socio-cultural experiences. Students also have different personalities, perceptions of themselves as learners and self-esteem. In addition, ESL students exhibit different levels of English language proficiency. The findings of this study suggest that there is a need for teachers to become aware of and sensitive to the multitude of factors likely to influence students' participation patterns. This result is consistent with current recommendations for teaching ESL students (BC Ministry of Education, 1999). The report recommends that teachers should be aware of the possible cultural explanations for perceived student behaviour.

Knowledge of students' backgrounds, linguistic experiences and prior classroom experiences may be ascertained through personal interviews or questionnaires (see appendix A for examples used in this study). Such information can be used to assist the teacher in planning lessons and choosing instructional strategies that complement students' preferred learning orientations (e.g., familiar strategies such as individual assignments may ease students into an unfamiliar learning environment). Knowledge of students may assist the teacher in choosing everyday examples associated with different students' cultural backgrounds. For example, in this study the teacher incorporated students' everyday
knowledge when teaching the section, “Protection against infection”. Students were asked about the rules and behaviours they were taught in their homes to help reduce infection (e.g., washing hands and fruits before eating). In this way, more students were given opportunities to participate in whole-class discussions. Knowledge about students’ backgrounds can also be used to assign students to different groups or assign roles to group members. For example, during small group work, ESL students may be grouped with more proficient English Language speakers to elicit support for language learning. At the same time, ESL students may be assigned roles that encourage verbal participation (e.g., oral report of groups activity). These strategies promote ESL students’ social interactions during group work. To enhance student participation in talk and activities during whole class activities, the teacher could use different techniques to elicit verbal responses from quiet students. For example, asking specific students to read or make class presentations.

**Supporting English Language Learning and Science Discourse during Science Instruction**

In this science classroom, students were involved in whole class and small group social interactions. During these social interactions, the English language was used to talk about science and construct meanings about science phenomena. English language proficiency is therefore an important mediational tool in students’ learning of science. The results of this study showed that English language proficiency played a significant role in ESL students’ learning of science. For ESL students, success in science learning depends on being proficient in the English language and in the language of science (Kessler, Quinn,
Fathman, 1992; Mohan, 1986). Research has shown that ESL students may take up to five
years or more to gain the English language skills required to learn academic content
(Cummins, 1981, Wong-fillmore, 1986). Overall, ESL students face two major challenges
in the science classroom: learning the English language to communicate at the social level
and using that language to construct scientific meanings at the individual level. A major
implication of this situation is that ESL students require continuous support in English
language learning during academic content learning.

To enhance both language and science learning, teachers of science content should:

1) encourage student language use

2) help students understand everyday and technical terms and the meanings of
terms in formal style

3) explore the morphology of and everyday labels for technical terms

4) become aware of how to use discourse to construct taxonomies and ways of
reasoning in science and how students learn to construct scientific
understandings through discourse.

**Encouraging language use**

In this study, the teacher supported ESL students’ language learning by giving
students’ writing and editing assignments. This activity involved students working in pairs
and editing each other’s answers to assignments. Students were asked to edit aspects related
to spelling, grammar, logic and conceptual meanings, write down suggestions for improving
the written piece and also question their partners about both language and conceptual
aspects.
Exploring meanings of everyday and technical terms and terms in formal style

The results of this study indicated that knowledge of both everyday words and the specialized vocabulary of science, play an important role in ESL students' learning of science. A significant implication for classroom practice is that the multiple meanings of terms and concepts should be highlighted in both the everyday context and science classroom context. Exploring the multiple meanings of science terms and concepts can be easily incorporated into science instruction. For example, when introducing the term frequency in relation to colour, the teacher could highlight the meanings of frequency in the science classroom and in the everyday context.

