How Role Play Addresses the Difficulties Students Perceive when Writing Reflectively about the Concepts They are Learning in Science

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A thesis submitted to The University of Western Sydney in partial fulfillment of the requirements for the degree of Master of Education (Hons)

December, 2007

Acknowledgments

There are a number of individuals who contributed to this thesis through their moral support, advice and participation.

I am indebted to Associate-Professor Wayne Sawyer for his advice, patience and support throughout the years of my candidature. He opened my mind to a range of issues related to reflective writing in Science and it has been a privilege to have worked with him.

My appreciation is extended to the parents and students who contributed to this investigation and for their kind permission to participate in the study and their cooperation throughout the investigation.

I would like to express my thanks to Gabi Diugu who edited the text with such care and to Claudia Ford who formatted it with meticulous attention to detail.

Finally I would like to thank my family for their continuous support and encouragement over the years of my candidature. In particular, I dedicate this thesis to my husband, David.
Statement of Authentication

The work presented in this thesis is, to the best of my knowledge and belief, original, except as acknowledged in the text. I hereby declare that I have not submitted this material, either in whole or in part, for a degree at this or any other institution.

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(Susan Millar)
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ABSTRACT

A fundamental problem which confronts Science teachers is the difficulty many students experience in the construction, understanding and remembering of concepts. This is more likely to occur when teachers adhere to a Transmission model of teaching and learning, and fail to provide students with opportunities to construct their own learning. Social construction, followed by individual reflective writing, enables students to construct their own understanding of concepts and effectively promotes deep learning. This method of constructing knowledge in the classroom is often overlooked by teachers as they either have no knowledge of it, or do not know how to appropriate it for successful teaching in Science.

This study identifies the difficulties which students often experience when writing reflectively and offers solutions which are likely to reduce these difficulties. These solutions, and the use of reflective writing itself, challenge the ideology of the Sydney Genre School, which forms the basis of the attempt to deal with literacy in the NSW Science Syllabus. The findings of this investigation support the concept of literacy as the ability to use oral and written language, reading and listening to construct meaning. The investigation demonstrates how structured discussion, role play and reflective writing can be used to this end. While the Sydney Genre School methodology focuses on the structure of genre as a prerequisite for understanding concepts in Science, the findings of this study demonstrate that students can use their own words to discuss and write reflectively as they construct scientific concepts for themselves.

Social construction and reflective writing can contribute to the construction of concepts and the development of metacognition in Science. However, students often experience difficulties when writing reflectively about scientific concepts they are learning. In this investigation, students identified these difficulties as an inability to understand, remember and think about a concept and to plan the sequence of their reflective writing. This study was undertaken in four different classes at junior to senior levels. The difficulties
identified by students were successfully addressed by role play and the activities that are integral to it. These include physical or kinaesthetic activity, social construction, the use of drawing, diagrams and text, and the provision of a concrete model of the concept. Through the enactment effect, kinaesthetic activity enables students to automatically remember and visualise concepts, whilst visual stimuli and social construction provide opportunities for students to both visualise and verbalise concepts. In addition, the provision of a concrete model enables most students to visualise and understand abstract concepts to some extent. These activities, embedded in role play, enable students to understand, remember, sequence and think about a concept as they engage in reflective writing. This, in turn, enhances understanding and memory.

Role play has hitherto been regarded as a useful teaching technique when dealing with very young students. This study demonstrates that role play can be highly effective when teaching Science at the secondary level. This investigation looks at the activities embedded in role play, and demonstrates how they can be effectively translated from theoretical constructs into classroom practice.

Grounded theory (Glaser and Strauss, 1967; Glaser, 1978; 1998; 2002) was selected as the most appropriate methodology for this investigation. The problems of identifying and controlling variables in an educational setting were essentially resolved using this qualitative, interpretative approach. Students from four classes in Years 8, 10 and 11 were investigated. Data were gathered using classroom observations, informal interviews, and formal written interviews, focus group conversations and samples of student writing.
CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

1.1.1 Andrew’s Story

Andrew was seventeen. He was studying Year 11 Biology. After several months he was able to remember only a small amount of fragmented information about the topics he had studied. One topic he remembered covering was transpiration in plants. As Andrew described it, during the lesson on transpiration his teacher placed written notes on an overhead for the class to copy. A worksheet with questions to be answered from the copied text followed. Practical activities, including observations of the process of transpiration in plants, were later carried out by the students. At the end of this learning sequence Andrew was able to remember only very small, fragmented pieces of information about plant transpiration. He had not acquired the understanding necessary for any reflective writing about the concept. He did not know where to begin, he did not know what to sequence, he could not remember the technical vocabulary, nor could he understand or remember enough to write reflectively about transpiration. In his first
Biology examination he scored seventeen per cent. Such difficulties were not new to Andrew. Over his years at secondary school he had developed a reputation as a difficult and problematic student with his teachers. His parents dreaded parent-teacher nights as complaints about his laziness and ineptitude resonated with their desperation and Andrew’s own despair about his schooling.

1.1.2 Louisa’s Story
Louisa was a Year 8 student. Like Andrew she had little comprehension of the concepts presented to her in her Science class. When information was presented orally, Louisa experienced it as being “like listening to a poorly tuned radio station”. She grasped snippets of information. Her teacher usually displayed written notes on the overhead for the class to copy into their books. After completing this exercise, Louisa was able to remember very little. Her test results ranged between twenty-five and thirty per cent, while the class average was around sixty-five per cent. Writing reflectively about scientific concepts was outside her capabilities. She had a widely held reputation amongst her teachers as a dull and sometimes difficult student whose concerned mother represented her most significant problem. Louisa’s mother had frequently approached the school about Louisa’s difficulties. Her concern was viewed as interference.

1.1.3 Kate’s Story
Kate was a different type of learner. She was a bright, keen Year 8 student who enjoyed Science classes. Her examination results were always around eighty-five per cent, well above the form average. She worked well with secondary sources to present reports about scientific phenomena such as plant structure and function, without recourse to plagiarism. However she was reluctant to reflect and write about concepts in Science. She did not feel confident that she could express herself adequately. She did not know where to begin or what to write next. She complained that it was hard to know what to write, even when she understood the concept after it had been discussed in class, and she had completed diagrams and worksheets. For Kate, learning was rote learning. She said that, in order to learn her work, she needed the teacher to provide her with the correct notes, which she
could read over to ensure she understood them. Then she would rote learn them at home until she felt confident that she could do well in the test.

1.1.4 Andrew’s Learning Experience

Unlike Andrew and Louisa, who experienced learning difficulties in Science classes, Kate represents students who manage well in Science but have failed to process and integrate scientific concepts into their prior learning. Without this they do not gain the depth of understanding that enables them to write reflectively about the concepts they are studying. For each of these students the teaching methodology in their classrooms had been based on a Transmission model of teaching. In Transmission teaching, commonly referred to as “chalk and talk” the teacher delivers information to the students as lectures or notes to be copied, memorised and repeated back in an assessment (Barnes, 1976: 140). At no stage are students involved in the construction of their own learning. Students write primarily for assessment or to copy notes into their books (Halliday and Martin, 1993: 201; Prain, 1995: 62; Yore, Bisanz and Hand, 2003: 711). Neither Andrew nor Louisa had been able to respond to this approach.

I met Andrew half way through the second term of Year 11. Although Andrew excelled at the sports he played, he was very anxious and angry about his schoolwork. Over his years at school his difficulties with learning had resulted in some “acting out” at school. His average mark in Biology tests was nineteen per cent, and his parents, after years of anxiety about his schooling, were beside themselves about his prospects in the HSC\(^1\) and his future. Andrew had little understanding of the concepts he was studying in Biology and he smiled wryly at the thought that he might write about them himself when it was suggested. He had never attempted to write reflectively about concepts in Biology or written anything that was not copied from the teacher’s notes.

In this investigation reflective writing is utilized as a form of writing-to-learn. Students use reflective writing as part of the process of constructing conceptual meaning, and of

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\(^1\) HSC: Higher School Certificate, the final examination in secondary school education in New South Wales, Australia
becoming aware of their thinking. Reflective writing is defined as “an active process paying attention to process as much as product, grounded in the conviction that language is not just a means of encouraging literacy but the foundation of all learning” (College Entrance and Examination Board, 2003: 12). During reflective writing in Science classes, students express their own understanding of a scientific concept. To do this they must remember aspects of the concept, and express their thinking in a logical sequence. As writing is more succinct and demanding than speech, students are required to reflect on their thinking about concepts in order to express them in a written form. This contributes to the construction of meaning and the development of metacognition (Prain and Hand, 1998: 153). It is a different to approach to writing than the one adopted by the NSW Science Syllabus, which is derived from the theories of the Sydney Genre School. In this Science Syllabus, writing is viewed only as a means of communicating information, using particular genres that are claimed to be necessary for the construction of scientific concepts (Board of Studies NSW, 2003: 17; Halliday and Martin, 1993: 20).

In my teaching and for the purpose of this research I have chosen an Interpretation model of learning (Barnes, 1976: 140), in which teachers acknowledge that students must be actively involved in the construction of their own understanding and meaning. To achieve this, the teacher considers the cognitive level of each student and the prior knowledge and understanding that they bring to each lesson. The manner in which the teacher interacts with students demonstrates a respect for the students’ ability to contribute to discussion and learning.

The primary issue for Andrew was his inability to understand concepts sufficiently to be able to reflect upon them and record his understanding in writing. Because Andrew could not respond to the Transmission model of learning used by his Science teachers throughout his schooling, when working with him, in a one to one setting, I chose role play as a way to facilitate Interpretation learning. The role play was a pedagogical strategy to assist Andrew to construct conceptual understanding, using drawing, oral narrative, discussion, drama and kinaesthetic input, which includes the senses of touch, spatial orientation, pressure and movement. I hoped that this would provide opportunities
for engagement with the concept of transpiration that he was studying, and open
discussion with the teacher that would enable him to process the ideas and construct
meaning and understanding in his own terms.

At the beginning of the lesson Andrew had little understanding of the process of
transpiration except that it related to plants in some way. He was instructed to draw a
large, simple diagram of a plant, one metre long. He included the roots and root hairs, the
xylem rising from the roots to the leaves, and the stomates. Then he added the relevant
biological labels. As he drew, we talked about the way in which water entered the root
hairs by osmosis and traveled across the root cells to the xylem, and the various processes
by which it ascended the xylem and entered the leaves. We discussed how the stomates
worked and how water might evaporate from them. Next Andrew spread the diagram on
the floor and, pretending he was a water molecule, physically walked through the
diagram of the plant, explaining in detail what was happening to him as he went. When
he had emerged from a stomate he retold “his story” to me and had the opportunity to
further clarify aspects of the concept he did not understand. When he was satisfied, we
folded the drawing and put it away. I asked him to sit at the table and draw and label a
diagram of plant transpiration and write a paragraph explaining the process. For the first
time in his school career Andrew was able to draw a clearly labelled diagram of a
scientific concept, reflect on it and write a paragraph about it.

Andrew was very excited. In his next Biology test he scored eighty-two per cent. When I
interviewed his parents, they said that Andrew’s developing ability to learn effectively
had opened up discussion within the family about both his difficulties and their
recollections of similar difficulties at school. Andrew was motivated to learn, and this
influenced his family life in a positive way. He continued to learn how to use forms of
role play and reflective writing to learn concepts he found difficult. Andrew and his
family were delighted when, after receiving his HSC results, he was accepted into a
university course of his choice. Andrew went on to graduate and to lead a successful
professional life.
1.2 COGNITIVE DEVELOPMENT

1.2.1 The Research

In a recent report prepared for the Australian Department of Education, Science and Training (Goodrum and Rennie, 2007: iii) no consideration is given to the possibility that cognitive mismatch may contribute to the well documented difficulties that students experience when learning scientific concepts in secondary school (Goodrum, Hackling and Rennie, 2001).

According to research carried out by Shayer and Adey (1981), by the time students are fourteen the following variations will occur.

- Seventeen per cent of students will still be early concrete thinkers. They will be unable to use a concrete model, and will only partially understand simple cause and effect. They will be able to classify in a limited way, as their observations will focus on only one property of an object.

- Fifty-seven per cent of students will have reached late concrete operational thinking. They will be able to classify objects and describe their properties. They will be able to use simple concrete models that link one cause to one effect and demonstrate simple linear relationships. This bivariate thinking fails to account for interference from other variables.

- Seventeen per cent of students will have reached early formal operational thinking. They will begin to use multivariate data, understand more than 1:1 linear relationships and be able to relate multiple causes to an effect, and vice versa.

- Seven percent of students will have reached the stage of late formal operational thinking. At this stage they can think in abstractions, manipulate multivariate data, use probability, correlation and ratio and construct and use formal mathematical models.

(Shayer and Adey, 1981: 74)
1.2.2 Cognitive Development and Student Learning

In the school where this investigation took place each mixed ability junior Science class was selected after forty per cent of the most able students had been placed in faster classes. Therefore students who had reached the stages of formal operational thinking were unlikely to be in a mixed ability class. Approximately two-thirds of the students in a Year 9 mixed ability class would be expected to be late concrete operational thinkers, and up to one third would still be at the early concrete operational stage.

It is common for Year 9 students to study the characteristics of electrical circuits such as voltage, current and resistance which are all abstract concepts. Most students in a mixed ability class would have reached the early or late concrete operational stage of cognition. Students at the early concrete stage would have difficulty responding to a concrete model of these concepts but from it they may be able to develop an understanding that electrons move in a circuit, and pass energy around it. They would find it difficult to understand the differences between voltage, current and resistance. At the late concrete operational stage, using the concrete model presented in a role play, students would be able to respond to these abstract concepts. From the concrete model, they would be able to understand that moving electrons cause current in a circuit, electrons pass electrical energy around the circuit, and that resistance makes it harder for energy to be passed on. They would also understand simple 1:1 relationships such as: in a circuit if the voltage increases the current will increase, and if the resistance increases the current will decrease. Thus, students whose cognition has not developed to the level of formal operational thinking will experience difficulty in constructing and understanding many of the scientific concepts taught in Science classes. The concrete model provided by the role play, however, enabled these Year 9 students to construct a basic understanding of electrical energy (voltage), current and resistance.

According to Vygotsky (1987: 11) and Piaget (Gouge and Yates, 2002: 135) students can be helped to develop from one stage to the next by actively participating in their learning and reflecting on it, thus developing an awareness of their own thinking and learning
strategies. Structured group discussion provides social encounters in which students can construct concepts and then check and confirm their constructions (Vygotsky, 1978: 84). Such social encounters create an awareness of thinking and learning, and thus influence the development of cognition. Reflective writing also provides students with an opportunity to reflect as they remember, construct and organise the ideas to be expressed in a written form. Reflective writing helps students to become consciously aware of their understanding and thinking (Prain and Hand, 1998: 156) by providing extended opportunities for reflection. That is to say, as a means of reflection that promotes awareness of thinking and learning, reflective writing may also contribute to the development of cognition (Holliday, Yore and Alvermann, 1994: 885; Barnes and Todd, 1977: 202).

1.3 THE SIGNIFICANCE OF REFLECTIVE WRITING

1.3.1 Reflective Writing and Cognitive Development

The study of Science at secondary school is intellectually demanding for many students. There, Science quickly moves from concrete operational thinking with its reference to objects and simple causal relationships involving only two variables, to the multivariate relationships and greater levels of abstraction of formal operational thinking (McNally, 1977: 50). Because most scientific concepts involve various degrees of abstraction and multivariate thinking, students will experience difficulty understanding Science if they have not reached the formal operational level of cognition (Adey and Shayer, 1994: 165; Shayer and Adey, 1981: 137). Research by Shayer and Adey (1981) demonstrated that when students enter Year 7 at the age of twelve, only ten per cent are beginning to develop the characteristics of formal operational thinking. Therefore, if students are unable to develop this level of cognition during their early years at secondary school, they are likely to experience great difficulty in learning many scientific concepts (Adey and Shayer, 1994: 36).

There is a relationship between cognitive development and an awareness of one’s own thinking and learning strategies. Both evolve together (Adey and Shayer, 1994: 68). When students become more aware of their own thinking, their cognition develops, and
the converse also applies (Vygotsky, 1978: 208). Individuals develop an awareness of the strategies they use when they are thinking by reflecting on their own thinking, as well as the concepts they are learning. This awareness is referred to as metacognition (Adey and Shayer, 1994: 44). Metacognition and reflection drive cognitive development (Flavell, 1963: 263). Without these processes, which sometimes occur spontaneously, (Vygotsky, 1978: 174) student cognition will not develop. When students write reflectively, they must think about their own thinking and learning. As they write, they reflect on the concept they are learning – what they remember, how ideas must be sequenced, how accurately they have written about the concept, where there are gaps in their understanding, and the strategies they have used in their learning. Reflective writing such as this demonstrates the depth and clarity of a student’s knowledge of a concept. Although students may not, at first, be able to express the details of a concept in sufficient depth, reflective writing provides a good starting point for further discussion, reflection and clarification. Thus students can improve their understanding of concepts, become more aware of their thought processes, and develop metacognition. The involvement of students in metacognitive awareness of learning and thought processes then stimulates the development of their cognition.

In my classes I encouraged students to use reflective writing:

- to further construct concepts and integrate them into their prior knowledge
- to clarify ideas and express understanding
- to stimulate cognitive development through reflection about their thinking and learning

1.3.2 Reflective Writing - Difficulties Experienced by Students

Students’ reluctance to write in Science classes has been observed and discussed by researchers over the years. Sheeran and Barnes (1991: 107) observed that students “often perceived writing as an onerous task, to be got out of the way as quickly as possible, as part of the whole process of “getting through” the school day, and indeed the whole school system.” Britton, Burgess, Martin, McLeod and Rosen (1975: 24) considered that one of the most difficult language skills is to write reflectively when learning about new
concepts because, at this point, students are constructing new understandings, integrating and organising information for themselves, and attempting to express it in a particular form. They observed that students found this type of writing difficult (Britton et al, 1975: 19). Sheeran and Barnes (1991: 15) also observed the difficulties students experienced writing formally in Science when they were in the process of constructing new concepts. They wrote:

Pupils are grappling with several simultaneous demands
1. Trying to make sense of the subject matter and reorder it in a form that makes subjective sense.
2. Carrying out the teacher’s explicit requirements for content, genre, style and lay-out.
3. Intuiting the unspoken requirements of the task (i.e. the ground rules).
(Sheeran and Barnes, 1991: 15)

They suggested that rather than write in formal genres at this stage, students should write “expressively” for themselves as a way of clarifying and constructing meaning. Furthermore, they emphasized the need for students to use reflective and exploratory writing while learning concepts, therefore helping them to understand and to integrate new concepts into their own view of reality (Sheeran and Barnes, 1991: 13).

In another study, Rowell and Ebbers (2003: 12) noted the difficulty Year 6 students experienced in writing about the flight of birds after reading books about flight and discussing the concepts as a class. The students could describe flight orally and some could even explain it, but their understanding of the concept was superficial and therefore their ability to write about it reflectively was disappointing.

Sheeran and Barnes (1991: 110) noted that students frequently attempted to write without an adequate understanding of what was expected of them by the teacher. They suggested that students, whose parents were from professional backgrounds, were more likely to understand the “ground rules” of writing expected by teachers than those from lower socioeconomic groups who were more likely to be disadvantaged by a lack of understanding. This was also true for less able students (Sheeran and Barnes, 1991: 116).
Attempts to implement reflective writing in my own classes resulted in negative reactions from a significant number of students in each class. When the likely benefits to their learning were explained, students continued to express a reluctance to be involved. Like Kate and the students studying the flight of birds, students often appeared to understand the concepts they were learning, but, when asked to reflect and write about these concepts, they lacked the understanding and confidence to complete the task (Rowell and Ebbers, 2003). Students in my classes complained that writing was too difficult because they could only partially recall the concepts. They did not know how to begin and the information they could recall was difficult to sequence. Reflective writing was not what they expected to do in Science. For them, copying from the board and memorising were acceptable ways to learn, and they particularly wanted to avoid writing reflectively about scientific concepts because they found it difficult and frustrating.

At the beginning of each year I observed that classes were most comfortable with a Transmission model of teaching and learning. During their years at secondary school they had not learnt how the group discussion and reflective writing undertaken in Louisa and Kate’s classes might assist their learning since neither method had been carried out in their Science classes. The lack of recognition of reflective writing as a means to promote learning has been acknowledged since the 1970s when researchers first reported on the low quality and limited scope of written interaction in Science classrooms. Students in Science classes were observed to write mostly for assessment or to fill in worksheets (Barnes, 1976: 84; Sheeran and Barnes, 1991; Prain, 1995: 62; Yore, Bisanz and Hand, 2003: 711). Moreover, teachers tended to emphasise the importance of the “surface conventions” of writing such as spelling, punctuation and handwriting rather than the ability to organise ideas (Sheeran and Barnes, 1991: 3). Reflective writing has, in fact, not been observed very often in Science classrooms over the years. Bullock (1975: 68), in a British investigation of literacy in schools made this observation: “the validity of first hand experience and reflection in writing about science is generally ignored…. most students find writing difficult.” Over the years other researchers have repeated these initial observations, but little appears to have changed in the classroom (Durst and Newell, 1989: 381; Reaves, Flower and Jewell, 1993: 34; Halliday and Martin, 1993:
Teachers still tend to use writing only as a means to record facts or complete assessment tasks. According to the research carried out by Goodrum, Hackling and Rennie (2001: 85), the “chalk and talk” Transmission model continues to flourish in Science classrooms throughout Australia.

1.4 ROLE PLAY

1.4.1 Using Role Play – The Rationale

As a teacher I am curious about learning. As a Science teacher I am interested to know the particular forms of learning demanded by Science. Once I know this, I want to know how best as a teacher I can facilitate this learning process in the minds of students.

Stories like those of Andrew, Louisa and Kate are very familiar to me. Students, like Kate, who learn more easily than Andrew and Louisa, are often reluctant and lack the confidence to write reflectively about the scientific concepts they are learning. For students like Andrew and Louisa, who experience difficulties in learning in Science classes, the suggestion that they might write reflectively about these concepts is far beyond what they or their teachers expect them to achieve.

Prior to this investigation, in response to students’ perceptions that reflective writing was too difficult, I began to use role play. In this investigation role play is used to help students understand the abstract and multivariate concepts they frequently study in Science (Aubusson and Fogwill, 2006: 103). Each role play consists of a number of components in addition to the enactment of roles. Each role play has a story line which directs the enactment of the concept. As students plan the role play they participate in structured discussion in which they assume particular roles such as leader, reader and encourager to ensure that everyone in the group has an opportunity to contribute to the role play. During the enactment phase each student tells the story that relates to the part they are playing. The enactment itself automatically enables students to visualise and remember the concept as it is presented in the role play (Engelkamp 1998: 88:128). The process of role play allows students to experience a concept and this leads to the construction of understanding. Through the enactment of roles and the structured and
informal discussion between group members and the teacher that accompany it, students have the opportunity to clarify misconceptions by asking questions in small groups and class discussions structured for this purpose (Van Ments, 1999: 23; Aubusson and Fogwill, 2006: 101). Thus the role play used in this investigation does not refer only to a dramatic enactment but to a broader activity which also includes processes such as structured discussion, questioning, narrative, explanations, visualisation and reflection.