This study also showed that the use of everyday terms in formal style was problematic for ESL students. In particular, ESL students' had difficulty interpreting written questions where everyday terms were used in formal style. It is likely that most students' could experience similar difficulties due to their unfamiliarity with the use of formal language in science discourse. One strategy that could be used to minimise this problem, is to explicitly raise awareness of the way language is used in a formal way in science discourses. This could involve using assignment or test questions such as the examples in this study to discuss and illustrate how everyday terms are used in formal style.

It is not an easy task to identify the everyday terms/vocabulary that ESL students' have difficulties with. Most times, the teacher may be unaware of these difficulties as illustrated by the vignettes, “Mai's interpretation of concentrated” and “Sal's understanding of lobes.” One suggestion for minimising problems with everyday vocabulary associated with written texts is for the teacher to read and explain the text. In this way, linguistic and
situational cues could contribute towards making unfamiliar words and concepts and everyday terms used in formal style more accessible to ESL students. This strategy may not be practical because of time and curricular constraints.

A strategy that appeared to support ESL students' learning of both science and everyday vocabulary was peer mediation during small group work. Peregoy and Boyle (1997) point out that "if words are used that are not understood, collaborative group work permits learners to ask for repetition and clarification if needed (p.68).” The use of small group work is widely recommended for enhancing ESL students’ language learning (McGroarty, 1992; Meyers, 1993, Peregoy & Boyle, 1997).

**Exploring the morphology and everyday labels for technical terms**

In this study, students’ were supported in their learning of biology concepts by the teacher’s exploration of the meanings of component parts of terms or morphemes. This finding suggests that highlighting Greek and Latin morphology may be helpful to both ESL and non-ESL students during biology learning.

The study also showed that the use of everyday labels (e.g., waste product) to refer to a scientific term/label (e.g., faeces) supported ESL students in making connections between prior knowledge of concepts from their everyday experiences and unfamiliar technical labels. Such references to everyday labels helped ESL students interpret written and oral texts and helped them in their construction of scientific explanations.

**Supporting the construction of taxonomies and ways of reasoning**

The findings of this study indicate that science learning involves in large part the construction of taxonomies and ways of scientific reasoning. Many teachers do teach
concepts by comparing and contrasting concepts in taxonomies and they often use everyday words such as "essential" to trigger scientific ways of reasoning such as structure-function and cause-effect relationships. However, most teachers (as was the teacher in this study) are unaware of how they are using discourse in their teaching. They are also unaware of how discourse is used by students to construct scientific understandings. Hence there is a need for teachers to become more aware of how they use discourse during teaching to construct taxonomies and ways of scientific reasoning, and how their students learn to construct scientific understandings through such discourse. Such a reflective awareness may help them select teaching and learning strategies and illustrative exemplars that support the construction of taxonomies and ways of scientific reasoning, thereby supporting students’ learning of science concepts.

At the senior grade levels, it may also be beneficial to provide students with a basic awareness of scientific ways of reasoning through examples of written texts. This strategy could support them in constructing scientific ways of reasoning. The use of peer mediation is another strategy that could be used to support ESL students’ interpretation of written text and construction of scientific explanations (as illustrated in this study).

Enhancing Science Learning using Structured Small Group Work

Although small group work has been advocated and implemented as a way to enhance science learning (Mauro & Cohen, 1992; Stockton, 1992), the findings of this study suggest that the use of small group work in secondary science classrooms is not, in itself a solution for some of the problems faced by ESL learners. This caveat is also echoed by
Bianchini (1999). The findings of her study showed that despite an explicitly designed instructional strategy and curriculum, student differences in participation and achievement remained.

While small group work provided students with opportunities to elicit support for language and science learning from more knowledgeable peers (as illustrated in the previous chapter), some ESL students in the study indicated that group work was not always constructive. A limitation of group work was the tendency for students to go off task. Many students also stated that time constraints resulted in students' copying work rather than discussing and sharing information. Also, time constraints meant that there was little opportunity for sharing among groups and consolidation of work. Some students made the following suggestions about how to improve upon and benefit from group work. Steve proposed:

We should have individual groups doing the work and then in the end we share it as a class so everybody has information together. [Steve, interview]

Steve is suggesting oral presentations as a way for all students to share information discussed within groups. His comments indicate that whole-class discussion after small group work would be beneficial to synthesise and consolidate knowledge. This suggestion is supported by the findings of Crawford, Kelly and Brown (2000). Their study revealed that whole-class discussions have the potential to add to the effectiveness of small group work.
Another student, Joe felt more comfortable working with peers. He found group work more beneficial than teacher explanations because:

if you miss something it's so hard to catch up on it. So you end up asking your friend but you didn't [sic] really want to do that because he's busy concentrating. [Joe, interview]

Joe therefore felt that a review at the end of the lesson involving groups of students discussing what they had not understood would be beneficial in learning science. He elaborated on how this strategy could work in practice:

[the teacher could say] you guys go into your little groups of four or something and explain something that you don't understand. And if all four of you guys can't really understand it, then all four of you guys go ask him and try and let him explain it. [Joe, final interview]

Small group work was therefore recommended to review and assess student understanding at the end of a lesson.

A significant issue emerging from the above comments is that small group work should be carefully structured around the purpose of the task and time constraints to optimise benefits for student learning. In this regard, Johnson and Johnson (1990) maintain that simply placing students in groups and telling them to work together does not enhance learning.
They assert that learning is enhanced in small groups when teachers structure and promote: 1. face-to-face interactions (e.g., students challenging each other's reasoning), 2. positive interdependence (e.g., students coordinate efforts to complete tasks), 3. personal responsibility (e.g., contributing one's efforts to accomplish the group's goals), 4. interpersonal skills (e.g., cooperation skills) and 5. reflection of group sessions (e.g., describe actions that were helpful or unhelpful). Research findings in science education also show that small group work involving collaborative reasoning and arguing supported science learning (Jones & Carter, 1994; Mason, 1998; Rivard & Straw; 2000). The findings of this study support the contention that small group work involving ESL students and more proficient English speakers supported English language learning.

**Using Multiple Semiotic Representations to Construct Meanings**

The results of this study showed that using multiple semiotic representations (e.g., oral, visual and written information) supported students' constructing meanings of scientific concepts. This is consistent with Lemke's (1998) views about the construction of meanings — that the union of meanings derived from different semiotic representations, constitute the meaning of the concept. The implication of this finding for classroom practice is that a variety of semiotic representations should be used to illustrate a concept.

In this study, verbal explanations that were supplemented by written summaries and visual illustrations appeared particularly helpful to ESL students with limited English language proficiency. The implication of this finding for classroom practice is that teachers should use both oral and visual teaching representations such as verbal analogies,
demonstrations, and written summaries to provide ESL students with situational and linguistic cues to meaning.

**Accessing Prior Conceptual Knowledge in the First Language**

While prior knowledge of concepts in the first language does not necessarily enhance the learning of concepts in the second language (as illustrated by the vignette, "Sal's understanding of lobes"), evidence also shows that some students may know the meanings of science concepts in their first languages but be unfamiliar with the English scientific label. In the vignette, "Shen's understanding of dentine", science terms were translated into Chinese and explained in Chinese in previous science classes. This practice has significant implications for ESL students learning science, especially when references are made to pre-requisite concepts taught in previous grades. Teachers cannot assume that students who have been taught science in other countries are familiar with the English label for the concept. Also, teachers cannot assume that inadequate responses in English are indicative of a lack of understanding of the science concept.

Lai, Lucas and Burke (1995) suggest that under certain circumstances (e.g., using specially prepared materials or ESL support teachers), the concept label in the first language should be introduced before introducing the English language equivalent. This strategy provides students with opportunities to access their prior knowledge of science concepts in their first languages and use that knowledge to mediate the construction of meanings in the second language. While this strategy may be appropriate where a number of students speak the same first language and an ESL support teacher is present, this strategy may not be
logistically feasible in multicultural classrooms. In mainstream science classrooms, references to pre-requisite scientific terms and concepts should be accompanied by an exploration of the underlying conceptual meanings (in English) to help students make connections between scientific terms and conceptual meanings already encountered in the first language.