After taking part in a role play, students seem to have a better understanding of the concepts they are learning. Role play can provide a concrete model of abstract concepts such as the concepts of electrical energy, current and resistance studied by the Year 9 students. Role play also provides a structure for small group or class discussion enabling students to participate in the social construction of meaning. Structured groups were used in all the classes participating in this investigation. In a structured group, each group member assumes a role such as reader, organiser or encourager. These roles structure and stimulate participation and tend to prevent domination by one or other member of the group. The teacher circulates amongst the groups listening, clarifying misconceptions and asking open questions to stimulate thinking and the construction of meaning. Such collaborative learning promotes the social construction of knowledge through discussion (Vygotsky, 1987: 85). Meaning is constructed by testing, clarifying and explaining understanding amongst peers and the teacher. During this process students reflect about the concept and their own thinking and learning. Each student in a group may learn at a different level. By using structured group discussion, teaching and learning may be differentiated as students are able to discuss at their own level and have access to interaction with both their peers and the teacher.

1.4.2 Role Play - Louisa’s Learning Experiences

Louisa’s experiences at school were similar to Andrew’s. Although she generally experienced difficulty in learning at school she found Science particularly difficult to understand. In her Year 7 and 8 Science classes the teachers had adopted a Transmission style of teaching, which included lectures, copying from the board and overhead, writing notes from dictation, writing down and answering questions from the board and filling in
work sheets. The resulting notes were expected to be rote learned and reproduced in class tests. Louisa could not follow the lectures, and frequently did not understand the notes she had copied from the board. Most of her worksheets were incomplete, although she said that sometimes she copied from a friend. She felt very frustrated in class and was always nervous that the teacher would single her out to respond to a question she would be unable to answer. She often felt foolish and afraid of impending, although unintended, humiliation in the classroom.

When I first encountered her, Louisa was in a mixed ability Science class in Year 9 so, unlike for Andrew, the learning was not one-to-one. The class was learning about Electricity and, although students could construct a simple series circuit to turn on light bulbs, they were finding the concepts of voltage, current and resistance difficult to understand.

As in Andrew’s case, role play was used as a way to involve students in a physical depiction of the concepts. In addition to information from the kinaesthetic senses, the role play included oral narrative, discussion and drama, followed by individual reflective writing. This learning process was designed to help students construct and visualise the abstract, and therefore difficult, concepts of electrical energy (voltage), current and resistance. Through their participation in role play and reflective writing I wanted the students to begin to differentiate between the concepts of voltage (electrical energy), current and resistance. Their reflective writing would communicate their level of understanding of each concept and this information could be used to plan the following lesson.

The students began the lesson in structured groups in which they adopted roles such as drawer, labeler, and encourager. Using these roles the students drew, labelled and discussed the simple circuit they had constructed in the previous lesson. This circuit consisted of a power pack, leads, a light bulb and a switch. When they were satisfied that they understood the structure of the circuit, the role play was carried out to demonstrate
the function of voltage, current and resistance in the circuit. The role play was set up as follows:

- The students stood in a circle representing the conducting leads of the circuit.

- By attaching the label, “electron” to themselves, students took on the role of electrons in the circuit. As the electrons passed electrical energy around the circuit they represented the current in the circuit.

- A carton labelled “lamp” (resistor) stood on a stool about half way around the circuit. The carton had slits on either side so that electrical energy could be passed through into the “lamp”.

- The teacher was labelled “power pack” and held a supply of small pieces of coloured paper representing electrical energy.

During the role play the students, as electrons, represented the current in the circuit. They passed the electrical energy around the circuit. The current or number of electrons passing energy through the circuit was measured in Amps.

The teacher as the “power pack” provided electrical energy to the circuit when the switch was turned on. The electrical energy was measured in volts. She passed out the small pieces of coloured paper, representing bundles of electrical energy, to the electrons and they passed it on around the circuit. The electrical energy was all used up in the circuit. The resistor, or lamp in this case, used up most of the electrical energy and a small amount was changed into heat in the leads. When the electrical energy reached the “lamp”, which had most resistance in the circuit, it was more difficult for the electrons to pass the electrical energy along. Most of the electrical energy was transformed into light and heat energy in the lamp. A small amount of electrical energy passed through the carton but was used up in the conducting lead by the time it reached the other terminal of the power pack.
After the role play students were asked to pair up and explain this model of a circuit to one another to ensure that everyone had an opportunity to discuss and verbalise the concepts and ask for clarification if required.

Finally the students were asked to sit down, and to reflect and write about electrical energy, voltage, current and resistance. Louisa wrote:

What is electricity?
Electricity is passed around a circuit.
Electrical energy is measured in volts.
The electrons pass the energy around the circuit.
An electric current is made by electrons.
The electrically current is measured in Amps.
Resistance is when it makes it harder for the electricity to pass through.

Although this may seem a small achievement, Louisa was very excited. For the first time in a Science class she had been able to understand enough about the concepts she was learning to write reflectively about them. Later the following year, when I interviewed her parents, they considered this to be a turning point, both in Louisa’s learning and in her own view of herself as a learner. They, too, mentioned the positive influence this had on their family life. For Louisa, the role play had “made electricity come alive.” She could “see” what happened in a circuit and she could understand enough to begin to reflect on a scientific concept and record her understanding in writing. Her writing indicated that she had probably reached a concrete stage of cognition at which she could begin to interpret a concrete model of an abstract concept. Louisa’s case demonstrates why it is so important to present abstract concepts using a concrete model for students at her stage of cognition. I am not suggesting that Louisa’s learning difficulties were over, but she had made a beginning. Her attitude changed in Science and, during that year, her confidence increased and she did not question her ability to write reflectively about scientific concepts.

1.4.3 Kate’s Learning Experiences and Role Play
Kate, the third student being considered, had a different experience of learning in Science. Kate was in a Year 8 mixed ability class where, like many of her peers, she
appeared to be able to learn about concepts competently. In previous years she and the other students in her class had been used to a Transmission model of Science teaching, where the teacher presented students with the correct information, followed by worksheets and appropriate diagrams to colour and label. Students in the class, including Kate, expressed great reluctance and a lack of confidence when asked to write about the concepts they were studying in Science. For this reason a role play was used to help students construct meaning and understanding that could be further consolidated by reflective writing. The use of Transmission learning which provides no opportunity for social construction or reflective writing resulted in only a superficial understanding of the concepts. This became evident when students like Kate were presented with the cognitive challenges of reflective writing.

At the beginning of the year we were studying pollination. During the previous lesson students had dissected flowers and had identified and drawn the different parts. At the beginning of the lesson, two large diagrams of the cross section of a flower were hung on the board. The teacher used a “bee” on a stick to demonstrate the process of pollination, showing both cross-pollination and self-pollination. Because some students asked what happened to the pollen after it was caught on the stigma, fertilisation was also demonstrated. Students were able to ask questions throughout the demonstration.

Then the role play began. This was the first role play the students had carried out in Science.

- Students worked in structured groups of three. They were given ten minutes to draw and label a large, one metre diagram of a flower including the following: the stem, sepals, petals, anthers, pollen, stigma, style, ovaries and nectaries. In addition some groups labelled pollen tube, ovaries, and ovules.

- Then two groups combined their flower diagrams. They spread them on the floor so that they could walk into them. Again students worked in structured groups assuming the roles of the insect, encouragers, questioners, and coordinator. Each
student, in turn, pretended to be an insect. The insect entered the first flower to reach the nectaries.

- It then left the first flower and entered the second flower to feed from its nectaries.

- Each time the insect went in and out of a flower it brushed past anthers covered with pollen which it then transferred to the stigma.

- Pollen could move from the anthers of the first flower to its stigmas – self-pollination - or from the anthers of the first flower to the stigma of the second flower – cross-pollination.

- As each student role played an insect she told the story about what was happening between her and the parts of the flower.

- During each role play other members of the group listened carefully and discussed the process to clarify concepts. The role of every member of the group was to listen carefully to each “insect’s” narrative, to ensure that everyone in the group understood the process of pollination.

- The teacher moved from group to group listening to the stories and discussing the concepts with the students.

- The students knew that, at the end of the role play, they would be required to put their diagrams aside and reflect and write about pollination.

Kate wrote the following:

**Pollination**

Pollination is when pollen transfers from the anther to the stigma. This occurs when an animal, bird, bee or insect enters the flower to feed on the nectaries and when it enters, brushes past the anther and when it leaves transfers the pollen from the anther to the stigma.

Self pollination is when a plant pollinated themselves.

Cross pollination is when a plant gets its pollen from another flower.
Fertilisation is when pollen lands on the stigma and goes down the style and makes the pollen tube then reaches the ovary to make an ovule. That turns into a seed.

This was the first time Kate had written in this way in a Science class. In view of her initial reluctance to write, she was surprised and pleased with what she had been able to do so easily. The role play had enabled her to visualise the process of pollination. She said that she could go over pollination in her mind as she thought and wrote about it. She said she felt she understood it and could remember it.

When students write reflectively about a concept, their understanding may not be complete. However, the writing provides both the teacher and the student with information about each student’s level of understanding. This provides a starting point from which to plan the next group discussion or lesson. Reflective writing is a valuable example of assessment for learning, as it provides feedback which can be used to improve both teaching and learning (Black, Harrison, Lee, Marshall and Wiliam, 2003: 122).

1.4.4 Role Play – Observations and Questions

The role plays I discussed earlier were of two types:

- In the first, the students, like Andrew and Kate, drew a large diagram of the concept they were studying, added the technical labels, and then placed it on the floor. In turn, students became the central character of the concept and told their story as they walked through the diagram. Each student listened to the accounts of other members of the group, commenting on their accuracy and asking questions about areas of misunderstanding and confusion. The teacher’s role was to visit each group, listen to their interpretation of the concept, ask and respond to questions.

- In the second, students like Louisa similarly adopted the role of a central character within a scientific concept. During the role play students interacted with others and observed the role play. The teacher and the class discussed the
concept as it was played out. Students were asked to explain their role to other students and the teacher, and were encouraged to ask questions to clarify their conceptual understanding.

For most students, either of the role plays resulted in positive learning experiences, such as greater engagement and understanding. After each role play they were expected to reflect and write about the concept. There was rarely any reluctance expressed about writing reflectively at this stage and I was often asked if we could use role play more often. From my point of view, the results were intriguing, and feedback from both students and parents was encouraging.

Without role play students had perceived difficulties when asked to write reflectively in Science classes. Role play seemed to resolve these difficulties making it easier to write reflectively about the concepts they were studying in Science. These observations raised the following questions:

1. What are the difficulties students perceive when asked to write reflectively about the scientific concepts they are learning?

2. Can role play alleviate these perceived difficulties so that students experience less difficulty when writing reflectively about the concepts they are learning?

1.5 THE INVESTIGATION

1.5.1 The Aim of the Investigation

The questions I asked about reflective writing in my Science classes defined the substantive area as writing in Science classes. The substantive issue derived from that area has been defined as:

How role play addresses the difficulties students perceive when writing reflectively about the concepts they are learning in Science.

My aim has been to investigate this question in both junior and senior classes in a girls’ school, in order to provide data from a range of ages and levels of cognition. From the
data analysis, I have aimed to draw generalisations for female students over a range of age groups.

1.5.2 The Structure of the Investigation
The investigation of the substantive issue was carried out using Grounded Theory, a qualitative approach to research derived from Glaser and Strauss’s (1967) seminal work. Four mixed ability classes were investigated towards the beginning of the school year. In their previous years at high school, all the classes had experienced a Transmission approach to teaching and learning. The first sample was a Year 10 class in which students were studying mitosis. The second was a Year 8 class studying photosynthesis. The third sample was a Year 11 Physics class studying Astronomy and the fourth was the same Year 8 class, but this time learning about transpiration. Data were collected from lesson notes, informal conversations in class, formal written questionnaires, informal conversations in focus groups, and writing samples. The methodology derived from Grounded Theory is discussed in detail in Chapter 2.

There is a large body of research related to the substantive area. A selection of this research was reviewed before the investigation was carried out and is recorded in Chapter 3 under the heading, PART 1, INITIAL FINDINGS OF THE LITERATURE. The initial findings are discussed under the following headings in Chapter 3:

3.1 Relevant Learning Theory
3.1.1 The Influence of Piaget
3.1.2 The Influence of Vygotsky
3.2 How Learning Scientific Concepts, Cognition and Writing are Related
3.2.1 The Cognitive Demands of Secondary Science
3.2.2 Cognitive Development and Writing in Science
3.2.3 Second Generation Cognitive Science and Scientific Literacy
3.3 Writing-to-Learn
3.3.1 From Theory to Practice: Evaluation of Writing-to-Learn
During data analysis questions arose which required clarification. It is the practice when using Grounded Theory to return to the research literature as one means of resolving these questions. Information from the literature is then used as additional data. This literature was researched and is recorded in Chapter 3 under the heading, **PART 2, LITERATURE REVIEWED DURING THE INVESTIGATION.** This review of literature is discussed under the following headings:

3.5 Role Play
3.6 Learning Styles
3.7 Teaching Using the Kinaesthetic Modality
3.8 Imagery and Visualisation
3.9 The Nature of Memory
3.9.1 The Enactment Effect

Data from each class were analysed and compared. As a result of data analysis four hypotheses emerged and these contributed to the “emergent theory”. This provides an explanation of the substantive issue and suggests ways to resolve it in the classroom. The three hypotheses which emerged from the data analyses were as follows:

**Hypothesis 1**

Students perceive the following difficulties when writing reflectively in Science:

- not having access to diagrams, the textbook and correct information
- lack of technical terminology
- inability to spell the required words
- inability to construct understanding
- inability to think about the concept
• inability to remember the concept as a whole or in detail
• not knowing how to begin to write
• not knowing what to write

These problems largely result from a Transmission approach to teaching and learning.

**Hypothesis 2**
Interpretation learning, which includes role play, helps to overcome the difficulties listed in Hypothesis 1. In addition it diminishes the fear of failure and builds students’ confidence in their ability to learn.

**Hypothesis 3**
Role play is a form of interactive learning that allows the social construction of meaning through small group structured discussion. This enables students to verbalise a concept as it is clarified. The physical nature of role play also enables students to visualise a concept automatically through the enactment effect. Both help students to think about the concept and understand its sequence. Role play provides a concrete model of an abstract concept which enables students to visualise and understand such abstract concepts.

**Hypothesis 4**
Role play is a form of Interpretation learning that provides social construction through small group structured discussion. Structured discussion enables students to verbalise the concept as it is clarified. The physical nature of role play enables students to visualise and remember the concept automatically through the enactment effect. Visualisation and memory help students to think about the concept and understand it at various levels of detail. Role play provides a concrete model of an abstract concept, making it easier for students to visualise and understand abstract concepts.
This process of data analysis which resulted in the formulation of these hypotheses through the methods of Grounded Theory is recorded in Chapter 4.

During data analysis memos were written to record ideas about relationships amongst the data. The memos provide additional depth to the data analysis and are used in the conclusion to the investigation as a basis for a critical examination of the “emergent theory” and the conclusion to the investigation. This is set out in Chapter 5.

1.5.3 The Setting of the Investigation

The investigation took place in an independent Catholic girls’ school in a suburb of a large Australian city. The school draws largely from middle income families. Most students come five to fifteen kilometres to school by bus and are drawn from primary Catholic feeder schools in the surrounding suburbs. There are eight hundred students at the school. They range in age, from eleven and twelve in Year 7 to seventeen and eighteen in Year 12. There are approximately one hundred and fifty students in each of Years 7 to 10. This number drops to one hundred and twenty in Year 11 as students migrate to a local Catholic school which is co-educational in the senior years. In Year 11, students select eleven to fourteen units of study. Over the last ten years the average numbers taking Science in Year 12 are as follows: Physics eleven, Chemistry eighteen, Biology thirty and Senior Science six. The school has sixty-two teaching staff and twenty-five ancillary staff. There are nine full-time Science teachers.

Students perform above the State Average in the School Certificate Examination in Science. The table below contains a typical sample of Science results.

<table>
<thead>
<tr>
<th></th>
<th>Percentage of Students School</th>
<th>Percentage of Students State of NSW</th>
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<tbody>
<tr>
<td>Band 6</td>
<td>6.5</td>
<td>4.7</td>
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<tr>
<td>Band 5</td>
<td>39</td>
<td>25</td>
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<tr>
<td>Band 4</td>
<td>39</td>
<td>33</td>
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</tbody>
</table>
A statistical examination of the relationship between Higher School Certificate and School Certificate results indicates that the standard of student achievement in the Higher School Certificate is expected on the basis of School Certificate results. In other words the standard does not improve or diminish.

The model of teaching and learning followed at the school is generally Transmission teaching. In recent years, efforts have been made to change this, and teachers have been encouraged to use differentiated learning and Assessment for Learning. Efforts have also been made to reduce the loss of teaching time experienced over all year groups because of extra-curricular activities.

I have taught Science in the school for seventeen years. For nine years I have been Head of Science. One of my responsibilities is implementing the current Science Syllabus with the assistance of Science staff. I am particularly interested in the cognitive development of students and effective approaches to teaching and learning. Over the years I have received a number of awards for my work in this area: NSW National Excellence in Teaching Award Award, 1994; BHP Science Merit Awards 2002 and 2004; NSW Premier’s Award 2006.
CHAPTER 2
METHODOLOGY

2.1 PLANNING THE INVESTIGATION

Investigations based on Grounded Theory are planned around a substantive issue which is addressed by the research. The substantive issue is derived from a substantive area, in this case, writing in Science classes. The substantive issue addresses an aspect of the substantive area. In this investigation the substantive issue has been:

- How role play addresses the difficulties students perceive when writing reflectively about the concepts they are learning in Science

Thus, the investigation has focused on the difficulties students perceive when they write reflectively in Science, and how role play may address these difficulties and assist students to write reflectively about new concepts they are learning.
Like most people with a scientific background, I had been trained to carry out experiments based on the scientific method, testing the effects of independent variables under controlled conditions. Therefore I considered a quantitative, experimental approach to my planning of this investigation. This quickly led me into difficulties as I struggled to identify the independent variables to test. Moreover, it was impossible to identify and control all the variables that could exist in an educational setting. Furthermore, I was unable to control the ones I could identify. For example, it was difficult to standardise the presentations of different topics over a range of classes. Another problem was the design of a scoring tool for writing samples which would produce a valid, reliable result across different topics, in different classes and teaching situations. For these reasons I decided to use Grounded Theory, a qualitative, interpretative approach to the investigation. This allowed me to resolve many of the problems associated with the identification and control of variables, and with the scoring of writing samples.
2.2 GROUNDED THEORY

Grounded Theory was initially developed by Glaser and Strauss in 1967 as a methodology for sociological research. In its early days it was viewed with some suspicion by the academic community (Glaser, 1998: 4) as it was not considered to be sufficiently well-defined. This was a time when sociological texts frequently began their first chapter with a discussion about the nature of Sociology – was it a real Science or not? These discussions were prompted by the need for a methodology that could provide authentic and useful information out of the complex interaction of variables present in human social settings. Grounded Theory is one such methodology, which enables the researcher to extract new and practical insights from data collected during the complex interactions of teaching and learning.

There are a number of versions of Grounded Theory all subject to ongoing academic debate. The version I have used is based on the original writings of Glaser and Strauss (1967) and further clarified by Glaser (Glaser, 2002; Glaser, 1998; Glaser, 1995; Glaser, 1994; Glaser, 1992; Glaser, 1978).

Glaser and Strauss (1967) aimed to describe a way to “generate theory implicit in the data from a number of samples rather than confirm hypotheses with statistically analysed evidence” or by relying on conjecture (Glaser and Strauss, 1967: 48; Dey, 1999:15). Grounded Theory, unlike scientific experimentation, does not involve testing a hypothesis. Instead, data collection relates to a substantive issue, from which questions and possible solutions emerge as data are collected. The initial data collection empirically addresses the substantive issue as a whole. For example, data collected from the first sample in this investigation addressed students’ perceptions by asking them to write reflectively about the concepts they were studying in Science.

In Grounded Theory the function of the literature review differs significantly from its function in Scientific Experimentation. In the latter, relevant literature is reviewed before the experiment is planned, and may be used in the formulation of a hypothesis. In
contrast, the research literature in Grounded Theory is viewed as additional data. The questions raised during data analysis indicate areas in which a review of research may provide additional data to explain the substantive issue. Thus reading of research literature continues throughout the investigation. Research related to the substantive issue may be reviewed before commencing the investigation, in order to provide information about the substantive area and to sensitise the researcher to what is already known about it. However, it is important that the researcher does not develop preconceived ideas about the outcomes of the investigation from this initial review of the literature (Glaser, 1992: 31). Thus, in this investigation the literature is reviewed in two parts. The first part is “The Initial Review of Literature”, carried out before data collection while the second is “Literature Collected as Data”, which covers literature reviewed during the course of the investigation in response to questions raised during data analysis.

Data analysis proceeds by comparing the data gathered from each sample as they are collected. The comparison of data is fundamental to Grounded Theory. Comparison of data begins with the first sample and continues throughout the entire investigation. Data are coded, compared, sorted into categories and compared again. This is not a linear process but relational, where all new data are compared with the data from every other sample (Glaser and Strauss, 1967: 106). As a result of the comparison, one category identified as the core category emerges from the data. All other categories relate to the core category (Glaser, 1978: 95). Hypotheses are induced from the core category and its subsidiaries. The analysis and comparison of data at each level influences the design of the investigation. This is referred to as “emergent design” and it can involve the classes chosen as samples, the questions asked, classroom interventions carried out and the research literature referred to (Glaser, 1992: 101).

The “emergent theory” develops from the hypotheses. For this reason the “emergent theory” is described as being “grounded in the data” and, as such, fits the real world, predicts and explains aspects of the substantive issue, and relates directly to all participants in the investigation (Glaser and Strauss, 1967: 239). The “emergent theory”
provides individuals and institutions with possible solutions and responses to the substantive issue (Glaser, 1978: 85).

Grounded Theory is not a descriptive form of qualitative research, but rather depends on concepts developed from the data. According to Glaser it is not about what the participants do, and what this means, but rather it is “a generated abstraction from their doings and their meanings that are taken as data for conceptual generation” (Glaser, 2002: 2). The ability of the researcher to conceptualise from the data is a very important aspect of Grounded Theory.

Researchers using Grounded Research are expected consciously to suspend their own professional and personal views about what the outcomes of data analysis could be (Glaser, 1978: 36). As Glaser (1994: 4) puts it, “Grounded Theory is suited to researching problems where there is not a preconceived idea of what is likely to be demonstrated or supported. Grounded Theory gets beyond conjecture and preconception to the underlying processes of what is going on.”

Because of the multivariate nature of qualitative research, concerns about validity, reliability, the involvement of the investigator and bias in the analysis of data there is continuing discussion about the methodology and evaluative criteria of Grounded Theory. For example Dey (1999: 15) reiterates Glaser’s concerns about forcing data and using preconceived concepts and theories ands, like Glaser, he is quizzical about the researcher’s objectivity during data analysis. Dey (1999: 91) suggests that the lack of precise definitions for codes and categories must be acknowledged and their scope and relevance made clear. Silverman (2006: 47), like Glaser, emphasises the need to deal specifically with contrary cases as one way to establish the validity of an investigation. Miles and Huberman (1994: 278) suggest the following evaluative criteria for qualitative research, including Grounded Theory:

Objectivity and confirmability – freedom from unacknowledged researcher bias and explicitness about inevitable bias.
Reliability, dependability and auditability – is the process of the study consistent and reasonably stable over time and across researchers and methods.