IV. Implications for Teacher Education

Pre-service and in-service science teachers are faced with increasing numbers of ESL students in secondary science classrooms. Many in-service teachers report that they are uncertain about how to teach ESL students (Naylor, 1994). To alleviate the sense of uncertainty about ESL students, pre-service and in-service teachers need to become aware of possible issues influencing ESL students’ participation and learning of academic content. For example, science education courses in Teacher Education programmes and in-service teacher workshops could explore issues such as socio-cultural factors and language aspects (e.g., morphology, using everyday language in formal style) to raise awareness of the social and language issues facing ESL students during science learning in mainstream classrooms. The findings of this study provide insights into the learning experiences of ESL students and offer practical examples and suggestions that may be used by teachers to enhance both language and science learning.

The findings of this study may also be used to dispel the notion that language teaching is not a significant aspect of science teaching. Biology teachers, in particular need
to be aware that talking about language and teaching language are integral aspects of biology teaching and learning. This study offers exemplars of how an experienced teacher incorporates language aspects during the teaching of biology terms and concepts and can be used to illustrate the role of language in science teaching and learning. These exemplars may also be used as case studies in teacher education programs to raise awareness about the skilful language teaching that goes on in a biology classroom.

The notion that teaching and learning science terms and concepts is not simply learning the meaning of a word for a thing also has significant implications for how science is taught in schools. Many pre-service and in-service teachers holding the traditional view that teaching science concepts involves teaching the meaning of a label for a thing/process, may be using the traditional teaching method of pointing to the thing and describing/defining it. If teachers are to teach concepts as more than labels for things/processes, then they should be aware of the role of language in the construction of scientific knowledge.

Raising awareness about current notions about the role of language in the construction of scientific knowledge implies that current models such as the functional model of language proposed in this thesis should be critically examined in relation to science teaching and learning. For example, this study provides concrete examples of teaching science using multiple semiotic representations, constructing taxonomies, and constructing ways of scientific reasoning. Such vignettes could be used in pre- and in-service teacher workshops to stimulate critical discussion and the development of specific teaching and learning strategies consistent for classroom practice.
V. Further Research

There are two areas that are worthy of further research. Studies in these areas would contribute to and support current findings and extend the literature to promote more generalizable conclusions.

Studies of Different ESL Student Populations

This study was conducted in an urban multicultural high school in Vancouver. The ESL student population in the study was pre-dominantly Chinese speaking. Hence, socio-cultural factors and language experiences reported in this study were reflective of this distinct ESL student population and do not necessarily reflect the range of factors that interact with ESL students from other cultural groups or communities. Duran et al. (1998) reported on the language related experiences of Spanish speaking students during science learning outside the classroom. Their study does not focus on socio-cultural and affective factors interacting with science learning in classrooms. There is therefore a need for further research to provide insights into the socio-cultural, affective and language aspects interacting with the science learning of ESL students’ of different linguistic and cultural backgrounds in different communities.

Studies in Different Academic Contexts

The few studies that have investigated ESL students’ learning in secondary school science have been conducted in Biology (Duran, Dugan & Weffer, 1998; Lai, Lucas & Burke, 1995). There is also a need for studies to provide insights on ESL students’ learning
difficulties in other secondary science subjects like chemistry, physics and mathematics. It would also be interesting to explore the functional model of language in relation to these other subjects and find areas of similarities and differences. Such comparisons could lead to a more general model of language applicable to all subjects.