Internal validity, credibility and authenticity – truth value. Do the findings of the study make sense? Are they credible to the people studied, members of the research community, and others?

External validity, transferability, fittingness – Do the conclusions of a study have any larger import? Are they transferable to other contexts? Do they fit with what we already know? How far can findings be generalized?

Utilisation, application, action orientation – What does the study do for participants? What is the pragmatic value of the research?

These issues are discussed in this chapter particularly with reference to the practice of Grounded Theory in the works of Glaser. They are discussed further as part of the data analysis in Chapter Four and emergent theory in Chapter Five.

### 2.3 SAMPLING

The random and representative samples of a controlled Scientific Experiment are not relevant to investigations based on Grounded Theory, and nor is sample size. Rather, samples used in investigations based on Grounded Theory are determined by their relevance to the substantive issue and to the emergent theory. The researcher makes a decision to sample a particular group on the basis of its ability to provide required information in response to questions raised during data analysis. Sampling such as this is referred to as “theoretical sampling” (Glaser, 1998: 158). Theoretical sampling provides successive rounds of information about identified questions and solutions raised by previous data and by the emergent theory. It is not used to verify a preconceived hypothesis (Glaser, 1978: 85).

Questions related to the substantive issue begin to emerge from the data of the first sample. Data analysis indicates the type of data then required to further investigate the problems raised by the first sample, and drives the selection of further samples. The
selection of samples is “deductive and purposeful”, as each sample is used to support, and add depth and detail, to the emergent theory (Glaser, 1992: 137).

The usefulness of the emergent theory can be influenced by the number and the type of samples chosen. Group diversity can increase the variety of data collected, revealing similarities between different groups. This allows the emergent theory to be generalised over a wider population. Sampling similar groups can help to define the conditions under which a category operates and may increase the predictive ability of the theory (Glaser and Strauss, 1967: 52). Theoretical sampling can increase the diversity of samples, making wider generalisations possible, and decrease the amount of data required to complete an investigation (Glaser and Strauss, 1967: 111).

Samples selected for this investigation are drawn from Science classes I taught in Years 8, 10 and 11. The samples used in the investigation are listed in the table below. The number of students in each sample is listed in the second column. The topic taught to each sample is listed in the third column and the date that each sample was investigated is listed in the fourth column.

<table>
<thead>
<tr>
<th>Class in Order of Sampling</th>
<th>Student Numbers</th>
<th>Topic Taught</th>
<th>Date Sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 10 Science</td>
<td>24</td>
<td>Mitosis</td>
<td>February 2005</td>
</tr>
<tr>
<td>Year 8 Science</td>
<td>24</td>
<td>Photosynthesis</td>
<td>February 2005</td>
</tr>
<tr>
<td>Year 11 Physics</td>
<td>9</td>
<td>The Hertzsprung-Russell Diagram</td>
<td>March 2005</td>
</tr>
<tr>
<td>Year 8 Science</td>
<td>24</td>
<td>Transpiration</td>
<td>March 2005</td>
</tr>
</tbody>
</table>

I chose a range of classes because the substantive issue is relevant across all secondary Science classes. This increased the diversity of the samples, leading to the possibility of
wider generalisation with the emergent theory. Samples were drawn from mixed ability Year 8, 10, and 11 classes in the school where I teach, for reasons of accessibility, convenience and the rapport I had developed with students during my time at the school. In addition, these classes were chosen as suitable “theoretical samples” for this investigation.

2.4 DATA COLLECTION

2.4.1 The Approach to Data Collection

At the beginning of the year students were advised that I would be investigating their use of reflective writing as a means of learning about scientific concepts. The students understood that their writing would be analysed against writing criteria provided at the beginning of the lesson. They knew that the investigation would view their writing not from a personal viewpoint, but in the context of the substantive issue in general, and that therefore their writing samples would remain anonymous. In addition to providing writing samples, students were occasionally asked to answer specific questions in written evaluations of lessons. Furthermore, a number of students from each class were asked to take part in short Focus Group discussions. The students were aware that I would be taking notes about the lessons, and that conversations held during a lesson could be recorded in these notes. Students were told that they did not have to agree to their work being included, or to taking part in any other of the data collecting activities. No one objected.

During the course of an investigation, the responses of students may alter if they know they are involved in a research project. This depends on their perception of their role in the investigation, which may differ from that intended by the researcher. For example, they may be affected by “novelty, special attention or mere awareness of participation” (Adair, 1984: 339). In addition, the investigator may have preconceived ideas about how the students will respond in a particular situation and the students may also have their own perceptions of the purpose of the investigation. Interviewing students after an investigative lesson can help to resolve these issues (Adair, 1984: 341). For example, students from each class were asked to compare their perception of participation in this
investigation with their response to normal classroom activities. In Grounded Theory this issue can also be resolved by the continual comparison of data from different samples, as this tends to isolate idiosyncratic behaviours and responses.

In this investigation the process of data collection was, from the students’ point of view, no different from the established classroom routine where work, including writing, was collected, commented on and returned. Students were familiar with the process of evaluation, as they routinely completed written and oral evaluations of group work and units of work. I had the impression that the students forgot about my investigation, as none of them ever mentioned it or questioned me about it.

Another difficulty that can occur during data collection in Grounded Theory is “observer-expectancy” or “experimenter bias”. This occurs when the researcher expects or wishes for a given result, and unconsciously manipulates data collection and forces data. Some data may be misinterpreted or ignored to support the desired outcome. In Grounded Theory this problem is approached in three ways:

1. As in all forms of research, the researcher remains aware of the possibility of “experimenter bias” and consciously strives to regard the data impartially.

2. Disconfirming evidence of categories is explicitly sought in the data. The disconfirming evidence is as important to the emergent theory as the confirming evidence.

3. The continuous comparison of data from different samples results in patterns in the data that form categories. These comparisons tend to reveal biases that do not fit the data resulting in an emergent theory that is not workable i.e. does not produce workable solutions to the substantive issue.

Descriptive data, carefully and systematically collected, are the bases for analysis and theoretical development in Grounded Theory (Glaser, 1978: 85). For each sample, I recorded the date, year group, period, and lesson plan. Data were collected from classes in the following ways:
• Focus groups
• Written surveys
• Writing samples measured against writing criteria prepared before the lesson
• Lesson notes of classroom activities and observations

Data were also collected from the research literature in response to questions raised through data analysis which could not be resolved by further theoretical sampling.

2.4.2 Written Surveys

Written surveys differed from class to class. The surveys used with each sample related to the problems identified by “theoretical sampling”, and were part of the “emergent design” of the investigation. The following table lists the questions used in a written survey of students in each successive sample.

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>QUESTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How easy is it to write about mitosis in your own words?</td>
</tr>
<tr>
<td>2</td>
<td>Do you generally write your own notes or copy from the board?</td>
</tr>
<tr>
<td>3</td>
<td>Would you say that writing in your own words is a difficult thing to do?</td>
</tr>
<tr>
<td>4</td>
<td>If it is a bit difficult, what sort of things would make it easier to do?</td>
</tr>
<tr>
<td>5</td>
<td>Some people say that it is easier to write if you have a picture in your mind of what you are writing about. What do you think about this comment?</td>
</tr>
</tbody>
</table>

Table 2.4.2.2
### YEAR 8 PHOTOSYNTHESIS

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>QUESTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Please answer the following questions. Your name is not required.</td>
</tr>
<tr>
<td>1</td>
<td>How easy or difficult was it to write about photosynthesis?</td>
</tr>
<tr>
<td>2</td>
<td>Was there anything you did in class that made it easier to write about photosynthesis?</td>
</tr>
<tr>
<td>3</td>
<td>Was there anything you did in class that made it more difficult to complete the writing task?</td>
</tr>
<tr>
<td>4</td>
<td>When you write is it easier if you have a picture in your mind about the topic?</td>
</tr>
<tr>
<td>5</td>
<td>Is it generally easy to write about things you are studying in Science in your own words? Is it something you usually do? Please explain your answer.</td>
</tr>
<tr>
<td>6</td>
<td>Please add any other comments you would like the teacher to know about.</td>
</tr>
</tbody>
</table>

### Table 2.4.2.3

**YEAR 11 HERTZSPRUNG – RUSSELL DIAGRAM**

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>QUESTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sometimes during your learning we have acted out concepts, e.g. black body radiation, or walked through them, e.g. H-R Diagram. These exercises have been followed by individual writing.</td>
</tr>
</tbody>
</table>
| 1      | How do you find this type of learning in relation to  
  a. understanding the concepts  
  b. remembering the concepts  
  c. ease of writing about the concepts |
| 2      | Which ways of learning make the following easiest for you  
  a. to understand the concept  
  b. to remember the concept |
Table 2.4.2.4
YEAR 8 TRANSPERSION

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>QUESTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How did this type of role play and story telling assist you, if at all?</td>
</tr>
<tr>
<td>2</td>
<td>It’s easier to write if you have a visual picture in your mind of the idea you are writing about. Do you think this activity helped you “get the picture” about transpiration at all?</td>
</tr>
<tr>
<td>3</td>
<td>Sometimes when we write it is hard to remember everything about a topic like transpiration. Would you say this type of activity helps you remember transpiration?</td>
</tr>
</tbody>
</table>
2.4.3 Focus Groups

The table below provides details of the focus groups interviewed from each successive sample. The identity of each sample appears in the first column, the number in each focus group is listed in the second column and the date in which each focus group was interviewed is recorded in the third column.

<table>
<thead>
<tr>
<th>Year</th>
<th>Student Numbers</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Science</td>
<td>5</td>
<td>February 2005</td>
</tr>
<tr>
<td>8 Science</td>
<td>6</td>
<td>February 2005</td>
</tr>
<tr>
<td>11 Physics</td>
<td>9</td>
<td>March 2005</td>
</tr>
<tr>
<td>8 Science</td>
<td>6</td>
<td>March 2005</td>
</tr>
</tbody>
</table>

The Focus Groups took place during the lunch break or, in the case of Year 10 and 11 classes, at the end of the lesson, and lasted between 10 to 15 minutes. I developed a number of questions to ask each Focus Group but often, after the conversation began it followed its own pace and direction to some extent. This occurred because I was an established teacher in the school and known to the students. Rather than taping discussions I took key word notes during interviews, as suggested by Glaser (1998: 107) and wrote field notes directly after interactions with participants.
The following tables list the focus questions prepared in advance for each focus group.

Table 2.4.3.2
YEAR 10 FOCUS GROUP QUESTIONS - MITOSIS

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>QUESTION</th>
</tr>
</thead>
</table>
| 1      | How do you learn best?  
What helps you understand what you are learning in class? |
| 2      | How can students acquire the correct information in class? |
| 3      | How does class discussion help when you are asked to write about mitosis yourself? |
| 4      | If I spent some time explaining something to you, do you think it would be easy to write about it straight afterwards? |
| 5      | How do you find remembering and understanding technical words like chromatid or centromere? |
| 6      | Could you think about Mitosis and then describe it in writing? |
| 7      | What could we do during class to make it easier for you to think and write about Mitosis yourself? |
| 8      | How do you find writing if you have a diagram to use or a picture like you had when you learnt and wrote about mitosis? |
| 9      | Some people say you can have a picture in your mind when you write. What do you think about that? Is that your experience at all? Could you give me an example either way? |
### Table 2.4.3.3

#### YEAR 8 FOCUS GROUP QUESTIONS – PHOTOSYNTHESIS

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>QUESTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>We did a number of different learning activities in this lesson – structured group discussion, using a word equation, making up role play and performing it – in what way did any of these activities help or not help you to understand photosynthesis?</td>
</tr>
<tr>
<td>2</td>
<td>Do you think any of these activities can help or not help you remember photosynthesis? How did X help?</td>
</tr>
<tr>
<td>3</td>
<td>How could you be sure that you had correct information by the end of the lesson? How was this a concern for you?</td>
</tr>
<tr>
<td>4</td>
<td>How do you find learning technical words in class such as <em>xylem</em> or <em>chlorophyll</em>? What accounts for difficulty or ease in understanding and remembering technical words?</td>
</tr>
<tr>
<td>5</td>
<td>What are your views about the discussions in small groups? Explain how you think they contribute or do not contribute to your learning of a concept like photosynthesis?</td>
</tr>
<tr>
<td>6</td>
<td>Some people say you can have a picture in your mind when you write. What do you think about that? Is that your experience at all? Could you give me an example either way?</td>
</tr>
<tr>
<td>7</td>
<td>Tell me about learning styles.</td>
</tr>
<tr>
<td>8</td>
<td>How do you react to reflective writing when you are learning a new concept? What does it achieve or not achieve for your learning?</td>
</tr>
</tbody>
</table>
Table 2.4.3.4
YEAR 11 FOCUS GROUP QUESTIONS –
HERTZSPRUNG-RUSSELL DIAGRAM

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>QUESTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Teachers generally explain concepts to students. How do you view this role in the lesson?</td>
</tr>
<tr>
<td>2</td>
<td>Describe the sorts of things did we did in class that hindered or contributed to your understanding?</td>
</tr>
<tr>
<td>3</td>
<td>There are quite a number of technical words to understand in most scientific concepts. How easy or difficult was it to understand and remember technical words in this lesson?</td>
</tr>
<tr>
<td>4</td>
<td>A substantial part of the lesson was taken up by role play. Elaborate on your reaction to the role play as a way of learning about the H-R Diagram.</td>
</tr>
<tr>
<td>5</td>
<td>What sorts of things did we do that made writing about the H-R diagram easier or more difficult?</td>
</tr>
<tr>
<td>6</td>
<td>There was a lot of discussion during the lesson. Elaborate on your reaction to class discussion as a way of learning about this concept.</td>
</tr>
<tr>
<td>7</td>
<td>What about group discussion with other students where the teacher comes around and talks with you all during the lesson?</td>
</tr>
<tr>
<td>8</td>
<td>Some people say you can have a picture in your mind when you write. What do you think about that? Is that your experience at all? Could you give me an example either way?</td>
</tr>
<tr>
<td>NUMBER</td>
<td>QUESTION</td>
</tr>
<tr>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td>1</td>
<td>Some people say you can have a picture in your mind when you write. What do you think about that? Is that your experience at all? Could you give me an example either way?</td>
</tr>
<tr>
<td>2</td>
<td>In this lesson you drew and labelled a large diagram of transpiration. In what ways did this help you learn?</td>
</tr>
<tr>
<td>3</td>
<td>You used the diagram to carry out a role play. In what ways did the role play help you or not help you learn?</td>
</tr>
<tr>
<td>4</td>
<td>There is quite a lot to remember about transpiration. Which class activities helped you or did not help you remember details about transpiration?</td>
</tr>
<tr>
<td>5</td>
<td>How helpful would it be to have a picture of transpiration in your mind? What would this make easier or more difficult to do?</td>
</tr>
<tr>
<td>6</td>
<td>If you were sure you had correct information about transpiration by the end of the lesson how had you arrived at this conclusion?</td>
</tr>
<tr>
<td>7</td>
<td>Could you identify things you did in class that helped you remember how transpiration worked?</td>
</tr>
<tr>
<td>8</td>
<td>You probably took part in quite a lot of discussion as you worked on the role play. How did this discussion help or not help you</td>
</tr>
</tbody>
</table>

Table 2.4.3.5

YEAR 8 FOCUS GROUP QUESTIONS – TRANSPERSION
2.5 CODING AND CATEGORIES

2.5.1 Coding

Initial data analysis, in which data are named and classified according to codes, is referred to as “Open Coding.” The codes are key points identified by the researcher that describe what is recorded in the data. To establish codes, the researcher asks questions of the data such as “What is happening in this data? What accounts for it? What patterns are occurring here?” (Moghaddam, 2006: 55). During analysis it is important to code all comments from participants, and to ensure that all points of view are incorporated into a code. No part of the data should remain uncoded. “Open Coding” and comparison of coded data results in verification. If data is forced or not part of a wider pattern of observation, it will not reappear in the coding of successive samples.

Codes and categories are derived from the perceptions of the participants and their approach to the substantive issue (Glaser, 1978: 33). The analysis of successive samples may require new codes be added to the data analysis. In this investigation data were initially sorted into the following open descriptive codes:

- Copying Notes from the Board
Over successive samples, all data from participants were coded in this way. At different points during the sampling when data analysis added no new information to a code, it was then defined as “saturated”. Saturated codes were no longer sampled.

Grounded Theory is not a descriptive qualitative methodology and it is essential that the researcher conceptualises from the original open descriptive codes. This is fundamental to the practice of Grounded Theory. Thus open codes are combined together conceptually (Glaser, 1992: 15) to form the following conceptual codes:

- Learning in Science
- Interpretation learning
• Literacy
• Metacognition
• Fear of failure
• Visualisation
• Reflective Writing Through Role Play
• Learning and Understanding in Science

Conceptual codes which are used to generate categories and their properties. The following table lists categories and their properties derived from conceptual codes in this investigation. Categories are listed in the left-hand column and properties in the right-hand column.

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>PROPERTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission Model of Teaching and Learning</td>
<td>Fear of Failure</td>
</tr>
</tbody>
</table>
| Role Play | Role Play and Understanding  
Role Play and Remembering  
Role Play and Visualisation  
Role Play and Structured Group Discussion  
Role Play and Reflective Writing |
| Interpretation Model of Teaching and Learning | Learning and Understanding in Science |
Questions arising from these categories and their properties determined the direction of theoretical sampling and the choice of research literature consulted during the investigation. Theoretical sampling continues to a point when no further information is gleaned from the codes. This is referred to as the point of saturation. At this point no further information relating to a code or category is likely to arise during further sampling (Glaser, 1978: 35). The identification of a “saturation point” depends, to a large extent, on the judgment of the researcher as well as on the availability of time and other resources.

2.5.2 Forcing Data

Forcing data is a significant issue to consider when carrying out Grounded Theory. Forcing occurs when the researcher allows preconceptions, personal biases and preconceived ideas about the outcomes to influence the choice of data (Glaser, 1992: 46). It prevents the researcher from analysing what is actually happening in the data. To overcome this, data are carefully analysed sentence by sentence, and all comments by participants are noted and coded. When analysing data, Glaser (1992: 4) suggests keeping the following two questions in mind to help prevent forcing data:

1. What are the chief concerns of the people in the substantive area? What accounts for most of the variation in processing the problem?
2. What category, or what property of a category does this incident indicate?

It is important to allow the theory to emerge from the data and to be aware of possible bias.

2.5.3 Comparisons, Conceptualisation and Categories

Comparison of data is the basis of grounded Theory. Open codes are compared, sorted and conceptualised to reveal patterns and relationships in the data. Conceptual codes are then compared and sorted into categories. Categories are analogous to independent variables, and are used to record the conceptual patterns in the data (Moghaddam, 2006:...
Further concepts may then be derived from categories. Additional data collection through theoretical sampling expands and deepens the understanding of categories.

In the course of data analysis codes are developed into concepts and concepts into categories by asking questions such as “How?” and “Why?” For example the descriptive open code “discussion and understanding” can be developed conceptually by asking how discussion could be carried out in a class to develop understanding, and how this could then assist reflective writing. The data collected as a result of these questions can then be linked conceptually to demonstrate how discussion, understanding and reflective writing are related. The conceptual codes that relate to discussion can be linked to form a discussion category.

As data are collected and analysed from successive samples, questions arise about the categories and their properties. These can be resolved by further theoretical sampling or by reference to the research literature (Glaser, 1992: 137). For example, data analysis from two classes indicated that some students claimed that their ability to write reflectively and to learn was influenced by their learning style. This claim was investigated and resolved by recourse to the literature. Thus, a review of the literature becomes an integral part of the data and the data analysis, which may support, refute or raise questions about the emergent theory.

### 2.5.4 Core Category and Hypotheses

Theoretical sensitivity develops from the educational background of the researcher. It refers to the ability to understand the relationships between open codes from which to generate concepts, to develop categories and their properties, and finally to formulate the hypotheses from which the emergent theory evolves. It sensitises the researcher to choose questions that are likely to provide data that will inform the substantive issue. On the other hand it can introduce bias by suggesting or presenting preconceived ideas to the researcher (Glaser, 1978: 39).

As concepts are organised into categories, one category and its properties are likely to emerge as the core category. The core category is identified as the central category
around which other categories cluster. It is the particular issue that accounts for most variation in the substantive area and it provides explanations and solutions for the substantive issue (Glaser, 1992: 75). The core category becomes the independent variable of the investigation and there is usually only one. From the core category, its sub-categories and properties, it is possible to develop hypotheses using inductive reasoning (Glaser, 1998: 95). The hypotheses are used to develop the emergent theory. Once hypotheses have been established, the researcher returns to the data to search for information that will support or refute them. Hypotheses will become the basis of the emergent theory if they “fit” the data well. “Fit” refers to validity; that is it shows whether the hypothesis adequately represents information supported by the data. “Fit” is a consideration for all data analysis (Glaser, 1998: 18).

2.5.5 Memos

Memos are used to record any thoughts, insights and ideas that occur to the researcher during the long process of data analysis. These may, for example, include thoughts about relationships between and within concepts, categories and the research literature, or they may be used to connect categories and their properties. Memos are an essential tool used to record insights which may otherwise slip from memory during the process of data analysis (Moghaddam, 2006: 56). As data are coded, compared, categorised and compared again, the researcher’s ideas at each level of analysis are recorded as memos on separate cards.

Memos are used over the entire process of developing emergent theory through data analysis. They are used to pinpoint relationships between data and, as such, provide breadth and depth to theoretical concepts. Glaser (1978: 84) describes memos as “the way to theoretically develop ideas with complete freedom into a memo fund that is highly sortable”.

Finally, memos are coded using “theoretical codes”. These are codes that link the memos to the core category. Once coded, memos can be sorted in a process referred to as “theoretical sorting”. “Theoretical sorting” can begin with any memo, as the order will
make no difference to what emerges as theory. The sorted memos provide the outline of the final report.

### 2.6 CHARACTERISTICS OF EMERGENT THEORY

Glaser (1978: 4) describes “emergent theory” in the following terms: “The emergent theory is a group of related hypotheses which are integrated, saturated and made to fit the data. They are probabilistic, not verified facts, and they must be able to be modified if new data emerges.” It “should be able to explain what happened, predict what will happen and interpret what is happening” (Glaser, 1978: 4).

In Grounded Theory the usefulness of the emergent theory is an important consideration. Its validity refers to its usefulness and how well it “fits” the data (Glaser and Strauss, 1967: 49). Because ideas emerge from the data and many comparisons between data are made, the emergent theory is likely to “fit” the data unless forcing has occurred. According to Glaser and Strauss (1967), a successful emergent theory must have four interconnected features:

1. **“Fit”:** The emergent theory must relate to the data so that it can be used in classrooms. If the data have been force the “emergent theory will not be a good “fit” and will therefore not be valid (Glaser and Strauss, 1967: 239).

2. **“Workability”:** The emergent theory provides suggestions which can be used to resolve the substantive issue in practical situations (Glaser, 1998: 18).

3. **“Relevance”:** It must provide solutions and suggestions to solve a problem that is recognised by a significant number of people. Its solutions and suggestions must be worth trying (Glaser and Strauss, 1967: 242).
4. “Modifiability”: The theory can be changed if and when new data becomes available. This includes data that does not support the theory in its current form (Glaser, 1998: 18).