Studies in different academic contexts would also contribute to a database of ESL students’ learning experiences in secondary science subjects. This database could serve as a resource for teachers and teacher educators. Furthermore, such a body of research may also contribute to recommendations and suggestions regarding educational reforms for ethnocultural and linguistic minorities.
REFERENCES


Language Arts, 67, 567-575.


Rutherford, M. (1993). The RADMASTE centre: Some linguistic aspects for material production for Pre- and In-service teacher education. *SAMEpapers, 139-147*


Shapiro, B.L. (1989). What children bring to light: Giving high status to learners' views and actions in science. *Science Education, 73*(6), 711-733


Wong-Fillmore, (1986). Research Currents: Equity or excellence. Language Arts, 63, 474-481.


APPENDIX 1: INTERVIEW QUESTIONS - PILOT STUDY

Biographical Details: (filled out by interviewer at the beginning of the interview)

Name: ......................... Age: ........ Grade: .......

Male/female: ........ First Language: ..............

Language spoken at home: ..........

Family members: ............

Brothers and sisters at school: ...........

Previous schooling: ..............

Medium of instruction in science: ...........

Year of arrival in Canada: ..............

Year enrolled at the school: ............. grade level ...........

Number of years in the ESL program: ..............

Number of years in transitional science: ...........

Number of years in regular science: ............

Current courses: ......................

The following represent some of the questions that students were asked during the semi-structured interview.

Personal Factors:

1. What do you want to be when you leave school?

2. What do your parents want you to be when you leave school?

3. How do you feel about school?
4. How do you get along with your classmates?
   Who are your friends and whom do you study with?
   How do you feel about speaking your first language at school?

Learning Science:

1. Why did you choose science?
2. Do you like science? Why?
3. Will you be taking science next year? Explain?
4. Why do you think we should learn science?
5. What do you think science is?
6. How do you think students learn?
7. How do you learn science concepts?
8. What do you find difficult about learning science? Give me a specific example?
9. In what ways do your friends help you in science?

Learning Specific Concept/Topic:

1. Have you heard the word (i.e., specific science concept) being used before?
   Explain when and where?
2. If you have not heard the word before, what do you think of when you hear the word?
3. What do you associate with the word or topic?
4. What is your understanding of the word/topic?
5. What word/s are used in your first language to refer to the concept?

6. If you translate the word into your language, what word would you use?

7. What does the word mean in your first language?

8. Does the word in your first language have other meanings? Explain?

Language Use:

1. When a teacher mentions a new word in English, how do you try to understand what it means?

2. Do you find it easy to follow your teacher when he/she explains a concept? Elaborate?

3. Do you find it easy to follow your friends when they talk to you? Explain?

4. What strategies do you think would help you grasp the meanings of words and sentences in science more easily?
APPENDIX 2: STUDENTS' WRITTEN RESPONSES AFTER LESSONS

Name: ____________  Date: ______________

The main points I learned from today's lesson are: (points or diagrams or paragraph).

Some words, definitions, problems, experiments, explanations I still don't understand or would like explained again are:
APPENDIX 3: BACKGROUND INFORMATION

Name: ___________________________  Age: _________

In order to understand and enhance your learning in biology, we would like to know a little about your background and your previous learning experiences.

Language(s) spoken by you ___________________________

Language(s) spoken at home ___________________________

In which country were you born? ___________________________

In which country were your parents born? ___________________________

In which year did you arrive in Canada? ___________________________

Did you speak any English before coming to Canada? Explain?

________________________________________________________________________

________________________________________________________________________

What grade were you placed in? ___________________________

What kind of classes/program did you attend to learn English? Explain?

________________________________________________________________________

________________________________________________________________________

How many years have you spent in the ESL program? ___________

How many months/years have you spent in transitional science?

________________________________________________________________________
What aspect(s) of science do you find difficult to learn? Explain?

Some people find new concepts in science difficult to learn. What helps you the most in understanding new concepts and words?

Is there anything else about your background that you think influences your learning in science?
APPENDIX 4: REVISED INTERVIEW PROTOCOL

The following represent some of the questions that students will be asked in the initial semi-structured interviews.

Education and Language Histories: (To clarify written responses about background information where necessary)

What is your first language?

What language do you use to speak to your parents?

In what language were you taught science in your previous country?

How many years were you in an English Second Language Program?

Was science part of the ESL program? Explain?

Describe how you felt learning science in a Second Language?

Was it difficult learning science concepts when you did not know how to speak English?

What were some difficulties that you experienced while learning science? Explain with a specific example.

Affective Factors:

Do you like school?

What do you like most about school?

Do you try to do well at school? Why is this?

What do you want to be when you leave school?

What do your parents want you to be when you leave school?
Who do you study with in class, in school, at home?

How do you feel about speaking your first language at school?

Do you speak your first language in class? If yes, when and for what reason?

Conceptions of Learning:

What is the best way for you to learn something new? Give me an example?

Do you think about how you learn?

What do you think learning in a classroom involves?

What do you think your role should be during "learning"? Is it? Is it not? Why?

What should the teacher's role be?

What is the role of other students during learning?

Could you explain what you think learning is?

What do you think "to learn" means?

Participation:

How often do you ask questions in class?

When do you ask questions in class? In which situations?

What do these questions relate to?

How often do you answer questions in class?

When do you answer questions?

How often do you participate in class discussions? Elaborate?

What do you do when you don't understand something in class?

Do you ask the teacher for help if you don't understand something?

When do you ask for help? How often do you ask for help?
Do you pay attention during lessons? How much of the time?

**Learning Science/Biology:**

Why did you choose biology over chem, physics, science and technology?

Are you taking any other science courses?

Which of the sciences do you like? Why?

Will you be taking any sciences next year? Why? Why not?

Why do you think we should learn science?

What do you think science is?

How well are you doing in this class?

Do you think you could do better?

What does the teacher expect you to do in order to do well in this class?

What do you find difficult about learning biology? Give me a specific example?

In what ways do your friends help you learn biology?

Do you try to see how different parts of biology relate to each other?

What teaching/learning methods do you like best? Why?

What teaching/learning methods help you learn new concepts best? Explain how?

**Language:**

When a teacher mentions a new word in English, how do you try to understand what it means?

What strategies used by your teacher help you grasp the meanings of new words in science more easily?

Do you use a dictionary in class? If yes, what kind?
When you read the textbook, how do you try to understand what new words mean?

Do you find it easy to understand your friends when they explain to you? Why? /Why not?

The following represent some questions that students will be asked in the final interview.

Do you think it is important for students to talk about learning?

Did talking about your learning experiences help you in any way?

Do you think your participation in lessons has changed during the course of the year?

In what way/s has the manner in which you participated in class changed during the course of the year?

Has this change been beneficial to you? In what ways?

Do you think the researcher's presence affected your participation in any way?

Do you think your fellow students have changed in the way they participate in class?

Have you noticed any changes in how your teacher has taught lessons during the course of the project? Give me some specific examples?

How have these changes influenced your learning? Explain?

What do you think still needs to be changed in order to assist you in understanding new concepts?
The following represent some of the questions that students will be asked about critical incidents in short recall sessions.

**Personal Understandings and Language Related Aspects:**

Have you heard the word/concept being used before? Explain when and where? Was it in another science class, TV, aquarium, science world, and book?

If you have not heard the word/concept before, what do you think of when you hear the word/concept?

Could you explain what you think the word/concept means?

If you translate the word/concept into your first language, what word would you use?

What does that word/concept mean in your first language?

In what ways is the meaning of the word in your first language similar or different from the meaning of the English word?

**Learning and Teaching Strategies:**

What do you think your teacher was trying to explain about the concept?

What strategies helped you gain an understanding of those ideas?