Thus, in this case, the emergent theory must be able to explain:

- the difficulties experienced by students when asked to write reflectively about the scientific concepts they are learning
- what was happening in the classroom in relation to reflective writing
- suggestions about how to successfully implement reflective writing in a classroom and resolve some of the difficulties students perceive when asked to write reflectively about concepts they are learning in Science
- how the theory can be modified if new data becomes available
CHAPTER 3
LITERATURE REVIEW

PART 1
INITIAL FINDINGS FROM THE LITERATURE

The literature reviewed in this chapter is related to the substantive area, writing in Science.

Although writing-to-learn is a recognised concept in the literature, it has no precise and consistent definition which is generally accepted as the ‘correct’ definition (Bangert-Drowns, Hurley and Wilkinson, 2005: 26). In this investigation writing-to-learn is used interchangeably with reflective writing which is defined as the form of writing-to-learn which students use in the process of constructing conceptual meaning. Reflective writing is also used to help students become aware of their thinking. Very little research directly addresses the difficulties students perceive when asked to write in this way (Marzano, 1998: 92). This may be due to the fact that by far the most commonly used forms of writing in schools demonstrate only knowledge retention and language competence (Halliday and Martin, 1993: 201; Prain, 1995: 62; Yore, Bisanz and Hand, 2003: 711) - thus the types of writing exemplified by reflective writing in Science are marginalised and under-researched (Cremin, Gough, Blakemore, Goff and MacDonald, 2006: 273). When students, in this investigation, were asked about the difficulties they perceived as they sat in front of an empty page unable to put pen to paper, they mentioned the following: a lack of understanding of the concept, an inability to remember details about the concept, an inability to begin writing, and once having begun difficulty in sequencing information about the concept. With these perceptions in mind, I researched the literature from the substantive area was researched under the following headings:

3.1 Relevant Learning Theory
3.1 RELEVANT LEARNING THEORY

From the mid-twentieth century the theories of Piaget and Vygotsky have had a significant influence on approaches to teaching and learning in both primary and secondary schools in the West. Their ideas have been used as the basis for constructivism in its various forms. Both researchers emphasised the way in which active individual involvement contributed to the construction of learning and its integration into prior knowledge. They recognized that reflection on learning and thinking strategies was essential for the development of metacognition, the underlying process which drives cognitive development. As Flavell (1963: 262) observed, “All in all there is no doubt that *l’homme piagetien* is assigned a very, very active role in the formation of his own cognitive world”.

3.1.1 The Influence of Piaget

Piaget described himself as a “genetic epistemologist”, a researcher who was trying to discover how knowledge originates and then develops in the human mind (McNally, 1977: 2). Piaget’s research demonstrates that knowledge arises from action and that each
person actively acquires knowledge for themselves (Flavell, 1963: 82). He rejected the idea that knowledge could be absorbed passively.

Piaget investigated the development of cognitive structures and processes and described how they change over time in response to interaction with the environment. In his view the active construction of knowledge and learning results in the formation of a succession of new structures within the brain (Inhelder and Piaget, 1958:338). Each new set of structures represents the development of another stage of cognition, and each successive stage of cognition accommodates the new experiences required for the next structure to develop (Dawson, Fischer and Stein, 2004: 3).

As his work progressed Piaget organised these cognitive structures into four main stages of development, which were used to classify and record children’s progress (McNally, 1977:13). The development of cognitive structures begins at birth and progresses through the sensorimotor and preoperational stages before reaching the concrete operational and formal operational stages most commonly observed in students at secondary school.

According to Piaget, students who have reached the concrete operational stage think by observing and actively interrelating or “operating” with the characteristics of objects they encounter in their environment (Piaget, 1971:17). For example, “concrete operational thinkers” can:

- classify and place objects in an ordered series,
- understand simple causal relationships where one cause is related to one effect, such as: more heat causing temperature to rise,
- use a simple associative model where one event causes another,
- recognize the conservation of weight and volume towards the end of this stage,
- reverse operations e.g. recognise that if temperature rises, more heat must be present, and the reverse also holds true.

(Shayer and Adey, 1981: 72)
At this stage students are unlikely to have developed the ability to understand ratio and proportion, and therefore, by the late concrete operational level will be unable to fully understand concepts such as density, which is expressed as the ratio of weight to volume. What is more, because of its multivariate characteristics, volume itself is unlikely to be fully understood by students at this stage and this contributes to their inability to understand density as a ratio (Shayer and Adey, 1981:88). Thus, according to Piaget, students at the concrete operational stage can think about Science only in very limited ways.

For Piaget, students at the formal operational stage can think in a way that is recognizably more scientific. They are able to think at a higher level of abstraction and can manipulate multivariate data. Thus, it is necessary to stimulate the development of students’ cognition to the formal operational stage where they will understand scientific concepts with greater ease. The ability to think at this level may contribute to greater satisfaction in Science lessons and result in fewer complaints about the boredom reported by twenty-five per cent of students surveyed in Australian schools (Goodrum, Hackling and Rennie, 2001: 122).

At the formal operational stage students are able to:

- systematically think about a larger number of possibilities;
- make comparisons, some of which may be abstract;
- manipulate more than two independent variables at the same time;
- apply thinking from familiar to unfamiliar situations;
- work with formal scientific models;
- plan controlled experiments;
- use ratio and proportion effectively;
- use compensation, equilibrium and correlation.

(Adey, 1999: 5; Shayer and Adey, 1981: 65)

In Piaget’s (1971: 306) view, formal operational thinking is not hereditary and, unlike learning in the previous stages, is generally acquired only with considerable effort and through explicit teaching and considerable difficulty. Recent research from evolutionary
psychology has confirmed that the first three stages of cognitive development are observed across cultures, but that the final stage of formal operational thinking is relatively uncommon (Geary and Bjorklund, 2000: 63). Unlike the previous stages, it is not developed directly from operations which involve sensory-motor experiences of the external world (Piaget, 1971: 322).

Evolutionary psychologists such as Geary (2000: 328) classify cognitive abilities as *biological primary abilities* and *biological secondary abilities*. Learning your own language as a child is an example of a biological primary ability, as it depends on the innate adaptations of the human brain. Geary (2000:334) maintains that children are highly motivated to develop biological primary abilities. He defines *biological secondary abilities* as those which are culturally determined and the acquisition of formal operational thinking is a *biological secondary ability*. Thus, these abilities do not appear in all cultures as part of a developmental sequence, but generally as a result of schooling (Geary, 1995: 25; Inhelder and Piaget, 1958: 337).

Piaget established that cognitive structures do not necessarily appear at a particular chronological age of maturation (Flavell, 1963: 264). They appear in a predictable sequence and are probably linked to social and educational factors in an individual’s environment as well as to the maturation of structures in the brain. This view is expressed as follows:

> In sum, far from being a source of fully elaborated “innate ideas”, the maturation of the nervous system can do no more than determine the totality of possibilities and impossibilities at a given stage. A particular social environment remains indispensable for the realisation of these possibilities. It follows that their realisation can be accelerated or retarded as a function of cultural and educational conditions (Inhelder and Piaget, 1958: 337).

In Piaget’s view it is the disequilibrium between mind and environment that motivates cognitive development (Piaget, 1977: 13). In addition, although Piaget discounted language as having any influence on cognitive development (Borel, 1987: 70), he considered that the need to communicate with other people and survive in a particular environment does drive the development of the mind (Inhelder and Piaget, 1958: 243).
Metacognition is the awareness of one’s own thinking and learning processes and their structures. It develops as individuals reflect on the strategies they use for learning and become aware of them. Piaget considered it to be the process by which individuals develop cognitive structures and thus move from one stage of cognition to the next (Piaget, 1971: 320; Flavell, 1963: 263). The development of metacognition gives students control and choice over the way in which they think and learn about specific concepts (Gouge and Yates, 2002: 135; Prain and Hand, 1998: 159). Metacognition is of particular interest to this investigation. When students write reflectively they can become aware of how they construct their learning and of the thinking strategies they use when challenged. Thus, reflective writing in Science serves to develop metacognition which contributes to the development of higher levels of cognition.

Central to Piaget’s research was the search for a description of the cognitive processes that occur during human development. He was not attempting to discover the age at which each stage of cognition is reached. Nor was his research an analysis of population norms. For him, sampling methods and the standardisation of technique were secondary to discovering the cognitive processes active in a particular individual at a particular time (Flavell, 1963: 262; Shayer and Adey, 1981: 45). However, the ages recorded by Piaget (Inhelder and Piaget, 1958: 335) at which each stage is reached are generally cited as population norms. As Shayer and Adey (1981: 45) note, “Most potted Piagets will tell you that concrete operations is attained around the age of nine, and formal operations about the age of twelve to fourteen”.

In the late 1970s Shayer and Adey (1981: 9) carried out a study of twelve thousand British secondary school students in order to establish population norms for the ages at which Piagetian stages of cognitive development are reached. They discovered that only ten per cent of sixteen year olds in British schools had reached the level of late formal operational thinking. Moreover, they concluded that it was unlikely that little more than ten per cent of the population ever reached this level of cognition. Piaget’s research had indicated that late formal operational thinking develops from fourteen to fifteen years and
upwards into adulthood (Inhelder and Piaget, 1958: 1). However, Piaget’s assumption that everyone attains this level of cognition was questioned even in his lifetime. In fact, many adolescents and adults are unable to reason and deal with abstract thought in the manner described by Piaget’s formal operational thinking (Shayer and Adey, 1981: 9; Stanovich and West, 2002: 430) and in the view of Shayer and Adey (2002: 1) eighty percent of the school population operate well below their potential level of cognition.

The general assumption that the ages cited in Piaget’s research represent a population norm has influenced the design and content of Science curricula. For this reason there is frequently a mismatch between curriculum content and the cognitive development or thinking abilities of students (Shayer and Adey, 1981: 50). The example of teaching “density” in Year 7 is a case in point. If students have not reached the level of cognition required, they will be unable to process the information or write reflectively about it. The relationship between cognitive development and curriculum design raises two issues in the classroom:

- it questions the purpose of teaching concepts where there is a cognitive mismatch between curriculum demand and student cognition
- it provides teachers with the challenge of how to raise the level of cognition of students to a point where they can understand scientific concepts more readily and write reflectively about them

3.1.2 The Influence of Vygotsky

The Russian psychologist, Lev Vygotsky (1896-1934) carried out his research in the 1920s and ’30s. His ideas began to appear in the educational literature of the West in the 1960s, at about the same time as Piaget’s research was creating so much interest in educational circles.

Unlike Piaget, Vygotsky stressed the role of language and social interaction in the construction of knowledge and the development of cognition. According to Vygotsky (2004: 437) people learn or construct understanding by listening and speaking in social groups. This process of construction is stimulated by the more expert members of society,
such as teachers and parents, who help learners to internalize concepts and solve problems through the medium of language, imitation and other forms of interaction.

Our minds comprehend and learn new experiences by talking and writing about them, most often in terms of what we already know (Kuhn and Hand, 1995: 123; Barnes and Todd, 1977: 15). This process enables us to add new experiences and learning to the constructions which already exist in our minds, so that our view of reality remains cohesive.

Students learn to understand concepts at school in a similar way. Vygotsky suggested that, as small children learn in the company of more experienced adults, so school students learn by discussing new concepts with their peers and their teachers (Gouge and Yates, 2002: 135). When students understand rather than simply reproduce by rote, they process information and construct it in their own terms so that it becomes integrated into their view of reality (Vygotsky, 2004: 531).

Vygotsky described a theory of learning in which both learning and cognitive development are social processes (Adey and Shayer, 1994: 8). In his view, cognitive development results from interaction between biological processes in the brain and social processes within a culture. From their cultural environment, including school, students absorb both what to think and how to think, and this interacts with and changes, the biological structures available in the brain. Thus, Vygotsky emphasised the connection between students’ active participation in learning and cognitive development (Vygotsky, 1987: 11).

According to Vygotsky (1978: 84), cognitive development can occur in two ways:

- spontaneously as a result of the activities and efforts of the individual;
- when learning takes place in the “Zone of Proximal Development.”

Vygotsky (1978: 86) defined the “Zone of Proximal Development “as the distance between the actual developmental level, as determined by independent problem-solving,
and the level of potential development, as determined through problem-solving under adult guidance or in collaboration with more capable peers”.

The “Zone of Proximal Development” occurs just beyond the individual’s “intellectual comfort zone”, the point at which they can think and learn with ease. The ZPD is the thinking level at which students can perform tasks with assistance from more capable individuals and it is the level at which cognitive conflict will be experienced (Vygotsky, 1986: 187). Cognitive conflict generates disequilibrium in the mind, which is resolved during the construction of concepts through collaborative activities in the classroom. In Vygotsky’s (1978: 89) view the only effective teaching takes place within the “Zone of Proximal Development” and it follows that, without teaching in this zone, there will be no cognitive development. For individual students the ZDP will constantly move with development and it will not be the same for each student. This places the onus on the teacher to be sensitive to the learning levels of students, and to differentiate lessons accordingly. Learning can be differentiated effectively by using carefully structured small group discussion, open questioning and reflective writing (Adey, 1999: 5). This approach to teaching and learning fundamentally challenges “chalk and talk” Transmission teaching, in which the teacher transmits knowledge to be memorised and later reproduced in examinations.

Vygotsky’s ideas contributed significantly to the development of Constructivist models of teaching and learning. Constructivism acknowledges that students come to Science classes with prior ideas and knowledge about the world that may well conflict with scientific explanations (Pea, 1994: 266; Driver, Asoko, Leach, Mortimer and Scott, 1994: 5). Reality is not viewed as existing in absolute terms outside each one of us. Instead, each person’s construction of reality is the result of an active, individual process that uses social interaction to integrate new concepts into previous knowledge (Driver, Asoko, Leach, Mortimer and Scott, 1994: 6; Sutton, 1992: 108). The challenge for teachers is to provide students with learning experiences that will help them construct new concepts within their Zone of Proximal Development.
Over the last 30 years Vygotsky’s research has been recognised as having profound implications for Science teaching. Although this is acknowledged at some levels of curriculum design, recent research by Goodrum, Hackling and Rennie, (2001: 155) indicates that Vygotsky’s model of teaching and learning is not widely recognised or practised in Australian Science classrooms, where “chalk and talk” Transmission models of teaching and learning continue to dominate. Ford and Forman (2006:1) claim that, apart from a greater focus on vocabulary and scientific method, Vygotsky’s sociocultural learning has not become a part of classroom learning in Science. In their view classroom practice needs to include greater participation of students in what they describe as scientific practice. They divide scientific practice into three components (Ford and Forman, 2006:4):

- The involvement of scientists in public and private debates about explanations of natural phenomena. These debates determine what will become regarded as authoritative scientific knowledge.
- The observations and measurements taken to support or refute a hypothesis.
- The relationship between the involvement of scientists in debate and the observations and measurements.

These components are summarised further into the two roles of “constructor of claims” and “critiquer of claims” (Ford and Forman, 2006:5). These, they claim, constitute the actual processes of constructing authoritative knowledge in Science. A scientist publishes scientific information including observations and measurements. Peers and the researcher debate the method, results and conclusions iteratively in order to construct a rational explanation of a natural phenomenon. In this process, the data and observations are used to arbitrate disagreements, to scrutinise personal interests and viewpoints and to develop a rational theory further so that it can be regarded by the scientific community as authoritative scientific knowledge (Ford and Forman, 2006: 14). In a Science classroom, students can learn about aspects of such scientific practice by playing the roles of “constructor of claims” and “critiquer of claims” using, for example, oral and written language, discussion, drawing, graphs, diagrams and role plays. In this way, students use social construction to learn how scientists develop knowledge through evidence and
argument. They also learn the difference between personal or political views and scientific views of knowledge (Ford and Forman, 2006:4).

3.2 HOW LEARNING SCIENTIFIC CONCEPTS, COGNITION AND WRITING ARE RELATED

Because of the multivariate and abstract nature of many scientific concepts, Piaget’s level of formal operational thinking is required to learn and understand them. The characteristics of student cognition in secondary schools, and the ways in which social interaction, discussion and writing can contribute to the development of cognition, so that students can meet the demands of the curriculum, are reviewed in the following sections.

3.2.1 The Cognitive Demands of Secondary School Science

The study of Science at secondary school is intellectually demanding for many students. Here Science moves quickly from concrete operational thinking, with its simple causal relationships involving only two variables, to the multivariate relationships and greater levels of abstraction of formal operational thinking.

As long ago as 1981 Shayer and Adey investigated the levels of cognition of twelve thousand British secondary students from Years 7 - 10. Previous research (Shayer, 1978) had demonstrated that many of the concepts taught in Science classes world-wide made cognitive demands beyond the level of many students to whom they were taught. In addition, a study of first year university students in the United States confirmed that many had little understanding of the basic scientific principles which they had covered in secondary Science classes (Adey, 1999: 4). Shayer and Adey (1981: 30- 41) developed Science Reasoning Tasks to assess the cognitive development of students at different ages. Their analysis of the cognitive development of their British subjects indicated that by the age of twelve

- 5% of students were still at the preoperational stage of cognition;
- 35% were at the early concrete stage;
- 50% were at the late concrete stage; and
10% were early formal operational.

By the age of sixteen

- 20% were still at the early concrete stage;
- 50% had reached the late concrete stage;
- 20% had reached early formal operations; and
- only 10% of students had reached the stage of late formal operational thinking.

(Shayer and Adey, 1981: 8)

From these results it is evident that the rate at which students attain each level of cognition varies greatly. What is more, the ages at which students reach each stage are significantly higher than the ages recorded by Piaget and his researchers. The British research suggests that ninety per cent of the population is unlikely ever to attain late formal operational thinking (Shayer and Adey, 1981: 9).

Shayer and Adey (1981: 72) developed The Curriculum Analysis Taxonomy to analyse the cognitive demands of the Science curriculum. The results of this analysis and their research into the cognitive levels of secondary school students demonstrated that a mismatch between the demands of the curriculum and the thinking abilities of students frequently occurred. The following is an example of The Curriculum Analysis Taxonomy, developed, in this case, to analyse the level of cognition required to process concepts related to the kinetic theory of matter. This topic is usually taught to Year 7 students and is well known to Science teachers. This example demonstrates the concept of mismatch between the demands of the curriculum and the thinking levels of most students in Year 7. For analytical purposes, Piaget’s last two stages of cognitive development are divided into the four sub-stages he used: early concrete, late concrete, early formal and late formal.
For each table the title indicates the stage described within it. The characteristics of student thinking at each stage are listed in the left hand column of the table. The features of the kinetic theory of matter that students can understand at each stage are listed in the right hand column.

**Table 3.2.1.1**

**EARLY CONCRETE STAGE OF COGNITIVE DEVELOPMENT**

<table>
<thead>
<tr>
<th>Thinking at the Early Concrete Stage</th>
<th>Thinking related to Kinetic Theory of Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students can</td>
<td>Students can</td>
</tr>
<tr>
<td>interpret one feature at a time;</td>
<td>understand that a solid changes to liquid, a liquid changes to gas, as separate pieces of information;</td>
</tr>
<tr>
<td>put objects in order but cannot use the information to sum up observations;</td>
<td>can order solid, liquid, gas but cannot use results from heating ice to conclude that increasing heat causes changes of state;</td>
</tr>
<tr>
<td>not produce a concrete model such as a skeleton that exhibits a one to one relationships e.g. this bone is the ulna, this bone is the femur;</td>
<td>not draw a model of the states of matter and label each part solid, liquid and gas;</td>
</tr>
<tr>
<td>understand simple one factor causes;</td>
<td>understand that heat causes ice to melt; heat causes liquid to change to gas;</td>
</tr>
<tr>
<td>classify according to one major property such as size or shape.</td>
<td>classify solids as things that are hard, liquids as things that pour and gases as things that can be compressed.</td>
</tr>
</tbody>
</table>
## LATE CONCRETE STAGE OF DEVELOPMENT

<table>
<thead>
<tr>
<th>Thinking at the Late Concrete Stage</th>
<th>Thinking related to Kinetic Theory of matter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Students can</strong></td>
<td><strong>Students can</strong></td>
</tr>
<tr>
<td>use seriation to find out what happens;</td>
<td>understand that ice melts into water, water evaporates into steam;</td>
</tr>
<tr>
<td>use classification to find out what happens. This is generally how they describe reality but they depend less on one property;</td>
<td>describe that when heat is added solids can change to liquids. Solids are hard and liquids pour; Particles in solids are close together and particles in liquids are not so tightly held together.</td>
</tr>
<tr>
<td>structure experimental results if they have a concrete model;</td>
<td>use a concrete model: when heat is applied a solid changes to liquid and then to gas; structure experimental results: when heat is added ice changes to water and then to steam;</td>
</tr>
<tr>
<td>use bipolar concepts such as if this increases then this decreases; they can understand and use linear direct or inverse relationships;</td>
<td>state that heat causes the melting, cooling causes the freezing; if heat increases melting increases;</td>
</tr>
<tr>
<td>account for the reason something occurs by describing categories or relationships rather than by providing a formal model;</td>
<td>grasp a simple kinetic theory picture of particles close together or far apart, but they cannot apply this model to explain experimental results such as when heat is added ice changes to water;</td>
</tr>
<tr>
<td>find one to one correspondences between two sets of readings;</td>
<td>state that when heat is added ice turns to water; when heat is removed water turns back into ice;</td>
</tr>
<tr>
<td>use the idea of reversibility;</td>
<td>state that heat can be added, heat can be removed (cooling);</td>
</tr>
<tr>
<td>conceptualise relationships between simple variables two at a time.</td>
<td>state that heat causes melting, heat causes evaporation.</td>
</tr>
</tbody>
</table>
### Table 3.2.1.3

**EARLY FORMAL STAGE OF DEVELOPMENT**

<table>
<thead>
<tr>
<th>Thinking at the Early Formal Stage</th>
<th>Thinking related to Kinetic Theory of Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Students can</strong></td>
<td><strong>Students can</strong></td>
</tr>
<tr>
<td>use simply structured formal models with guidance e.g. the kinetic theory of matter;</td>
<td>understand that materials can be classified as solids, liquids, or gases depending on the state of their particles and that when a solid changes to a liquid the particles move around faster so they can roll over each other.</td>
</tr>
<tr>
<td>interpret data if a formal model is provided;</td>
<td>understand that gases can be compressed because the particles in a gas are further apart;</td>
</tr>
<tr>
<td>generate concrete models;</td>
<td>state that materials can be made from solid, liquid or gas; solids are rigid, liquids can be poured and gases can be compressed;</td>
</tr>
<tr>
<td>see the point of making hypotheses but need help to deduce relationships in experimental results;</td>
<td>formulate a hypothesis: if you add more heat then ice will melt faster, but they need help to find the relationship between the amount of heat measured and the time taken to melt a given mass of ice;</td>
</tr>
<tr>
<td>use the classification operation to impose meaning over a wide range of phenomena;</td>
<td>apply the kinetic theory of matter to describe pressure and compression as well as solids, liquids and gases;</td>
</tr>
<tr>
<td>describe, but will consider more than one aspect at once.</td>
<td>describe the structure of particles in a solid, liquid and gas, but can also consider the effects of adding heat, changes in the kinetic energy of the particles and what happens to particles as they change from one state to another.</td>
</tr>
</tbody>
</table>
Table 3.2.1.4

**LATE FORMAL OPERATIONAL STAGE OF DEVELOPMENT**

<table>
<thead>
<tr>
<th>Thinking at the Late Formal Stage</th>
<th>Thinking related to Kinetic Theory of Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Students can</strong></td>
<td><strong>Students can</strong></td>
</tr>
<tr>
<td>use the kinetic theory model deductively;</td>
<td>use the model to explain how the particles in steam are far apart and therefore the steam can be compressed;</td>
</tr>
<tr>
<td>generate and check possible ‘why’ explanations;</td>
<td>explain that when heat is taken away particles lose energy and move closer together and change from gas to liquid, for example. They can check this explanation empirically;</td>
</tr>
<tr>
<td>tolerate the absence of an interpretative model while investigating empirical relationships;</td>
<td>investigate the relationship between heat and the states of matter without using the kinetic model of matter;</td>
</tr>
<tr>
<td>understand multiple causes and effects and can think of reality in a multivariate way;</td>
<td>think of heat as kinetic energy that breaks the bonds between particles so they can move more freely;</td>
</tr>
<tr>
<td>actively search for an explanatory model and reflect on the relationships between variables;</td>
<td>describe and explain latent heat as the energy required by particles as they change from particles in a liquid to particles in a gas;</td>
</tr>
<tr>
<td>use deduction from the properties of a formal model to make explanatory predictions about reality;</td>
<td>predict that when enough heat is added to any material, a change of state will occur because the particles would gain kinetic energy;</td>
</tr>
<tr>
<td>think with abstraction and use abstract words, such as matter, that provide the opportunity to explore connections with non-matter;</td>
<td>use classification to build categories that can be subsumed in an overall category such as matter e.g. subatomic particles, atoms, molecules. The category of matter enables the category of non-matter to be explored e.g. energy;</td>
</tr>
<tr>
<td>test hypotheses against data, and make imaginative inferences using outside ideas and data;</td>
<td>test changes of state of different materials; if burning occurs, for example, they can use information about combustion to infer what may be occurring;</td>
</tr>
<tr>
<td>explain as well as describe.</td>
<td>describe what happens when ice is heated and they can explain why the observations are occurring in terms of particles and energy.</td>
</tr>
</tbody>
</table>
This analysis is of particular interest to Science teachers, bearing in mind that only ten per cent of their Year 7 students are likely to have reached the early formal operational level of thinking, and, while most of the remainder have reached levels of concrete operational thinking, five per cent remain at the preoperational level (Shayer and Adey, 1981: 9). Year 7 students are generally expected to make, draw or act out a concrete model of particles in a solid, liquid or a gas. They are generally expected to understand why gases are compressible while solids and liquids are not, what happens to particles when heat is added, and how they change from one state of matter to the other - all this at the level of early formal operational thinking (Shayer and Adey, 1981: 9). The many students in Year 7 who will not be able to think about The Kinetic Theory of Matter at the level demanded by the curriculum may be able to memorise information and reproduce it in a test. However, they will not be able to integrate the concept into their prior knowledge and fully understand it. For this reason they are likely to forget it (Vygotsky, 1978; 170; Shayer and Adey, 1981: 115).