What do you think may have helped you gain a better understanding of the concept?
APPENDIX 5 - PARENT CONSENT FORM

Dear Parent or Guardian,

I am seeking permission for your child to participate in a research project entitled Language and Participation: Learning in a Secondary Science Classroom. I will be conducting this project with the assistance of a doctoral student from the University of British Columbia, Ms. Kamini Jaipal.

The purpose of this study is to increase our understanding of how students from diverse backgrounds learn science concepts. We hope that as students reflect on their learning, this will help them improve their learning practices in science. Student feedback will also assist me in developing instructional strategies that address the needs of all students in this class.

The project will involve making audio and videotapes of classroom lessons and interviewing selected students. Two interviews will be approximately forty-five minutes in length. A further six discussion sessions of ten-minute duration will be scheduled at the convenience of the student during the course of the year. Some of the data collected for this study will be used for a master's and a doctoral theses by myself and Ms. Jaipal under the direction of our faculty advisor, Dr. Gaalen Erickson.

The identity of all students participating in this project will be kept strictly confidential. Written reports will identify students and the school by code names. Only the researchers involved in this study will hear or view audio - and videotape data. Participation or non-participation in the project will not affect your child's grade.
LANGUAGE AND PARTICIPATION: LEARNING IN A SECONDARY SCIENCE CLASSROOM

PARENT/GUARDIAN CONSENT FORM

Please check one of the statements below. Sign and return the form.

I have received and read a copy of the consent letter for the study entitled Language and Participation: Learning in a Secondary Science Classroom.

Name of Child ______________________

_______ I CONSENT to my child's participation in the study described in the letter.

_______ I DO NOT CONSENT to my child's participation in the study described in the letter.

Name of Parent (please print) ________________________________

Signature of Parent ________________________________________

Date ________________________________
Dear Student,

Students in your biology class are being asked to take part in a research project entitled *Language and Participation: Learning in a Secondary Science Classroom*. I will be conducting this project with the assistance of a graduate student from the University of British Columbia, Ms. Kamini Jaipal.

The purpose of this study is to increase our understanding of how students from diverse backgrounds learn science concepts. We hope that as students reflect on their learning, this will help them improve their learning practices in science. Student feedback will also assist me in developing instructional strategies that address the needs of all students in this class.

The project will involve making audio and video tapes of classroom lessons and conducting interviews with selected students. Two interviews will be approximately forty-five minutes in length. A further six discussion sessions of ten-minute duration will be scheduled at the convenience of the student during the course of the year. Some of the data collected for this study will be used for a Master's and a Doctoral theses by myself and Ms. Jaipal respectively under the direction of our faculty advisor, Dr. Gaalen Erickson.

The identity of all students participating in this project will be kept strictly confidential. Written reports will identify students and the school by code names. Only the researchers involved in this study will hear or view audio and video tape data. Participation or non-participation in the project will not affect your grade.
STUDENT CONSENT FORM

Please check one of the statements below. Sign and return the form.

I have received and read a copy of the consent letter for the study entitled Language and Participation: Learning in a Secondary Science Classroom.