Shayer and Adey’s (1981) research emphasises the importance of cognitive development in the teaching and learning of Science. If secondary students do not develop formal operational thinking skills, they will experience great difficulty in constructing many scientific concepts and in writing reflectively about them.

### 3.2.2 Cognitive Development and Writing in Science

Cognitive conflict or learning in the “Zone of Proximal Development”, reflection and metacognition are the underlying processes that drive cognitive development (Adey, 1999: 6; Barnes and Todd, 1977: 201). There are a number of ways to encourage students to think metacognitively. One is to ask questions about the strategies they use when learning or thinking about particular concepts. Another is to ask them to write reflectively to explore the concepts they are learning and explain how the writing has helped them to learn and think more effectively (Prain and Hand, 1998: 159). Writing demands more conscious thought than speech and is generally more abstract, focused and explicit than the spoken word (Vygotsky, 1986: 182; Britton, Burgess, Martin, McLeod and Rosen, 1975: 24; Bell, 1991: 177). The writing process involves planning, recall, reasoning and
evaluation before, during and after writing. Writing itself demands an awareness of the thinking used in the writing process thus, students must reflect on their ideas and thinking as they plan and write. This heightened awareness of the processes of thinking and learning, or meta-cognition, leads to the development of formal operational thinking (Prain and Hand, 1998: 153; Barnes and Todd, 1977: 202).

The development of writing and cognition are linked (Hand and Prain, 2002: 737). The qualities observed in the written product reflect students’ levels of cognition and can therefore provide useful information for teachers. In the 1980s Wilkinson, Barnsley, Hanna and Swan published the results of the Crediton Project, which explored the relationship between writing development and levels of cognition. In one part of the project researchers asked three different groups of students aged seven, ten and thirteen to write a narrative and an explanation. The writing was evaluated from word to sentence to discourse. Like Shayer and Adey (1981), Wilkinson, Barnsley, Hanna and Swan, (1980) discovered a wide range of developmental abilities at each age level. The weaker writing observed at age thirteen was not as advanced as the better examples from the ten year olds. Their results correlate well with Adey and Shayer’s (1981: 45) findings that formal operational thinking was only just beginning to develop in thirteen year old students (Wilkinson, Barnsley, Hanna and Swan, 1980: 67). The project demonstrated that the writing of descriptions, explanations and the like becomes more complex and abstract as cognition develops. Likewise, Shayer and Adey (1981: 75) also observed that as cognition develops, students are able to describe in more detail to include more variables and relationships. In addition, their ability to provide explanations of predictions, relationships and mathematical models develops fully at the stage of formal operational thinking.

This has implications for Science teaching and learning. When a teacher asks students to write a description or explanation or to analyse an experiment, the writing that students produce will depend largely on their level of cognition. Conversely, it is useful for teachers to know the different features of writing that can be expected at different stages of cognitive development.
3.2.3 Second Generation Cognitive Science and Scientific Literacy

Fundamental scientific literacy is defined by Klein (2006: 144) as the ability to read and write scientific texts and therefore understand them.

First Generation Cognitive Science interpreted *knowledge* as propositions created from a number of concepts, *thought* as logical connections between concepts and *language* as the means of representing knowledge and thought about phenomena. Science teaching founded on this model assumes that thinking arises from the existence of well formed concepts and processes such as formal operational thinking and the control of variables. Language is seen as the result of thought processes and as a means of communication rather than a way of contributing to thinking or a means to construct meaning. Although some of the ideas are similar, the research of Piaget and Vygotsky cited earlier in this chapter is not based specifically on first generation cognitive science.

Second Generation Cognitive Scientists describe *knowledge* as “fuzzy and contextual.” *Thought* is viewed as a process which arises from perceptions and language and, rather than being literal, it is based on narrative and metaphor (Klein, 2006:150). In their view, thought gives rise to *language* which, in its turn, can structure, clarify and express thought. For example, language is used to classify and organise complex action and observations so that they can be discussed further and provided with structure and explicit expression (Klein, 2006:154). The mind is viewed as a network of nodes and knowledge is considered to be a pattern of connections amongst these nodes rather than separate concepts made up from individual and separate words. Thus the network of nodes creates the “fuzzy and contextual” model of cognition.

Second Generation Cognitive Scientists do not deny the existence of formal logic or formal operational thinking, however they question that such forms are the basis of human cognition. In their view the processes of metaphor and narrative are thought to underlie and form the basis of human cognition as it develops in the course of social
interaction (Klein, 2006: 153) and adaptation to the environment (Klein, 2006:155).
Vygotsky also held the view that cognition developed through social
interaction (Vygotsky, 2004: 437) whilst Piaget concluded that the development of
human cognition was essentially an adaptation to the environment (Inhelder and Piaget,

Second Generation Cognitive Scientists think of mental constructs as expressive and
“fuzzy” rather than denotative and precise, as they must be in Science where words and
concepts have specific meanings. In Science classes, students must learn denotative
scientific meanings in order to gain scientific knowledge. They need assistance from
teachers to develop specific conceptual meanings and formal reasoning using the “fuzzy
and contextual” network structures of the mind. In addition, they require assistance to
accomplish the transition from oral narrative language to the denotative written texts of
Science.

The manipulation of objects within the environment appears to contribute to the
development of meaning. In addition language functions to give structure to experience.
Thus, the physical manipulation of objects followed by discussion can contribute to the
development of meaning and understanding (Klein, 2006:158).

The role of the teacher is to structure and facilitate these activities in the classroom so
that the meanings which emerge from student classroom discussions are scientific
meanings. Such discussion links the physical experience and ideas of students to
concepts, and writing further clarifies these. Thus, physical experience, oral and written
language can mediate between the expressive, narrative nature of everyday language and
the denotative nature of scientific language. For these reasons, scientific literacy
involving structured group discussion, individual writing and physical experience such as
role play is fundamental to an understanding of Science.
3.3 WRITING-TO-LEARN

The learning theories of Piaget and Vygotsky influenced the development of research into teaching and learning which resulted in changes to teaching methodologies. In the 1970s this included the identification of a Transmission model and an Interpretation model of teaching and learning. The Interpretation model promotes the active involvement of students in group discussion and reflective writing as a means of constructing new conceptual knowledge (Prain and Hand, 1998: 159). These models are discussed in the first part of this section. A meta-analysis which evaluates writing-to-learn interventions is outlined and discussed in the second part of this section.

3.3.1 Transmission and Interpretation Models of Learning

In 1975 Douglas Barnes, a British educationalist, influenced by the research of both Vygotsky and Piaget, carried out initial work which recommended that students discuss, read and write as part of the process of learning in all their subjects (Bullock, 1975: 189 - 192). Barnes had been into schools and investigated how language was used in, amongst other places, Science classrooms. He recorded the language of both teachers and students and observed how the language of each influenced the learning process. For example, he observed that teachers’ language reflected their ideas about the nature of knowledge and learning. This, in turn, influenced their teaching practice and the way in which they related to students in the classroom (Barnes, 1976: 31). After investigating the teacher’s role in learning, Sheeran and Barnes (1991: 43) would later conclude that, “success in Science appears to have much more to do with understanding the cognitive and communicative rules that are operating in the classroom environment, rather than being dependent on the use of ‘scientific language’.”

As a result of his early observations in classrooms, Barnes (1976: 140) classified two approaches to teaching. He defined these as “Transmission Teaching” and “Interpretation Teaching.” The Transmission teacher provides students with information as they listen and copy passively. Information is mostly learned by rote and reproduced in tests and exams. In this scenario, student contributions to classroom learning are not seen as relevant, and so there is very little discussion between teacher and students. The greater
part of the lesson is taken up with “teacher talk”, which focuses on closed questioning and the teacher’s thinking (Barnes, Britton and Torbe, 1986: 78).

In fact, Barnes (1976: 173) observed that seventy per cent of these question and answer Transmission lessons were taken up by teacher talk. Students were unlikely to be asked to discuss and think about concepts and would rarely, if ever, write reflectively about concepts they were learning. This attitude to learning, and to student discussion and writing in particular, implies that student contributions and ideas about the concepts they are learning have little value in the eyes of the teacher. This attitude is then adopted by the students.

Barnes (Barnes, 1976: 142; Barnes, Britton and Torbe, 1986: 78) observed that Transmission teaching was commonly used in Science classrooms and that learning in schools was generally too passive. Passive learning was the accepted mode in schools, and the idea that Science could be mastered by the use of social interaction, including structured group work, oral and written expression, was not a consideration. Moreover, teachers generally viewed Transmission teaching as a way of getting through the set work and satisfying the requirement that students memorise and know a body of established scientific knowledge (Sheeran and Barnes, 1991: 30; Barnes, Britton and Torbe, 1986: 81). By presenting students only with the views and thinking of the teacher, Barnes concluded that Transmission teachers were unlikely to tap into the learning processes of their students (Barnes, 1976: 23). Barnes (1976: 84) observed that by far the most common form of writing carried out in Science classes was copying information, completing worksheets, and writing for examinations. Over the years, other researchers have commented on the low quality and quantity of oral and written interaction in Science classrooms. They repeat the observations made by Barnes in 1976, and repeated by Sheeran and Barnes in 1991, that students in Science classes write mostly to copy information, record practical work or complete examinations (Yore, Bisanz and Hand, 2003: 711; Prain, 1995: 62; Halliday and Martin, 1993: 201; Reaves, Flower and Jewell, 1993: 34; Durst and Newell, 1989: 381). Barnes (1976: 142) observed that if they write at
all, it is to satisfy the generally implied demands of the teacher, rather than to construct knowledge or develop metacognition using reflective writing.

Barnes (1976: 140) described a second model, which he referred to as “Interpretation Teaching”. This model was influenced by his knowledge of the work of Piaget and Vygotsky, who both emphasised the active participation of individuals in their own learning. Interpretation teaching is a constructivist methodology in which teachers acknowledge that students must be actively involved in the construction of their own knowledge. The Interpretation teacher is sensitive to the cognitive levels of her students, and to the prior knowledge and understanding they bring to the learning process. The teacher’s language and interaction with students during Science classes demonstrate a respect for the student’s ability to contribute to classroom discussion and learning (Barnes, 1976: 140).

Barnes (1976: 103) adopted Vygotsky’s (1987: 85) view that the social need to share our thoughts leads to the construction of meaning and the development of cognition. When individuals compare their view of the world with others they develop models of reality which are more diverse than any they could construct for themselves. Students at school can develop their thinking in a similar way, by participating in structured groups in which there is verbal interaction with other students and the teacher (Hand and Prain, 2002: 744; Sutton, 1992: 71). In this situation students can think about concepts aloud, communicate their ideas to others, including the teacher, and, in turn, listen and respond to the thoughts of their colleagues (Barnes and Todd, 1977: 24). Thus, students can explore and evaluate their thinking. For many students this is how they formulate and test hypotheses about the concepts they are studying (Barnes, 1976: 108). Carefully planned group discussion, which includes considered teacher support and feedback for students, is vital for the success of Interpretation learning. Such dialogue is acknowledged as central to the development of thought and language (Moffett, 1968: 73). Through dialogue students can learn from their peers and teacher. The ability to be specific and provide detail orally and in writing can be developed in structured groups in which students are required to question, collaborate and provide details as they reflect on the concepts they are learning.
If students do not discuss with each other and their teacher in this way, or if they just listen passively, very little other than rote learning is likely to occur (Moffett, 1968: 82).

According to Moffett (1968: 94) class discussions, as opposed to carefully structured group discussions, tend to be a series of limited interactions between the teacher and a number of students in the class. Barnes (1976: 21) observed that when students take part in such class discussions they generally attempt to provide answers that will satisfy the implied demands of the teacher. Whole class discussion is often an ineffective strategy for reflection about concepts and for exploratory discussion, because the teacher does not have access to all the students. The size of the group can also be threatening. For these reasons it is easy for many students to opt out of learning. In the view of both Moffett (1968) and Barnes (1976), the development of thought and the construction of ideas require more than this form of Transmission teaching. Small structured groups, in which each student has a specific role to carry out, provide students with an opportunity to use discussion and language effectively as a means to explore and reflect on new learning:

The importance of language is that it makes knowledge and thought processes readily available to introspection and revision and that it enables us to reflect on our thoughts. Students’ talk and writing is the main way they explore the relationship between what they know and the new observations and interpretations they meet (Barnes, 1976: 19).

Group work must be structured to include all students and to guide them so that they do not just copy and produce what they think the teacher wants to hear, but process, integrate and internalise information about the concepts they are learning (Barnes, 1976: 52). In Interpretation teaching and learning the teacher provides direction for such discussion in small structured groups. The teacher ensures that students have the skills required to work in a structured discussion group. They explicitly teach students how to try and resolve personal difficulties that they may experience within a group, how to listen and encourage all members of the group to participate and how to respond each other appropriately (Moffett, 1968: 98). During group discussion, teachers move amongst the groups and listen. As they listen, they may suggest strategies, identify irrelevant data and correct misunderstandings, but their role is not to provide answers to the questions. Barnes (1976: 185) encouraged teachers to allow students time to think through new
concepts and to accept mistakes and misinterpretations, which further questioning and discussion could rectify as part of the learning process.

The effectiveness of a group discussion is influenced by a number of factors, including the concepts involved in the discussion, the level of skill the students have to take part in a structured discussion, and the nature of the questions that the teacher has designed to guide the discussion (Barnes and Todd, 1977: 28) Students must be explicitly taught to use this type of exploratory discussion in a structured group, as students find it difficult to work in a different paradigm of classroom expectations, where previously the implied demand from teachers has been to produce a correct answer (Barnes and Todd, 1977: 82).

In Barnes’ (1976) view, the reflective and exploratory nature of writing-to-learn is another important aspect of the Interpretation model. In addition to carefully structured group discussion, he emphasized the need for students to use exploratory writing while learning concepts, as a means to clarify ideas (Barnes and Todd, 1995: 24; Barnes, 1976: 31).

Unlike discussion, writing is more focused, detailed and explicit in its expression of concepts and ideas (Bullock, 1975: 144). Through writing students are made aware of thoughts and understanding which would otherwise remain inexplicit, unstructured and only partly understood. Students need to reflect carefully on their understanding of concepts in order to express them. The exploratory and reflective nature of writing-to-learn provides another opportunity for students to construct meaning on their own terms and to integrate it into their structures of reality (Reaves, Flower and Jewell, 1993: 40).

Rather than use “final draft” texts deemed to be the genre in which scientific knowledge must be constructed during the learning process (Christie and Misson, 1998: 10; Halliday, 1998: 91), Barnes, Britton and Torbe (1986: 73) emphasised the need for students to use a wide range of exploratory and reflective writing to provide them with opportunities to think about concepts, clarify their views and integrate new with previous learning. This, they claimed, leads to a deeper understanding of concepts and encourages students to think for themselves. Other writers have supported this approach:
Writing for learning in science should extend beyond traditional records of observations and formal reports. Students should write to explain, to sort out what they understand, to consider alternatives, to respond to and test the written explanations of others, to reformulate ideas in their own words, to speculate about possible explanations and to puzzle over and interpret what others have thought and written (Prain, 1995: 63).

Hanrahan (1999) describes an example of the development of Interpretation teaching in a Year 8 lower ability Science class. Like Barnes over twenty years earlier, she observed that in many classrooms student interpretations of scientific ideas and concepts are not encouraged, and only the teacher’s voice is heard (Hanrahan, 1999: 712). In this writing-to-learn intervention she used anonymous journal writing to investigate the effects of affirmative dialogue on student attitudes to learning. Like Barnes (1976: 118), Hanrahan (1999: 699) acknowledged the importance of student beliefs and feelings as they participate in the learning process. Most students in the investigation responded positively to the teacher’s attitude of encouragement and interest in their developing ideas and the assumption by the teacher that they could write well in their learning journals (Hanrahan, 1999: 707). Although the actual levels of literacy in this classroom were not high, students were motivated to learn by the way the teacher spoke to them about their ideas and their writing. The students felt empowered to think and developed a sense of their own worth. Then they began to construct their own understanding of Science (Hanrahan, 1999: 712)

3.3.2 From Theory to Practice: An Evaluation of Writing-to-Learn

In 2005 Bangert-Drowns, Hurley and Wilkinson undertook a comprehensive review of the literature on the effects of school-based writing-to-learn interventions on academic achievement. They were looking for the effects of writing-to-learn likely to be found in practical situations such as classrooms, rather than from interventions based on laboratory research. They selected only studies which used a quasi-experimental control group. In the forty-five research papers surveyed they found it difficult to define what precisely was meant by writing-to-learn or to find adequate direction informing teachers how to use it effectively in their classrooms (Bangert-Drowns, Hurley and Wilkinson 2005: 26). In one situation, writing-to-learn meant the joint construction of a text by students and
teacher. In another it meant writing about a topic or experience, whilst for others again it involved writing individually after a general group discussion or collaborative group work. In addition, they discovered that, although writing-to-learn was viewed as part of the learning process, it involved a large variety of tasks, many of which had no impact on learning (Bangert-Drows, Hurley and Wilkinson 2005: 31) In addition, many of the investigations were very short term and it was difficult to differentiate between the effects of rote learning and writing-to-learn. The researchers suggest that writing-to-learn may be found to have a greater effect on learning if the grasp of conceptual structure were measured, rather than the recall of factual knowledge (Bangert-Drows, Hurley and Wilkinson 2005: 27). They found that when writing activities were repeated over a longer period of time they had more effect on learning. On the other hand lengthy writing assignments had a negative effect on student learning. They added that students who lack the cognitive development required to complete a particular piece of writing may find longer writing tasks difficult and tedious, and that this could lead to a lack of motivation that could weaken the learning effects of writing (Bangert-Drows, Hurley and Wilkinson, 2005: 30). In their study, writing-to-learn was not found to be an effective learning tool in Years 6-8 and this was thought to relate to developmental issues in which students may have been asked to write in ways beyond their developmental abilities (Bangert-Drows, Hurley and Wilkinson 2005: 53).

Overall, however, the results were inconclusive. In seventy-five per cent of the studies, writing-to-learn, as it was applied in the investigations, improved learning by a small margin, whilst in others it did not (Bangert-Drows, Hurley and Wilkinson 2005: 21). Writing-to-learn did significantly improve student learning when it was used as a tool for reflection, as this helped students to construct concepts and clarify areas of confusion (Bangert-Drows, Hurley and Wilkinson: 2005: 50). However, Bangert-Drows, Hurley and Wilkinson (2005: 29) noted that, overall their analysis demonstrated that there was a lack of understanding about what could be achieved by writing-to-learn, and a lack of direction about how it could be applied effectively in classrooms. This view has been supported by Prain and Hand (1998: 152) who wrote:
The current conceptions of writing-to-learn are embryonic and fragmentary. Little consideration has been given to the internal cognitive processes that lead to more accurate understanding and insights as a result of the struggle to compose.

Three years later the same authors (Hand and Prain, 2002: 740) added:

There is inconclusive evidence on the effects of using different kinds of student writing-to-learn in science. Most studies fail to provide a detailed account of classroom context or teacher’s method or focus of student learning and therefore provide limited evidence of the effects of these factors on student learning.

Nevertheless, a number of researchers have provided insights into the effective use of writing-to-learn in Science classrooms. Newell and Winograd (1989: 211) discovered that effective use depended on the nature of the writing. For example, they found that producing written explanations improved the understanding of concepts more than note-taking or answering study questions. They concluded that explanations have the ability to integrate new and prior learning in a way that rote learning and note-taking do not. For this reason explanations also enhanced the retention of constructed knowledge.

A number of researchers have found the process of writing-to-learn to be most effective when individual writing is preceded by oral discussion (Hand and Prain, 2002: 749; Rivard and Straw, 2000: 578). On the completion of a four year study of writing-to-learn in Science classrooms, Hand and Prain (2002: 749) commented on “the importance of discussion as a clearing house for ideas and as a way to develop and refine student focus and interest. Classroom discussion of relevant conceptual knowledge was a very important element in guiding student writing”. In an exploratory study by Rivard and Straw (2000: 578) a total of 43 students were divided into four groups. Each group was asked to construct a scientific explanation of ecological data from the field using a different learning strategy. The four groups were organized as follows:

- one group explored the topic using discussion about the task;
- another used only individual analytical writing about the task;
- the third group discussed the task followed by individual analytical writing;
- the control group was told just to complete the task.
Students were scored on multiple choice tests, essays and concept maps. A pre-test, post-test and delayed post-test were administered. Their results demonstrated that discussion and writing appeared to enhance the retention of Science learning over time, but did not have a substantial effect on immediate learning. This was followed by discussion alone, which the researchers thought of as important for sharing, classifying, asking questions, hypothesising, explaining and formulating ideas. However, although group discussion was effective for the retention of facts and simple concepts, writing seemed to be needed if more complex integrated concepts were to be retained. In this case, writing on its own did not enhance learning or appear to integrate knowledge effectively. The poorest results were scored by the control group with undirected learning. (Rivard and Straw, 2000: 588). This research indicates that the most effective application of writing-to-learn in Science classrooms involves the use of structured discussion followed by individual writing about a concept.

A number of researchers agree that from a theoretical perspective some form of writing-to-learn could be expected to improve learning in Science classrooms, but that adequate research has not been carried out (Bangert-Drown, Hurley and Wilkinson 2005; Yore, Bisanz and Hand, 2003). There is insufficient definition of what constitutes effective writing-to-learn in a Science classroom, and no research that provides an adequate theoretical research base to inform practice in Science classrooms.

3.4 WRITING IN SCIENCE CLASSES IN NSW

The current approach to writing in the NSW Science Syllabus is derived from the Genre Theory of the “Sydney School” of linguists (Christie, 1989), which has its origins in the theories of Halliday (1975). The development of these theories and the implication of both as models for Science teaching and learning are described and evaluated from the literature. The influence of Genre Theory on writing in Science classes in NSW is also surveyed.

3.4.1 Writing in Schools and the Influence of Genre Theory

Genre Theory, based on the idea that scientific knowledge is constructed using specific scientific genres, has influenced the teaching of writing in Science classes in Australian
schools for the past 20 years. This influence is evident in the most recent New South Wales Science Syllabus Support Document (Board of Studies, 1999), in which the theoretical understanding supporting writing in Science classes is based on Genre Theory. For example, by the time they enter secondary school:

Students are expected to have a reasonable understanding of the main science text types¹ used in School science as set out in the table below.

<table>
<thead>
<tr>
<th>Name of text type</th>
<th>Purpose of text type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recount</td>
<td>Retelling a series of events</td>
</tr>
<tr>
<td>Procedure</td>
<td>Instructing how to do something</td>
</tr>
<tr>
<td>Report</td>
<td>Describing what something is like</td>
</tr>
<tr>
<td>Explanation</td>
<td>Saying how and why something happens</td>
</tr>
<tr>
<td>Exposition</td>
<td>Convincing someone of a point of view</td>
</tr>
<tr>
<td>Discussion</td>
<td>Drawing a conclusion after discussing several points of view on an issue</td>
</tr>
</tbody>
</table>

(Board of Studies, 1999:177)

Genre Theory is derived from Halliday’s (1976) systemic functional linguistics. Halliday (2004: 205) views language not only as a system of rules or a way to communicate our thoughts and feelings but as our major resource for the construction of meaning about the world and our experiences within it. In fact, Halliday (1985: xvii) maintains that it is impossible to construct meaning from experience without the use of language. Moreover, he identifies genres as the basic oral and written linguistic forms with which we construct meaning from our experiences. In Halliday’s view, genre “is the language people produce and react to, what they say and write, read and listen to, in the course of daily life” (Halliday and Martin, 1993: 123).

According to Halliday (Halliday and Martin, 1993: 84), genres have evolved to create meaning in all the different contexts of human existence. Thus scientific knowledge, like all human experience, is constructed using particular genres. Halliday considers that the genres and language of Science have evolved to construct “a special kind of knowledge - a scientific theory of experience” (Halliday, 2004: 223; Halliday and Martin, 1993: 20).
In Halliday’s view, scientific thinking develops from commonsense thinking through the use of specific scientific genres that explore the structure and function of phenomena, and the reasons why these phenomena occur (Halliday and Martin 1993: 168). He maintains that it is impossible to consider scientific content separately from the genres and language in which it is encoded. This central idea depends on Halliday’s view that there is a direct connection between our experience, the meaning we create from it, and the generic form in which it is expressed (Halliday, 1985: xix). Therefore, if students are able to use the spoken or written genres related to Science, they will be able to understand scientific knowledge and participate in its construction (Halliday, 2004: 91):

It follows that to be illiterate in science is to be denied access to a crucial aspect of its technology. Most significantly it follows that science cannot be understood “in your own words.” It has evolved a special use of language in order to interpret the world in its own, not in commonsense, terms (Halliday and Martin, 1993: 200).

In Halliday’s view scientific knowledge “has evolved as a metaphoric reconstrual of experience” (Halliday, 2004: 92) and its accompanying linguistic form governs how scientists create meaning in Science and how students must learn to create scientific meaning at school. Language and meaning in the form of specific genres cannot be separated (Eggins, Martin and Wignell, 1987).

Because of the relationship he deduces between genres and the construction of scientific knowledge, it is essential, from Halliday’s point of view, for students to understand the technical terms and use the generic linguistic forms in which scientific knowledge is said to be constructed (Halliday and Martin, 1993: 198). Students must understand that scientific language has a different purpose from everyday language (Halliday and Martin, 1993: 168). According to Martin (Halliday and Martin, 1993: 186), if students are not explicitly taught the characteristics of these genres, particularly the impersonal report, they will experience difficulty learning scientific concepts and acquiring scientific literacy. In his view, failure to understand scientific concepts and difficulty with thinking and writing about Science are related to a lack of mastery of the oral and written genres required in a particular scientific context (Halliday and Martin, 1993: 167; Christie, 1989: 163).
To determine the genres and linguistic forms used in the construction of scientific concepts, Halliday analysed publications by Newton, Priestley, Dalton, Darwin, and Clerk Maxwell as well as Secondary Science textbooks and writings from *Scientific American* (Halliday and Martin, 1993: 71) He concluded that scientific knowledge is constructed most frequently by the report, explanation, experimental report and exposition.

The dominant linguistic form used in scientific genres to create meaning is the grammatical metaphor (Halliday, 2004: 94; Halliday and Martin, 1993: 80). Grammatical metaphor occurs when processes expressed as verbal phrases are converted into nouns to identify new technical abstractions. For example, “*If a fire burns more intensely it gives off more smoke*, is changed to, *Fire intensity has a profound effect on smoke injection*” (Halliday, 2004: 19).

According to Halliday, grammatical metaphor began its evolution as the dominant linguistic form of expression in Science in the 18th century, developing from linguistic forms that already existed in English. It was developed by scientists such as Newton and Priestley as a way to reify abstract concepts in their formal writing. This development allowed scientists to discuss the processes of Science as if they were objects (Halliday and Martin, 1993: 64). Nominalisation is the most commonly used form of grammatical metaphor.

Students first experience this linguistic form when they come to study Science at secondary school. Prior to this, Halliday (2004: 19) maintains their linguistic abilities have not developed to a point where they can fully comprehend or use it. According to Halliday (2004: 115) this ability develops around the age of puberty. He maintains that the necessity to create scientific knowledge using grammatical metaphor is the basis of the difficulties students frequently experience in Science classes. Although, in his view, meaning is first created by spoken language, written language uses grammatical metaphor to develop meaning further by removing it from its direct relationship with experience (Halliday, 2004: 120). According to Halliday, the view of the world created by this form
of scientific grammar is very different from the world-view created by everyday spoken language and it is this that poses the challenge for students (Halliday, 2004: 128).

3.4.2 GENRE THEORY: THE “SYDNEY SCHOOL”

The Australian Genre School developed in the early 1980s from Halliday’s Genre Theory, partly as a reaction to the “natural” approaches to writing which assumed that writing developed in much the same way as speech (Christie and Misson, 1998: 47; Halliday and Martin, 1993: 198). In the view of the genre theorists, these “natural” approaches described language development only in the most general terms and failed to provide an explicit, systematic methodology that teachers could use to teach language.

Some teachers, they noted, continued to teach traditional grammar, whereas others provided their students with opportunities to use language for discussion, reading and writing, assuming that, in the course of events, they would learn to use language effectively. In addition, these teachers viewed writing as a neutral commodity, important only for the expression of individual ideas and knowledge and the development of thinking (Christie, 1989: 153). Most significantly, “naturalist” views were seen as failing to acknowledge specific genres as fundamental for the construction of meaning in Science (Christie, 1989: 161). Such views also assumed that content could be separated from the language used to construct it (Christie, 1989: 153).

Halliday’s followers have applied genre theory to the Science curriculum maintaining that students “must learn the various text types or genres in which knowledge is constructed” (Christie and Misson, 1998: 10). Like Halliday, Christie (1989: 43) asserts that if students have not mastered these scientific genres, using the linguistic forms identified by Halliday they will experience difficulty learning scientific knowledge and skills (Halliday, 1998: 91). Christie considers that “much school failure is language failure: failure to use the linguistic patterns appropriate to a range of information, attitudes and ideas valued by schools” (Christie, 1989: 163). Teachers need to understand
and explicitly teach the genres in which scientific knowledge is claimed to be constructed, so that their students can understand Science

Although genre theorists state that scientific knowledge is constructed using particular genres such as the report and explanation (Halliday and Martin, 1993: 186) they do not accept the constructivist views on which the writing-to-learn model is based. They claim that students cannot explore, construct and integrate new knowledge using their own language. They do not subscribe to the idea of social construction of knowledge using exploratory language, but maintain, instead, that the only means of constructing scientific knowledge for students is to master specific oral and written scientific genres.

### 3.4.3 An Evaluation of Genre Theory

According to Halliday (2004: 121) “spoken language will always have priority because that is where meaning is created and the categories and relations of experience are defined”. However, most of the linguistic analyses of scientific texts undertaken by Halliday and his colleagues (Halliday and Martin, 1993: 91) involve formal scientific writing. Their assumption is that scientific knowledge is, in fact, constructed by these formal written genres. Halliday (2004: 60) analysed the genres and linguistic forms purported to construct scientific knowledge by studying the formal writings of scientists such as Newton, Priestley, Dalton, Clerk Maxwell and Darwin. In his analyses he failed to acknowledge that these formal texts are the distillation of years of experimentation and thought, and do not necessarily reflect the forms of language used during the construction of the scientific ideas. For example, it is currently unknown precisely how Newton constructed scientific ideas, or the language he used, because to date no one has completed a linguistic analysis of his working notebooks (Iliffe and Mandelbrotte, 2006). In other words, Halliday neglects the important issue of ‘register’ in the forms of scientific writing he is analysing. He defines ‘register’ in the following passage:

> Types of linguistic situation differ from one another, broadly speaking, in three respects: first, as regards what actually is taking place, second, as regards what part the language is playing and third, as regards who is taking part. These three variables, taken together, determine the range within which meanings are selected and the forms which are used for their expression. In other words they determine ‘register’.
Although Halliday (1978: 7) acknowledges that scientific register reflects the conventions of the day he fails to explain how, if it can be constructed only in specific genres and linguistic forms, scientific knowledge continues to be constructed when these conventions change. For example, in the nineteenth century the use of the passive voice became a convention to give an impression of objectivity to scientific writing (Halliday and Martin, 1993: 57). This convention was dropped in the latter part of the 20th century. During the 20th century there was a tendency to use grammatical metaphor increasingly, until the density of the language led to a revision of the convention away from nominalisation. (Halliday and Martin, 1993: 84) In the 1970s when Halliday first analysed journals such as Scientific American the conventions of scientific language included the use of the past passive voice, latinised nouns, long adjectival clauses and impersonal forms of language. These are no longer regarded as the only acceptable way to express scientific knowledge in written language (Rundblad 2007; Stevens 2007; Roland 2007). Rundblad (2007: 254) and Matthews and Matthews (2007:36) note that the passive voice with its attendant impersonalisation can be used to disguise the author or researcher so that the research appears to be more objective, and therefore more persuasive, because a reduced experimenter effect is implied (Rundblad 2007: 254). Thus, on the one hand Halliday maintains that there are a set number of genres and linguistic forms with which scientific knowledge can be constructed, while on the other hand we know that the nature of scientific genres and their contexts have continued to change (Halliday and Martin, 1993: 84). In spite of changing conventions within scientific writing over time, scientific knowledge has continued to be constructed and understood.

Paradoxically, although Halliday (Halliday and Martin 1993: 54) recognised only a small number of scientific genres in which they considered Science is constructed, he acknowledged that Science is constructed over a wide range of registers and styles, and that the contexts in which scientists construct knowledge are many and varied (Halliday,
This argument depends on a strong systemic distinction between ‘genre’ and ‘register’. Genre is defined as:

a set of communicative events, the members of which share some set of communicative purposes (Swales, 1990:58).

Thus a genre can be used for a large number of registers.

Halliday and the Sydney Genre School insist on the use of a small number of narrowly defined formal written genres. They express no explicit theoretical reason for this except that, without them, scientific concepts will not be understood or learned. This implies that Science is a linguistically limited pursuit. In fact this does not appear to be the case. Latour and Woolgar (1986) analysed all the literature produced by the members of a scientific laboratory. They discovered a large variety of written genres including:

drafts of articles in preparation, diagrams scribbled on scrap paper, letters from colleagues, reams of paper spewed out of the computer, excerpts from draft paragraphs, while more advanced drafts pass from office to office being altered constantly, retyped, recorrected, and eventually crushed into the format of this or that journal, scribbled on blackboards, dictated letters or prepared slides for their next talk (Latour and Woolgar, 1986: 50).

Further investigation of the concept of register leads to a different view of the use of language in Science. Scientists use both formal and informal discourse in the construction of scientific knowledge and both forms of discourse interact (Latour and Woolgar, 1986: 53; Gilbert and Mulkay, 1984: 47; Knorr- Cetina, 1981: 14). Gilbert and Mulkay (1984: 57) observed that formal written experimental reports exist alongside an alternative linguistic resource which they referred to as “the contingent repertoire.” This consists of informal discourse, such as the conversations and note-taking which are excluded from formal discourse.

In informal talk, the scientific views of scientists and their actions in the laboratory generally appear much more personal, open to debate and dependent on other social influences, such as the implications of group membership, personal preferences and social position (Latour and Woolgar, 1986: 153-190).
Scientists interviewed by Gilbert and Mulkay (1984: 58) acknowledged that the practice of constructing scientific knowledge differs from the process of constructing a formal research report. Formal written genres and their linguistic forms represent only one concern experienced by scientists when writing final research reports. Other concerns identified by Latour and Woolgar, (1986: 194) and Knorr-Cetina (1981: 98) include status amongst peers, the possibility of awards, advancement, future grants, competition, what is acceptable in the scientific community and potential or anticipated criticism. These and other considerations influenced the manner in which information was selected and expressed in their reports.

Thus, the research report itself is a genre defined by specific conventions which can vary depending on the motives of the writer. It contains a distillation of laboratory work in which only significant and essential information from laboratory discourse and action has been selected (Gilbert and Mulkay, 1984: 55; Knorr-Cetina, 1981: 94). The formal scientific writings that Halliday analysed will also reflect conventions, demands and concerns besides the construction of scientific knowledge and these concerns will influence the structure of the genre and linguistic forms used in its construction.

How does the analysis of formal scientific writing by Halliday, and the construction of scientific knowledge by scientists, relate to students studying Science in secondary classrooms? Latour (1987: 99) divides scientific knowledge into two areas. There are the “settled parts” of Science, about which there is agreement, and the “unsettled parts” which continue to be the subject of empirical research, debate and controversy. At school students study the concepts that scientists agree upon as part of the “settled parts” of Science. Even when school students are carrying out “experiments”, they are generally demonstrating “settled” knowledge. This is different from the type of knowledge construction undertaken by scientists who are constructing meaning in the “unsettled parts” of Science. For scientists this involves extensive debate.

Like Halliday, the Sydney Genre School does not differentiate between the genres used by scientists and those used by students. By definition, if the context changes, so must the
genres. For this reason and others that have been discussed, it cannot be claimed that school students learning the “settled parts” of Science will use the same genres as practising scientists. As Sawyer and Watson, (1995: 70) observe:

The genre school make great play of the fact that genres arise from social contexts, and yet in the social contexts of schools they want the language of the expert-to-expert scientists used to those and by those being initiated into scientific understanding. The language of Science as characterised by Halliday, Christie and others may well be the least appropriate to use in the context of school Science classrooms.

The practical application of Genre Theory in Science classrooms creates a number of difficulties. To write in the specific genres recommended, students generally extract information from secondary sources and organise it using a scaffold. Little research appears to have been carried out on how much Science students learn in this way (Sawyer, 1995:12). With its emphasis on form, Genre Theory encourages students to concentrate on language structures rather than on the meaning of the concepts they are studying (Sawyer and Watson, 1995: 74).

The Sydney Genre School is so committed to the use of genre to construct scientific knowledge that a particular genre can become an end itself and the scientific understanding can be lost in the process of creating the text (Sawyer, 1995:12). Particular questions that are raised in this evaluation include:

- the assumption that particular formal scientific writing represents the only way in which scientists construct scientific knowledge;
- the validity of extrapolating from the formal writings of scientists to the school classroom;
- the lack of empirical evidence that students in Science classes do construct knowledge using the various genres listed by Halliday and members of the Sydney Genre School;
• the lack of empirical evidence supporting the list of genres with which, according to genre theorists, students construct scientific knowledge at school.

Halliday and the “Sydney School” focus on a narrow range of formal written scientific genres. Identification of these genres has been problematic, and varies from one source to another (Halliday and Martin, 1993: 202; Christie and Rothery, 1989: 10). Christie and Rothery (1989: 10) argue that meaning is embedded in genres such as the descriptive report, discussion, exposition and explanation, whereas Martin (Halliday and Martin, 1993: 202) identifies the major scientific genres as the report, experiment and explanation. The NSW Science Syllabus (Board of Studies NSW, 2003: 42) identifies scientific genres as the discussion, explanation, procedure, exposition, recount, report, response or experimental record. Which is the definitive list of genres that can be used to construct scientific knowledge in classrooms? According to the “Sydney School”, whichever written genres are required, it follows that attempting to understand meaning without attending to the correct form will lead to a failure in understanding (Halliday, 1998:91).

Much of Genre Theory as it is applied in secondary schools is not explicit or clear. Although specific written genres are to be used for the construction of scientific knowledge, writing has other uses. According the “Sydney Genre School”, writing is carried out for the following reasons:

Firstly, it provides the students with records and notes of work, which they may need to use for their own revision purposes or for developing a more extensive project of some kind. Secondly, it is used to test both a student’s understanding of work learnt and/or his or her ability to develop a particular kind of genre. Rothery (1984: 106-7)

In other words, writing is used for recording, revision and assessment which implies that writing is used to copy notes and reproduce them during a written test. This view of the purpose of writing fits the model of Transmission teaching (Sawyer and Watson, 1995:}
According to Sawyer (1995), Genre Theory’s singular emphasis remains the explicit teaching of formal written genres by modeling and scaffolding:

Although these genres are claimed to construe scientific knowledge, in practice their content is not viewed as highly by the Australian Genre School as mastery of generic form, however contradictory this may appear. (Sawyer, 1995: 12)

Genre theorists have developed a theory based on the underlying assumption that all scientific knowledge is constructed using specific written genres with particular linguistic patterns and cannot be constructed using any other form of language. This is a theory about the function of oral and written genres in the construction of scientific knowledge. However it lacks a theory of learning to support its application (Sawyer and Watson, 1995:75). Genre theory makes no contribution to theories of cognitive development apart from the hypothetical statement that the ability to use and understand grammatical metaphor develops as students reach the age of puberty (Halliday, 2004: 115; Christie, 1998: 69). There is no theoretical research on the relationship between the use of genres and student learning or the development of language, metacognition or cognitive development.

Genre Theory is not clear about the relationship between student understanding and the use of appropriate genres for the construction of scientific concepts. According to Genre Theory students construct scientific concepts by speaking or writing about them in a particular genre. It is unclear how a student can speak or write about a scientific concept in a structurally correct genre before the concept is understood. How the student comes to develop an understanding of the concept is not clear. Halliday (1998: 25) claims that once a student has internalised an experience it can then be made into a text, but he does not explain the process by which the experience is internalised. Christie (1998) described ten weeks of Biology lessons in which the students learnt scientific concepts and the explanation genre. In this study the students did not use the explanation genre to construct scientific knowledge for their own understanding. Rather they used it as a means of communicating their understanding. As their teacher explained, “The language they are using shows me what they’re learning. You can’t write an explanation of a process
unless you really understand it. Writing an explanation forces you to come to an understanding of how one event is logically related to others.” (Christie and Misson, 1998: 88) This implies that the students wrote the explanation genre after they understood the concepts. It is not clear how the students come to have some understanding of the scientific concepts before they write the explanation which constructs the scientific concepts.

3.4.4 The Approach to Writing in Science Classes in NSW

This view of genre described above is reflected in the NSW Science Syllabus Support Document (Board of Studies, NSW, 1999). In this document various genres are referred to as text types. Teachers are advised that:

Practice of oral and written text types listed in the Science Stages 4-5 Science Syllabus will also empower students with the skills to participate more fully in public forums where issues about science are discussed.  
(Board of Studies NSW 1999: 64)

Although the current NSW Science Syllabus espouses an approach derived from Genre Theory, there has never been a detailed literacy policy designed to support secondary science teachers and their students. For example, the Curriculum Review of 1994 (Curriculum Corporation, 1994) provided no clear directions about how to use oral and written language to construct concepts in the Science classroom (Yore, Bisanz and Hand, 2003: 690). In addition, there has been little guidance about how teachers and students might use oral and written language effectively to assist learning in Science classrooms. This aspect of literacy has not been acknowledged in syllabus documents as central to all teaching and learning in Science. Literacy is generally viewed as an extra subject area that for some reason has to be taught in Science, rather than as fundamental to all teaching and learning. This view is aptly expressed in the editorial of the Journal of the Australian Science Teachers’ Association (Carnemolla, 2007: 4):

More and more is being asked of (Science) teachers…… Teachers are expected to teach cross-curriculum areas such as literacy, numeracy, information communication technologies and deal with the emotional needs of a student population of increasing diversity.
In a document entitled *The Teaching of Literacy in Science in Year 7* (New South Wales Department of School Education, 1997: 10) the NSW Department of School Education supports the idea that language can be used to communicate and develop students’ understanding of Science. It is stated that “For effective learning in science, students need to be able to use literacy skills ……. to construct knowledge in a systematic way and to convey their understandings to others” (NSW Department of School Education, 1997: 8).

It is recognised that students develop understanding through the use of language (NSW Department of School Education, 1997: 15). The document also acknowledges that participation in cooperative learning activities can help students “to clarify their thinking, to share and test ideas, to communicate with others and reflect on their own learning and to respond to what they hear and see.” (NSW Department of School Education, 1997: 15)

The fundamental purpose of cooperative groups as a means of enabling students to discuss, construct and integrate new learning with what they already know is not explicitly stated. In addition, *The Teaching Literacy in Science Year 7* states:

> Generally students will need explicit teaching if they are to understand the more sophisticated literacy demands of the HSC science courses. Teachers will need to find a way of explaining how language works in science (NSW Department of School Education, 1997:14).

The extraordinary statement that “teachers will need to find a way of explaining how language works in science” reads as a resignation of responsibility by the authorities to make literacy teaching explicit to teachers.