_____ I AGREE to participate in the study described in the letter.

_____ I DO NOT AGREE to participate in the study described in the letter.

Name of Student (please print) ________________________________

Signature of Student _______________________________________

Date __________________________
## APPENDIX 7 - LOG OF CLASSROOM OBSERVATIONS

<table>
<thead>
<tr>
<th>DATE</th>
<th>DETAILS OF OBSERVATIONS</th>
<th>FIELD NOTES</th>
<th>AUDIO</th>
<th>VIDEO</th>
</tr>
</thead>
<tbody>
<tr>
<td>14/09</td>
<td>First field trip.</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>21/09</td>
<td>Learning strategies, unity/diversity</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>23/09</td>
<td>Unity/diversity, environment</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>27/09</td>
<td>Learning, interactions</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>28/09</td>
<td>Structure/function, adaptation</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>30/09</td>
<td>Field trip to Trout Lake</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>04/10</td>
<td>Test on Ch 1.</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>07/10</td>
<td>Review of test, scientific method</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>14/10</td>
<td>Ch 3, levels of organization, group work.</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>18/10</td>
<td>Quiz, review quiz, Field notes, cause @ effect.</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>19/10</td>
<td>Instructions for reading assignment,</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>introduction to Classification.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/10</td>
<td>Reading assignment - group work.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Date</td>
<td>Event Description</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01/11</td>
<td>Classification - dichotomous key.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>04/11</td>
<td>Classification Lab cont. Group work.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08/11</td>
<td>Quiz, complete lab.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>09/11</td>
<td>Test, handing out consent forms.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15/11</td>
<td>World Views, Theories of Evolution.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16/11</td>
<td>Theories of Change</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18/11</td>
<td>Evidences of Evolution, Fossil (Elephant) lab, group work.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22/11</td>
<td>Review of Elephant lab and graph.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23/11</td>
<td>Review of graph. Evolution of Barbellus Lab. Group work</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30/11</td>
<td>Completes Evolution.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27/01</td>
<td>Test on evolution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31/01</td>
<td>Table 18.1 @ 18.2, Taxonomy of Monerans, reproduction.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01/02</td>
<td>Monerans, Reproduction and Homeostasis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Activity</td>
<td>03/02</td>
<td>07/02</td>
<td>08/02</td>
</tr>
<tr>
<td>-------</td>
<td>---------------------------------------------------------------------------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>03/02</td>
<td>Quiz, participation marks, Defences</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>07/02</td>
<td>Discussion of science articles. Group work.</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sterile techniques - demonstration.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08/02</td>
<td>Lab on Bacteria—demonstration and group work.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>10/02</td>
<td>Lab on Bacteria. Group Work.</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>14/02</td>
<td>Editing - group work. Antibiotic Lab.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>17/02</td>
<td>Review of questions on worksheets, bacteria.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>21/02</td>
<td>Test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22/02</td>
<td>Protists, Video</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>24/02</td>
<td>Protists - Lab, Homeostasis</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>28/02</td>
<td>Microscope, Group work</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>01/03</td>
<td>Review of Test. Preview of Protist lab</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>03/03</td>
<td>Lab on Protists</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>29/03</td>
<td>Instructions for aquarium fieldtrip. Kingdom Animalia</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>31/03</td>
<td>Fieldtrip to aquarium</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Date</td>
<td>Activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------------------------------------------------</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>4/04</td>
<td>Classification of Animalia</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>5/04</td>
<td>Completion of fieldtrip reports. Coelom.</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/04</td>
<td>Lab - earthworm dissection-demonstration and group work</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>11/04</td>
<td>Lab - crayfish/grasshopper dissection-demonstration and group work</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>12/04</td>
<td>Invertebrates. Groups working on worksheets.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>18/04</td>
<td>Quiz. Completion of grasshopper lab.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>19/04</td>
<td>Insects - group work.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>20/04</td>
<td>Test on Invertebrates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/04</td>
<td>Introduction to Vertebrates</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>02/05</td>
<td>Circulatory systems</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>03/05</td>
<td>Quiz. Digestive system.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>05/05</td>
<td>Frog/Rat dissection lab. Demonstration and group work</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>09/05</td>
<td>Comparison of Frog and Rat - group work</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>10/05</td>
<td>Digestion. Nervous system.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Topic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------------------------------</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>12/05</td>
<td>Pre-test Questions. Test on Vertebrates.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>16/05</td>
<td>Introduction to Plants. Research on Plants.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>17/05</td>
<td>Characteristics of Plants.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>19/05</td>
<td>Plant taxonomy and adaptation.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>23/05</td>
<td>Quiz. Adaptation.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>24/05</td>
<td>Discussion of quiz and plant research projects. Plant life cycles - Alternation of generation.</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>