The New South Wales Department of Education and Training’s State Literacy and Numeracy Plan, *Focus on Literacy: Writing* (New South Wales Department of Education and Training, 2000) views the teaching of genres as a way of providing students with a framework for the more specialised writing demanded in secondary school. These attitudes are echoed in the Science Syllabus Support Document, where the purpose of writing in Science is explained with no reference to reflective writing or any form of writing-to-learn:

> Scientific activities are classified as chronicling science, challenging science, explaining events scientifically, organising scientific information and doing
science. All these activities are written or written about. Scientific language has distinct features that can be taught using the idea of text types. The purpose of communication demands a certain way to organize our information; the topic and the audience determine the words we use.

(Board of Studies, 1999: 177)

In the current NSW Science Syllabus (Board of Studies NSW, 2003) only the use of language for the purpose of communication (Board of Studies, 2003: 26) or for presenting information (Board of Studies NSW, 2003: 42) is discussed. The Science Syllabus states that:

Literacy is the ability to communicate purposefully and appropriately with others in a wide variety of contexts, modes and mediums.

In the syllabus, students are provided with ongoing opportunities to develop their use of the specific language and terminology of science to communicate their knowledge, understanding and skills to a range of audiences.

(Board of Studies NSW 2003; 26)

The Syllabus expresses the expectation that students will learn to select and use different types of texts or genres:

Students are expected to learn to select, and use appropriately, types of texts for different purposes and contexts including a discussion, explanation, procedure, exposition, recount, report, response or experimental record for oral or written presentation (Board of Studies NSW, 2003: 42).

In this document spoken and written genres are seen only as a medium for communication. There is no mention of their purpose as the means of constructing scientific knowledge as expounded by the genre theorists.

Writing-to-learn has had little impact on the current NSW Science Syllabus. In the Science Syllabus (Board of Studies NSW, 2003) there is no reference to the importance of well structured group discussion for the construction of knowledge and for the integration of new ideas into each student’s view of the world. Nor is there any mention of the importance of reflection, through group discussion and individual writing, as a way to develop metacognition and cognitive development. However, in the Support Document under “Speaking in Science” the following directive is given:
If the teacher provides activities which encourage exploratory talk, students build their field knowledge. Exploratory talk is different from the kind of social talk that students engage in frequently and teachers need to plan activities which develop speaking skills in predicting, explaining and hypothesizing if students are to be extended beyond the normal retelling and narrative of social talk.

In introducing new concepts, the teacher must provide opportunity for the students to build up the field by exploratory talk before moving on to reading and written tasks. Exploratory talk can be used again any time in the teaching/learning cycle of the topic, for example after reading tasks, as this can assist students to incorporate new information into their existing understanding (Board of Studies NSW, 1999:170).

The impression of literacy policy expressed in the documents from 1994 to 2003 is of an uncoordinated, inconsistent jumble of information lacking theoretical depth. Although the information is derived from Genre Theory, there is no information in the documents to explicitly inform teachers about the theoretical basis of Genre Theory, and why or how the use of genres might assist student learning. There is no information about how best to use oral and written genres in a Science classroom. In addition there is no reference to an evaluation of the efficacy of Genre Theory and the scaffolding that accompanies it, as an effective approach to speaking or writing in a Science classroom. On the other hand, writing-to-learn scarcely rates a mention.
LITERATURE REVIEW

PART 2

LITERATURE REVIEWED DURING THE INVESTIGATION

This review of literature was undertaken in response to questions that arose during the investigation of the substantive issue. The review of literature relating to each question is listed under the following headings:

3.5 Role Play
3.6 Learning Styles
3.7 Teaching Using the Kinaesthetic Modality
3.8 Imagery and Visualisation
3.9 The Nature of Memory
3.9.1 The Enactment Effect

3.5 ROLE PLAY

There is little research about the use of role play in Science classes (Aubusson and Fogwill, 2006:94) or about the relationship of role play to writing, although the existence of this relationship is commonly accepted (Cremin, T, Gouch, K, Blakemore, L, Goff, E., and MacDonald, 2006: 273).

Role Play can be used in Science to provide students with a physical, concrete model of abstract concepts (Aubusson and Fogwill, 2006: 102). It enables students to experience concepts and this experience leads to the construction of understanding as students act out ideas and clarify misconceptions through their actions, narrative and discussion with peers and the teacher (Van Ments, 1999: 23; Aubusson and Fogwill, 2006: 93). Teachers
can observe the level of understanding of each student as they observe the role play and listen to the discussion and questioning. The physical activity of role play tends to motivate students and make Science lessons more interesting. In addition, by opening up dialogue between the students themselves and the teacher, it enables the learning needs of individual students to be addressed (Van Ments, 1999: 25).

The teacher’s role is to create structured discussion within the role play that will enable students to focus on their understanding and construction of the concept. After a role play students are expected to be able to answer questions and write about the new concept as part of the construction of their understanding. Role plays are, however, imperfect models of a concept, and therefore students must also be made aware of the deficiencies of the model. (Aubusson and Fogwill: 2006: 94).

There are a number of ways in which role play can assist students in the construction of the concepts they are learning.

Role play is multimodal, providing kinesthetic information through movement, pressure and spatial orientation in addition to aural and visual information. According to Piaget and Vygotsky, all thinking originates in physical experience (Piaget, 1971: 334; Vygotsky, 1986: 53). Our first representations of experience, such as the physical manipulation of objects, are motor representations or action schema, which are internalized into the cognitive system as automatic knowledge. These physical schemas become the foundation of the next level of cognition (Piaget, 1971: 8). Piaget noted that, even after an adult has achieved more abstract forms of thinking earlier forms of thought can remain submerged within apparently completed mental structures (cited in Vygotsky, 1986:142). These can be used in the processing of new and unfamiliar material and can help in the understanding of new concepts (Piaget, 1976:6). The concrete presentation of concepts during a role play appears to enable this form of processing to occur.

According to Vygotsky (1986: 141) secondary school students may be able to use a concept correctly when relating to it in a concrete way, but may then be unable to express the concept in words. It is difficult for students to speak or write about a concept when
the concrete referent is no longer present and it has, therefore, become an abstraction (Vygotsky, 1986: 142). Role play can provide a physical, concrete representation of an abstract concept while at the same time students are expressing the concept in words.

Role play may also use drawing, which includes using symbols to represent objects, and often contains a narrative sequence. Klemm and Iding, (1997: 1), in their study of pre-service teachers found that pictures drew on multiple modalities of learning and stimulated memory, allowing teachers to express class experiences and their emerging understandings of Science in their journal writing.

Role play carries a story within it and as writing requires information to be organised and sequenced the narrative of a story line helps in this structuring (Blakemore and Frith, 2005: 48). There is evidence that narrative also helps to access information to be organised from the long term memory. For example Bower (1970: 531), in an experiment, asked college students to learn twelve lists of concrete nouns. Half the students were instructed to learn their lists using narrative. When asked to write down as many words as they could, the narrative group remembered two to four times as many as the other participants. Representing information in a narrative form is thought to aid recall because it increases the structure of the information and makes it more meaningful (Bower, 1970: 532).

Structured discussion is integral to role play in Science. This social construction helps students to clarify and structure concepts and expand the thinking of all participants by presenting information in varied ways (Moffett, 1968: 93). In the course of the dialogue students also develop their language by learning from the words and language structures of others (Moffett, 1968: 61). Significant learning may be hindered where students do not engage with each other in these ways, or if they merely listen (Moffett, 1968: 82).

Role play has also been shown to have a strong effect on verbal recall. Engelkamp and Zimmer (1994: 207) found that dramatic performance improved memory far more than learning phrases by verbal repetition or by observing the actions of another person. This improvement is attributed to the motor processes involved in the performance of actions
and there is strong evidence to suggest that kinaesthetic activities also stimulate imagery and visualisation. In a similar fashion Grainge, Coouch and Lambrith (2005: 1005) found that students were able to write more effectively after participating in dramatic activities such as role play.

### 3.6 LEARNING STYLES

The use of role play for teaching and learning includes the kinaesthetic modality. Because reference to different sensory modalities has so many associations with Learning Styles it is necessary to clarify the approach taken to these modalities in this investigation.

The issue of Learning Styles emerged during the course of the investigation because of references to the use of the kinaesthetic modality and visualisation during role play, and because of questions regarding learning styles that were raised by participants in the investigation. The idea of a preferred Learning Style and the use of the kinaesthetic, visual and auditory modalities were popularised in schools by the Accelerated Learning Movement in the early 1990s (Grinder, 1991; Rose, 1987). In the school where this investigation took place Learning Styles was an accepted model used for teaching and learning. The Learning Style Inventory (Dunn, Dunn and Price, 1989) was available for the use of both staff and students.

Learning Styles are commonly used as a way of reflecting on the effectiveness of both teaching and learning. The concept of Learning Styles is generally accepted uncritically by students, teachers and many academics (Looss, 2001: 186). During the course of this investigation students mentioned, in focus groups and conversations, the implications of their personal Learning Styles on their ability to learn. Some claimed to be visual learners whilst others claimed to learn only by doing. These students commented on the way concepts were presented and whether or not one presentation of another would be appropriate to their preferred Learning Style.

The concept of individual Learning Styles has been discussed in educational literature for the last forty years. (Willingham, 2005:1). However, one of the most significant problems
about this concept is the lack of a definition. In a critical review of research into learning styles, Coffield, Moseley, Hall and Ecclestone (2004: 147) listed seventy-one different models of Learning Styles. In each case the relevant characteristics of learners and the mode of instruction were not well-established and the claims for predicted learning behaviour varied widely.

There is no reference to Learning Styles in the literature of cognitive psychology. Cognitive psychologists, such as Looss (2001; 188) are critical of the way models of Learning Styles tend to treat sensory input, perception and learning as if they were the same process and thus fail to acknowledge that cognitive processing is required for comprehension to occur. In addition, Looss (2001) criticises the literature of Learning Styles in general, as simplistic in not accounting for other factors that may influence learning such as motivation, the decisions students make about what they will or will not learn, and the interest and relevance of the subject to particular students. She suggests that rather than appealing to individual Learning Styles, the use of different teaching approaches may increase the interest and motivation of individuals who do not relate to “chalk and talk”, thus enabling them to learn more effectively (Looss, 2001:191). Instead of individual modality based teaching, cognitive scientists recommend that teachers think of the best and most appropriate modalities in which to present a topic for the benefit of all students (Willingham, 2005: 5; Kavale and Forness, 1987: 236).

Research into Learning Styles is also generally considered to be poor when peer reviewed. Not only is there confusion about the definition of the concept, but there is no over-arching, empirically based theory of Learning Styles for which further evidence may be gathered. (Coffield, Moseley, Hall and Ecclestone, 2004: 143). The methodology of research into Learning Styles has often been questioned and it is claimed that there are very few robust studies that offer reliable and valid evidence and clear implications for practice based on empirical findings (Coffield, Moseley, Hall and Ecclestone, 2004: 11; Stahl, 1999: 2). Criticisms include that frequently the studies are not designed to disconfirm a hypothesis, and that subjects pre-tested for a Learning Style tend to anticipate particular experimental outcomes and are open to expectation and participation.
effects (Coffield, Moseley, Hall and Ecclestone, 2004: 42; Curry, 1990: 52). Moreover, much of the research cited by Dunn and Dunn was carried out by PhD students in the department where Rita Dunn was professor (Willingham, 2005: 7; Stahl, 1999: 2; Dunn and Griggs, 1995: 15; Curry, 1990: 4). Curry (1990: 54) also maintains that attempts to replicate claims made by research into Learning Styles have, at times, been unsuccessful, and that all require a well constructed evaluation of their ability to sustain their claims.

From the 71 models of Learning Styles that they identified, Coffield, Moseley, Hall and Ecclestone (2004: 18) chose 13 which, they judged to have been researched using sound methodology and which had achieved an acceptable level of reliability and validity. However, within this small sample they found few theoretical concepts on which to base these models of Learning Styles or the claims made for them. However, since models of Learning Styles are frequently quickly commercialised on the basis of one inadequate study (Coffield, Moseley, Hall and Ecclestone, 2004: 145) further research and a critical evaluation of their claims are generally unwelcome, and there is a desire to report positive results even if these are not observed. Coffield, Moseley, Hall and Ecclestone (2004: 143) conclude that Learning Style research is “inward looking, non-critical, small scale, and non-cumulative”.

Models of Learning Styles frequently come with tests that claim to identify specific Learning Styles. These often provide scant evidence of the reliability and validity of the tests and, if they do, validity and reliability are low. For example, out of a possible score of 1 for reliability, and a generally accepted score of 0.9, the widely used Dunn and Dunn Learning Style Inventories (Dunn, Dunn and Price, 1989) score a reliability of 0.6-0.7. This result is considered only moderately satisfactory by researchers (Coffield, Moseley, Hall and Ecclestone, 2004: 37; Stahl, 1999: 4). The results of using a test of low validity and reliability are that students can be labelled inappropriately by themselves and their teachers. Coffield, Moseley, Hall and Ecclestone (2004: 145) quote a secondary school student who, after completing the Dunn and Dunn Environmental Preference Survey (PEPS), attended a conference and reported, “I learned I was a low auditory, kinaesthetic learner so there’s no point in me reading a book or listening to anyone for more than a few
There is no evidence that teaching students by individually matching their learning to their apparently preferred modality or learning style has any affect on their achievement (Stahl, 1999: 2; Kavale and Forness, 1987: 237). The possible effects of teaching individuals to their modality strength have been widely studied, resulting in no evidence supporting the claim that this will improve achievement (Kavale and Forness, 1987: 237). Nevertheless, many reports from teachers indicate positive results for learning in their classrooms (Neely and Alm, 1992: 112; Orsak, 1990: 20, Stahl, 1999: 2). Since some of these teachers describe their previous teaching as lectures and “chalk and talk” the reason for improvements could be attributable to the adoption of more varied and interactive teaching methods. In any case, such reports from classrooms of different, effective approaches need to be supported by well designed, independent studies which could be of great benefit to both students and teachers.

In this investigation the effects of role play on the ability of students to write about concepts in Science have been investigated. Role play includes the use of kinaesthetic, auditory and visual processing as part of the processes of learning and writing. There is no suggestion that the effects observed in this investigation depend on the perceived Learning Styles of students.

### 3.7 TEACHING USING THE KINAESTHETIC MODALITY

There is disagreement in the literature about the definition of the kinaesthetic modality but for the purposes of this investigation it is defined as relating to the senses of spatial orientation, pressure, touch and movement. This definition is derived from the perceptions of a number of researchers. Druyan (1997:1084) describes the kinaesthetic modality as the motion perception. Rothschild (2000: 15) defines it as sensory input from the proprioceptors within joints and muscles and the semicircular canals within the ear.
These receptors provide us with information about touch and pressure and the body’s orientation in space.

By the 1990s a multi-modal approach to information processing had become generally accepted (Engelkamp and Zimmer, 1994). Processing systems may be classified in a number of ways. For the purpose of learning theory it is useful to classify them as linguistic, non-linguistic and affective (Marzano, 1998: 12). Kinaesthetic processing, along with the sense of smell, taste and sound and mental imaging is part of the non-linguistic memory (Marzano, 1998:22). The use of the kinaesthetic modality in a classroom involves students using their bodies in activities such as role plays, or by walking through a drawing or a model. In such activities, students integrate their actions with story telling, visual images, discussion, and writing, which thus involves linguistic as well as non-linguistic processing.

In the mainstream literature on the theories of secondary Science teaching, use of the kinaesthetic modality is rarely mentioned and, in practice is rarely used (Goodrum, Hackling and Rennie, 2001:103). There continues to be a predominant emphasis on linguistic presentation of new knowledge to students in secondary school Science classes using auditory and visual input (Goodrum, Hackling and Rennie, 2001:85; Marzano, 1998: 13).

There is, however, substantial evidence to suggest that the use of the kinaesthetic modality is very effective as a teaching and learning tool. For example, Marzano (1998) conducted a meta-analysis of over 4000 experimental and control group comparisons to identify instructional techniques that assist student learning when new knowledge is presented. In order to compare types of classroom strategies he classified them according to their “effect size”. One successful strategy was presenting new knowledge in non-linguistic formats. These included kinaesthetic activities and visualisations in the form of graphs, diagrams and pictures. The average “effect size” for teaching and learning strategies that used non-linguistic processing was 0.95 compared to 0.63 for linguistic processing and 0.86 for affective influences. This means that, assuming that the random
sample drawn from the population is normally distributed for ability in the context of the Marzano’s (1998) research, students using non-linguistic processing strategies for learning will achieve 0.85 standard deviations better than the average student (Marzano, 1998: 126).

3.8 IMAGERY AND VISUALISATION

In all the classes that participated in this investigation, the use of visual imagery or visualisation when writing and thinking about a concept was a constant theme. In the context of this investigation, visualisation is defined as the existence of visual images in the mind which are related to the concepts students are learning and writing about in Science.

Discussion about the contribution of visual imagery to learning and memory has existed since the time of Plato (Kosslyn, Ganis, and Thompson, 2001: 635). However, for much of the twentieth century the concept of visual imagery was generally dismissed as unscientific and not a suitable subject for research. Behaviorist psychology, which dominated psychological research, at least in the United States, from the 1920s to the 1990s, did not consider imagery a suitable subject of scientific study. It was argued that imagery was a mental state and this was “unscientific and led to confusing views of human nature” (Barsalou, 1999: 2). There was a change in attitude in the late1990s when evidence from PET and MRI studies confirmed that imagery does indeed arise in the brain, and that the ability to visualise has a connection to kinaesthetic activity (Kosslyn, Ganis and Thompson, 2001: 639).

Paivio’s Dual Encoding Theory (Sadoski and Paivio, 2001: 50) is based on evidence supporting the concept that all information is encoded in the brain verbally or as visual images. Concrete words are easier to remember than abstract ones because concrete words evoke an image which is easier to recall (Sadoski and Paivio, 2001: 63). Abstract
concepts are encoded verbally and, for most people, more effort is required to recall and retain them than for visual imagery (Paivio, 1979: 204). The Dual Encoding Theory claims that both verbal symbolic and visual symbolic systems are used in the writing process. When students can, simultaneously, retain words in auditory memory and images in visual memory, they are more likely to be able to create connections between them and write effectively. Visual imagery can serve to stimulate, structure and support writing in any genre (Sadoski and Paivio, 2001: 151). Thus, learning, language comprehension and writing have all been found to be more successful when both visual and verbal memories are created (Bell, 1991:77). There is evidence (Bell 1991:21) that people who comprehend, think and write fluently visualise concepts continuously as they do so. That is to say some people are defined as high imagers and some as low imagers (Bell, 1991:65). Low imagers experience more difficulty visualising concepts and forming a complete “picture” or gestalt of what they are reading, thinking or writing about. Bell maintains that students who write fluently can visualise concepts in their mind and verbalise them while individuals with poor language concepts do not visualise concepts adequately and therefore do not express them easily in language (Bell, 1991: 22). The inability to visualise and verbalise in this way results in difficulties with both writing and comprehension.

### 3.9 THE NATURE OF MEMORY

Memory is important during the writing process because, in addition to understanding, writing involves recall (Marzano, 1998:48). One of the initial problems students in this investigation identified was their inability to recall information about scientific concepts.

Memory is no longer thought of as a static store of information. Rather, it is now seen as a complex of interrelating systems and associative processes that both hold information in the brain and enable it to be retrieved (Baddeley, 2007: 308). Moreover, it is now known that memory is actively involved in the construction of knowledge as both new and existing information are integrated to maintain a coherent view of individual reality (Weinstein and Mayer, 1986:317).
There are currently a number of models of memory. All are subject to academic debate and research as scientists try to piece together a unified model to explain the many different manifestations of memory.

Two theories of memory have been used in this investigation to help to clarify classroom observations:

- Craik and Lockhart’s (1972) Levels of Processing Theory: this theory relates to the processing of information from the different sensory systems and to how the information from each sensory system becomes more and more associated as it connects at deeper levels within the brain. For example, information is encoded into the brain via the senses. All sensory systems have independent neural pathways that enter the brain. At levels of primary input the independent processing of visual, kinaesthetic, auditory, olfactory and gustatory memory systems has been identified. Information from these senses, from the emotions and from within the brain itself, is integrated into an increasingly complex outline of a memory as more and more associations are made (Engelkamp and Zimmer, 1994: 11; Lockhart and Craik, 1990: 88). For example, if a person has to remember to buy lemons, the more senses that are activated to produce the relevant information, the easier it will be both to encode and later to retrieve this information from the memory. Thus, visualising the lemon’s colour and shape, saying the word, “lemon”, holding a lemon, recalling its acidic taste, its texture and the smell of its skin will all work together to encode the message about lemons (Blakemore and Frith, 2005:154). In other words, the greater the number of senses used, the greater the number of associations formed and the greater the depth of processing, the more likely the information will be successfully encoded and recalled. In addition, when synapses receive repetitive stimulation from sensory pathways their connections are permanently strengthened. When this occurs a short term memory is converted to a long term memory. Thus, when students obtain information from a number of sensory systems it is
more likely to be encoded in the long term memory (Blakemore and Frith, 2005:133). This provides evidence for the observation that learning which uses a variety of sensory inputs and which students relate to emotionally is the most effective (Marzano, 1998: 127; Moreno and Mayer, 1999: 366).

- Engelkamp and Zimmer’s (1994) Multimodal Theory of Episodic Memory: the multimodal theory of memory builds on Craik and Lockhart’s (1972) theory that information is encoded from all the sensory modalities and is processed at deeper and deeper levels of association until both verbal and/or visual memory traces of events are produced. This theory also provides evidence for the enactment effect (Engelkamp and Zimmer, 1994: 207) which supports the classroom observation that information from the kinaesthetic modality stimulates visual imagery and the ability to recall enacted information.

### 3.9.1 The Enactment Effect

“The enactment effect” was first observed by Cohen (1989) when he investigated how well individuals carry out an action after receiving instructions in different forms. For example, when experimental subjects were asked to carry out Self Performed Tasks such as “comb your hair” or “point to the door”, their verbal recall was superior to that of those who had only seen and listened the same instructions. The ability for superior recall after Thus Self Performed Tasks or SPTs is referred to as “the enactment effect”.

Examples of the differences observed for SPTs and verbal recall tasks on one study are listed in the table below (Engelkamp, 1998). In the third row the table records the number of phrases retained out a total of 48 after self performed tasks and after verbal tasks. In the fourth row the table records the number of phrases recognized out of forty eight after self performed tasks and after verbal tasks.
Table 3.9.1.1

<table>
<thead>
<tr>
<th>Items Verbally Remembered After SPTs and After Verbal Tasks</th>
<th>Self Performed Task/48</th>
<th>Verbal Task/48</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retained Phrases</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Recognition of Phrases</td>
<td>47</td>
<td>39</td>
</tr>
</tbody>
</table>

(Engelkamp, 1998)

The enactment effect is unaffected by intelligence, although students considered to be mentally impaired, but teachable, took longer to complete the task (Cohen and Bean 1983: 295). Researchers agree that the enactment effect improves memory recall for specific information and causes information to be forgotten at a slower rate.

There has been a great deal of discussion about why the enactment effect improves memory recall so significantly. It is generally agreed that encoding for enactment is automatic, or strategy free, and results in an unconscious, automatic encoding experience. Recall after enactment is not improved by elaboration, attentions to items or increased presentation time as it is for verbal items (Cohen and Bean, 1983:289). Further evidence is provided from the study of mentally impaired, but teachable, subjects whose ability to use rehearsal and encode strategically is impaired. However, their ability to recall information equally as well as unimpaired subjects after carrying out SPTs, has provided additional evidence that the encoding of SPTs is automatic and not strategic or effortful (Cohen and Bean, 1983: 294).

Input during Self Performed Tasks is less susceptible to interference than for auditory and visual tasks. This means that recall will be more successful when a subject is asked to perform a list of actions while carrying out another activity which creates interference in the same channels than when a subject is asked to remember the same list of actions visually or auditorily presented with interference in the relevant channel. This, again, is further evidence that encoding during SPTs is automatic (Cohen and Bean, 1983: 294).

The following table of results from one study demonstrates the difference in interference between enactment (SPTs) and listening tasks (Backman, Nilsson and Chalom, 1986:...
The higher the number on the table, the more successful is the recall. The third row records the proportion of items recalled correctly after enactment and after listening with no other sensory interference. The fourth row records the proportion of items recalled correctly after enactment and after listening with other sensory interference.

Table 3.9.1.2

<table>
<thead>
<tr>
<th></th>
<th>Enactment</th>
<th>Listening</th>
</tr>
</thead>
<tbody>
<tr>
<td>No interference</td>
<td>0.78</td>
<td>0.45</td>
</tr>
<tr>
<td>Interference</td>
<td>0.61</td>
<td>0.16</td>
</tr>
</tbody>
</table>


All the results cited demonstrate how memory after SPTs differs from the memory effects observed for verbal encoding and recall. It has been demonstrated that whereas there is a significant difference in verbal recall between children aged 9 and 13, there is no difference in the recall of SPTs. This has also been observed in the elderly (Nilsson and Craik, 1990: 306). Experiments using verbal recall indicate that strategic and effortful encoding processes are used. Unlike recall after SPTs, verbal recall is improved by elaboration, specific attention to individual items, increased presentation time and strategies such as repetition (Engelkamp, 1998: 18).

There has been some debate about the reasons for superior recall after SPTs. Compared to verbal tasks which have verbal and auditory input, SPTs are multimodal tasks. For example a simple act such as “comb your hair” includes auditory instructions, objects with colour, shape and texture, body movements and possibly sounds, so that encoding occurs through a number of sensory pathways. Multimodal encoding is suggested as one reason for the success of the enactment effect as this would result in richer, deeper encoding and more information would be expected to be retained and recalled (Engelkampf and Zimmer, 1994: 458).

Other suggested explanations have been:
• the increased focus of attention to the task required in order to carry out the actions. Researchers thought that during auditory and visual presentation tasks subjects can tune in and out to stimuli more easily as they carry out the task (Cohen and Bean, 1983: 292).

• the concrete nature of the words and sentences used to encode SPTs. Investigations have recorded improved memory performance and increased imagery for concrete compared to abstract words (Sadoski and Paivio, 2001: 59).

Although all this input undoubtedly has an effect on the superior encoding and retrieval of SPTs, it is now generally accepted that the motor component of these actions is the cause of the enactment effect and that this motor effect is automatically encoded (Engelkamp, 1995; 227). The enactment effect thus provides additional evidence for the effectiveness of role play in assisting students to recall information about the concepts they are learning.
CHAPTER 4
THE FINDINGS

4.1 BACKGROUND

In previous chapters I have outlined the rationale of this thesis. According to the Piagetian model, students need to develop formal operational thinking in order to understand the Science curriculum. Metacognition and reflective thinking drive the development of cognition, thereby creating the neural structures in the brain that enable students to think at a higher level. For these reasons I introduced reflective writing into my Science classes. However, I soon observed that students experienced difficulty writing in this way about the concepts they were learning. Accordingly I then used role play in my classes as students did not appear to experience the same difficulties writing reflectively about a concept if first they had experienced it in a role play. I was therefore
motivated to carry out this research into the substantive issue: how role play addresses the difficulties students perceive when writing reflectively about the concepts they are learning in Science.

Individual writing plays an important role when students are learning new concepts. The speed of interchange in oral discussion affords little opportunity for reflection due to the short wait-time between question and answer. This is not to diminish the importance of both oral discussion and social construction as ways to share interpretations and insights about concepts and to build understanding. Both are an intrinsic part of an effective role play. However, individual reflective writing also plays a significant role as it is more sharply focused, and also demands more than oral expression. It provides opportunities for students to reflect on the content of a discussion and on their own understanding as they construct new concepts. Reflective writing helps students to become aware of what they understand, and furthermore what requires clarification. This may be extended to reflecting about the strategies they have used in order to learn the concept, and also how classroom activities have contributed to their ability to understand and write about it. All reflection on thinking and conceptual understanding, including that required for writing, develops metacognition, and metacognition drives the cognitive development so essential for learners in Science.

In this chapter the findings of investigations into the substantive issue are analysed, coded and compared. Data from four mixed ability classes are analysed: one Year 10 class, two Year 8 classes and one Year 11 Physics class. At the time of the investigation, only the Year 11 Physics class had experienced the use of role play as a learning strategy in Science.

Results were drawn from classroom conversations, focus groups, written questionnaires and writing samples. Data from the results were first analysed according to open codes derived from the data. Open codes were sorted into conceptual codes. From these, categories and their properties were identified and then investigated further using
Theoretical sampling. For each class, the investigation was described under the following headings:

- Theoretical Sampling and the Researcher’s Impressions
- Aims
- Lesson Outline
- Data Collection
- Writing Criteria
- Evaluation of Writing Criteria
- Examples of Reflective Writing
- Open Coding and Sorting
- Conceptual Codes
- Emergent Categories and Their Properties
- Disconfirming Evidence
- Emergent Theory

The purpose of each of these headings is as follows:

- **Theoretical Sampling and the Researcher’s Impressions**: The reasons for choosing a class are explained and the researcher’s impressions of the approach to learning and writing of the students in the class are described.

- **Aims**: The Aims describe:

  - the objectives of each lesson in relation to student learning outcomes and reflective writing;
  - the aspect of the substantive issue under investigation.

- **Lesson Outline**: Here the activities carried out by the teacher and students during the lesson are described.

- **Data collection**: The process of data collection for each class is outlined. This includes class conversations, focus groups, class discussion, formal written interviews, class field notes and reflective writing from each class.
• **Writing Criteria**: These criteria outline aspects of the concept that students are expected to include in their individual reflective writing.

• **Evaluation of Writing Criteria**: Students’ writing samples are evaluated against the writing criteria. The results are recorded in a table. An analysis of the percentage of students who meet different percentages of writing criteria is recorded in a second table.

• **Examples of Reflective Writing**: Depending on the size of the class, two or three samples of reflective writing are included to show an example of writing that met the highest, middle and lowest percentage of criteria in each class.

• **Open Coding and Sorting**: The open codes that emerged from the initial data, as they were classified, are listed and data have been sorted into them. Additional open codes were added, as required when data from subsequent classes were analysed. Codes that became saturated or no longer provide information relevant to the substantive issue were discontinued in subsequent samples.

• **Conceptual Codes**: The open codes are sorted into clusters from which concepts are developed. The conceptual codes which emerge from the sorted open codes are listed, discussed and compared with those that have emerged from the data from other classes.

• **Emergent Categories and Their Properties**: Categories and their properties developed from the conceptual codes are listed, discussed and compared with the categories that have emerged from other samples.

• **Disconfirming Evidence**: This evidence disconfirms evidence that supports the emergent categories. It is listed, discussed and compared with disconfirming evidence from other classes.

• **The Emergent Theory**: Hypotheses are induced from the emergent categories of each successive sample. These are listed, discussed and compared to develop the emergent theory.
4.2 YEAR 10 - A LESSON ON MITOSIS

This section records, sorts, compares and discusses data collected during a lesson taught to the first sample, a Year 10 mixed ability Science class of 24 students.

4.2.1 Theoretical Sampling and the Researcher’s Impressions

This Year 10 mixed ability class was chosen because most of the students had experienced a Transmission approach to teaching and learning in Science in their previous years at secondary school and were therefore unused to reflective writing and role play. During a class conversation a group of students explained to me that “a good teacher explains the work and then you have a class discussion. Then the teacher writes the information on the board and we copy it into our books so that we can go home and learn it”. Most of the students thought it “normal” to be dependent on the teacher for all their learning and the idea that they could construct their own learning was to them, both confusing and “weird”. It was not possible to use structured group discussion or role play well in this class at the beginning of the year. Trust, rapport and permission are required if new strategies are to be used. At the beginning of the year, these had not been established.

The attitude in the class generally was one of anxiety with students expressing a lack of confidence in their ability to learn successfully in Science. Some students made it clear that they had made a decision not to learn in Science because it was “difficult and boring”. Others, keen to succeed, tried to overcome the difficulties they feared. Seven students had been identified by the learning support teacher as having a learning difficulty.

4.2.2 Aims

The aims of the lesson were to:

- provide students with learning strategies to help them construct an understanding of the process of mitosis so that they could write reflectively
about it, thus constructing their learning in more depth and reflecting on their thought processes and level of understanding.

- investigate students’ perceptions of the difficulties they experienced when writing reflectively about the concepts they were learning in Science.

4.2.3 Lesson Outline

In the previous lesson students had used diagrams and information from their text book to make a model of the process of mitosis. They had worked in pairs to draw cells representing various stages of mitosis on large pieces of butcher’s paper. They had made chromosomes and chromatids from lengths of wool which they attached to the cells to model the process. They had labelled the chromosomes, chromatids, centromeres, centrosomes, spindle fibres and daughter cells and had then written a description of each stage beside their labelled diagrams. They were not required to use the technical names for the stages of mitosis.

During this lesson the students’ models were used as a stimulus for class discussion. At the beginning of the lesson the process of reflective writing was explained to the students. They were told that towards the end of the lesson that they would be asked to think about the process of mitosis and write about it. The reason for this was also explained.

The function of mitosis was explained and examples of mitosis were drawn from the context of the students’ lives. The teacher and students constructed diagrams of the process of mitosis on the board. Students volunteered to draw and add labels and explain them to the class with assistance from the teacher. This was combined with a class discussion in which all the students compared the information on the board with the information on their models. Students were able to ask questions throughout the lesson. When there were no further questions, the students were asked to write reflectively about the process of mitosis without reference to their models, which had been folded away.

4.2.4 Data Collection
After completing the reflective writing, all students answered questions in a written interview. Their writing samples were evaluated using the writing criteria. Although the lesson was planned around the writing criteria, they were not available for use by the students. During the lesson, conversations about learning in relation to the model of mitosis were held with students from different groups in the class. During the following lunch break, six students over a range of academic ability were interviewed in a focus group using the questions outlined in Chapter 2. Lesson notes were written during and after the lesson.

### 4.2.5 Writing Criteria

These are the criteria against which student reflective writing was scored to assess the level of ease or difficulty they experienced when writing about mitosis:

1. Chromosomes duplicate to form two chromatids held together at the centromere.
2. Chromosomes (chromatids) line up along the equator of the cell.
3. Spindle fibres join the centrosome at either end of the cell to the centromere of each duplicated chromosome.
4. The spindle fibres pull the chromatids apart to separate ends of the cell.
5. The cell divides to form two daughter cells.
6. Correct use of the following technical words: chromosome, chromatid, centrosome, centromere, spindle fibres, daughter cells.

### 4.2.5.1 Evaluation of Writing Criteria

Each of the writing criteria was scored out of 1, except for writing criterion 6 which was scored out of 3 because there are six technical words that students were required to use. Students scored 1.0, 0.5 or 0, depending how they met each of the writing criteria. For example, writing criterion 1 states “Chromosomes duplicate to form two chromatids held together at the centromere.” Student 17 wrote, “When one cell makes two it starts out with 4 chromosomes in the centre of the cell, then they double.” She received 0.5 for the concept of duplication and lost 0.5 because she did not mention the chromatids or the centromere. Writing criterion 2 states, “Chromosomes (chromatids) line up along the equator of the cell.” The same student wrote, “Then they (the duplicated chromosomes)
line up along the cells equator”. She received 1.0 point for the concept of duplicated chromosomes lining up along the equator of the cell. Six students handed in writing copied from the text book. This was not scored but has been recorded as “copied”. Seven students failed to hand in their reflective writing and they have not been included in the table.

In the following table, the results of the evaluation of student reflective writing compared to the writing criteria are recorded. The student number is recorded in the left hand column. The writing criteria are listed in each of the columns. Each student’s score for a
A particular writing criterion is recorded in the designated column. The total score for each student is in the right hand column.

**Table 4.2.5.1.1**  
**YEAR 10 MITOSIS**  

<table>
<thead>
<tr>
<th>Student</th>
<th>1 Duplicating</th>
<th>2 Lining Up</th>
<th>3 Spindle Fibres Joining</th>
<th>4 Spindle Fibres Separating</th>
<th>5 Cell Dividing</th>
<th>6 Technical Words /3</th>
<th>Score /8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
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<td>5.0</td>
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<td>0.5</td>
<td>0.5</td>
<td>2.0</td>
<td>4.5</td>
</tr>
</tbody>
</table>
The following table summarises the responses of students to reflective writing and the extent to which they met the writing criteria. The percentage of students meeting each condition is recorded in the left hand column. Each column records a possible student response to reflective writing.

Table 4.2.5.1.2

<table>
<thead>
<tr>
<th>Percentage of Students</th>
<th>Percentage of Writing Criteria</th>
<th>Writing Copied</th>
<th>Writing Not Submitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>50-64</td>
<td></td>
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</tr>
<tr>
<td>33</td>
<td>&lt;50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>&lt;50</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The table shows that fifty-five per cent of students in Year 10 did not participate in reflective writing, either by not submitting a script or by copying from the textbook. Only twelve per cent of students were able to meet over fifty per cent of the writing criteria.
4.2.5.2 Examples of Reflective Writing

The following writing samples represent the range from highest, to median to lowest in the Year 10 class. The writing sample below met the highest percentage of writing criteria in this class.

Figure 4.2.5.2.1

WRITING SAMPLE WITH A SCORE 5/8
The following writing sample met the median percentage of writing criteria.

Figure 4.2.5.2.2

WRITING SAMPLE WITH A SCORE 3.5/8

Mitosis
- Two pairs of chromosomes (skin cells)
- They double but they are attached to centromere.
- They line up against the center of the cell.
- They separate
- Membrane produces 2 skin cell's (daughter cell)

![Diagram of mitosis stages]
The following writing sample met the lowest percentage of writing criteria.

**Figure 4.2.5.2.3**

**WRITING SAMPLE WITH A SCORE 1.5/8**

During the process of mitosis, the chromosomes duplicate. The process of mitosis is used in the body for growth and repair.

- A. Chromosomes
- B. duplicate
- C. spindle fibers
- D. E. Chromatids
- 1. daughter cell
4.2.6 Open Coding and Sorting

In this section, all the data collected from class conversations, focus groups, written interviews and samples of reflective writing were analysed and classified according to open codes. Codes were created as the data were read and commonly expressed issues and perceptions were identified. In Grounded Theory, the emergent theory relating to the substantive issue evolves from the consideration of all the issues raised by participants in the investigation. Thus, for example, student perceptions about copying information from the board, assumptions of how learning in Science should be conducted, concerns about having correct information in their books and the impact of technical terms were all considered in terms of the substantive issue.

The open codes identified in the Year 10 data include:

- Copying from the Board
- Learning in Science
- Having the Correct Information
- Technical Terms
- Writing Reflectively – Easy or Difficult?
- What Makes Reflective Writing Easy?
- What Makes Reflective Writing Difficult?
- A Picture in Your Mind?
- Learning Styles
- Understanding - Does This Affect Your Ability to Write Reflectively?
- Discussion
- Teacher Explanations
- Reflective Writing

4.2.6.1 Copying from the Board

When students record knowledge about a concept, they can either copy from the board, or write reflectively about it themselves as part of the process of constructing the concept and integrating it into their prior learning. Out of the fourteen students who answered this question, seven said that they always copied notes from the board. One student, however,
said she wrote her own notes, whilst the remaining six said they would do either, depending on the circumstances. Two groups of three students were very disturbed by the lack of notes about mitosis on the board. They described a “good” teacher as one who explained the work and then wrote it on the board. The students could then copy it down and go home and memorise it. Another student said:

I like the teacher to explain everything so I can understand it and then I’ll write it myself from the board. Sometimes we do it with a worksheet and that’s faster and you can help each other.

Class conversations indicated that these students had rarely or never been expected to process information themselves, nor to write reflectively about the concepts they were learning in class. The students were very dependent on the teacher for their knowledge. For example, in the focus groups the students said:

Why don’t you just write it? We can learn it just as well off the board.

On the other hand other students wrote:

I’ll write my own notes if I’m asked to.

It depends if I understand what’s on the board. If I do, I’ll copy it.

Although I do both, I do like to write in my own words.

However, during class discussion and the focus group it appeared that students had no concept of reflective writing. When we spoke about writing, it meant either copying from the board, filling in worksheets or summarising information from secondary sources. As they said during class discussion:

We have to write sometimes using library books. You’re not supposed to copy it so you have to write yourself.

Copying from the board is an easy way to write about Science.

The students interpreted reflective writing and writing in their own words as any writing they completed which did not involve copying directly from a source or filling in a worksheet.

4.2.6.2 Learning in Science
During class conversations with individual students, many students expressed the belief that they could not learn in Science because they could not understand the teacher. In addition, they expressed concern about failure and did not want the humiliation of a poor report. Some were anticipating the end of the year when they would no longer have to attend Science classes. This concern was discussed with groups during class conversations. Some students expressed anger and antipathy towards Science because, in the past, they had been unable to understand the concepts they were studying. In class conversations students said:

- I hate science. It’s so boring. I just don’t get it.
- I hate it when we have assessments that are nothing about the work.
- It’s just not my thing.
- We never do any experiments.

Other students resisted more passively by not engaging with the work in various ways. They did not hand in their books when asked, delayed getting started on a task, copied from the text book when asked to write without it, or merely completed work in a dilatory fashion.

When students in the focus group and class conversations were asked how they learnt best in Science, and what helped them to understand what they were learning, they all identified their learning style. They considered that the reason why they could not understand many scientific concepts was because of the teacher’s inability to match the presentation of concepts to their Learning Style. In addition, a number of students said that their ability to understand a concept depended on how well it was explained by the teacher and whether or not these explanations were repeated during class discussions until they could understand. From my observation, most students opted out of class discussions when the teacher was clarifying a point that involved or interested only a limited number of students. When I asked particular students why they did not ask questions in class when they clearly did not understand the concepts, they responded by saying that they felt foolish and did not want to ask “stupid questions” in front of their peers.
4.2.6.3 Having the Correct Information

In the written interview, two students were concerned that if they wrote for themselves in their own words, the information might be wrong. In class conversations a large number of students expressed a lack of confidence in their ability to write correct information that they could learn for examinations. About reflective writing, they said:

- I can’t use all the right words.
- I get confused. I can’t do it. It’s too hard.
- It’s too hard to remember everything about mitosis.

When students in the focus group were asked how they could acquire the correct information, they unanimously referred to the teacher. Other possible sources of correct information mentioned were the textbook and particular friends in the class. All the students said that it was important to have a record of correct information so they could study for assessments and exams. Sometimes if they were not sure about the information in their books they would check the notes of students in other classes.

4.2.6.4 Technical Terms

Two students wrote that if there were “less long and difficult science words” the concept might be easier to understand. One student wrote, “(I could understand) if I changed the long, hard words to words I would normally use but mean the same thing”. Students in the focus group said technical words could be confusing and hard to understand. They said that some teachers helped by giving them lists and by making sure the technical words were explained before the lesson started.

4.2.6.5 Writing Reflectively – Easy or Difficult?

Although only eleven students had submitted their own reflective writing for evaluation, twenty students responded to this question in the written interview. Ten students said writing reflectively was difficult and six said it was easy. Another four said that sometimes it was easy and sometimes it was difficult. In the focus group students were unsure about reflective writing. It was a task that they had not experienced before. They did not think they could write reflectively about a concept after a teacher’s verbal explanation because they needed to copy it down first. They thought they could write if
they had the diagrams or the text book to refer to, but, in any case it would be hard to remember the entire process without recourse to the correct information.

Those students who found reflective writing easy made comments such as:

I like writing in my own words better. It makes it easier to understand.
It makes more sense if you have written it.

If these students were in fact thinking of their own reflective writing when they wrote these comments, it indicates that they could see some value in it. Those who found it difficult mentioned spelling and technical words commented:

My words aren’t the right words.
It’s difficult when you don’t understand the topic.

During classroom conversations some students said they did not know how to begin writing because the amount they needed to know and remember was overwhelming. They required access to diagrams, information from the text book and correct information before they could write reflectively about the process of mitosis. However, in spite of assistance from diagrams, their model of mitosis and the textbook, their reflective writing revealed a low level of understanding. I had the impression from the attitude of these students that most were completing the exercise as quickly as they could to satisfy their perceptions of the teacher’s expectations. One very able, focused student who thought that reflective writing was easy also experienced difficulties. She said that she thought she understood the process of mitosis in class but, when her writing was returned, she could see that her understanding was incomplete.

4.2.6.6 What Makes Reflective Writing Easy?

Students suggested a number of possibilities that would make reflective writing easier. These suggestions reflect the difficulty the students had in understanding the idea of reflective writing and how rarely it had featured in their learning. Their suggestions were as follows:

It is easier when the teacher explains it to us.
Being taught it more often makes it easier to write it down.
I’m a visual learner and having things visually would help me.
Having diagrams and the text book makes it easier to write about something.
Highlighting my notes is an easy way to write.
4.2.6.7 What Makes Reflective Writing Difficult?
Students in the focus group said that reflective writing was difficult if you could not understand the words or the concept. Several students said that they could not retain the concept of mitosis in their mind and therefore could not write about it.

4.2.6.8 A Picture in Your Mind?
The majority of students emphasised that they needed to refer to the diagrams in their textbook if they were going to write about mitosis. The students did not consider that their own diagrams of mitosis could be used for learning. When asked why, they said that they thought they were probably incorrect. The students expressed a lack of confidence in their own ability to construct concepts and to think. They relied heavily on what they believed to be authoritative material from the teacher.

In the focus group and class discussion, the students thought that it would help to have a picture in one’s mind when writing. The diagrams they had referred to in their textbook when they were looking for information about mitosis were cited as an example. They tended to confuse mental imagery with the diagrams and pictures in their textbooks. Out of seventeen written replies, nine students stated that a picture would help them to write reflectively, two thought it would sometimes help and six thought it would depend on the individual’s Learning Style.

When they were asked if they could think about the process of mitosis before writing about it, four of the students in the focus group thought it would be too difficult to think about the process because mitosis was long and complicated. The other two said that although they could understand it when it was discussed in class, they were unable to “hold it in their mind” so that they could think about the entire process. They could remember parts of the process but found it difficult to put all the pieces together.

4.2.6.9 Learning Styles
The concept of Learning Styles was frequently mentioned during class conversations and in this context it referred to their preferred modality for learning – visual, auditory or kinaesthetic. The students used this concept of Learning Styles to explain why scientific concepts were difficult to learn rather than to explain why they could be understood. The students considered that the teacher’s responsibility was to match her presentation with their Learning Styles. Her failure to present a concept appropriately could result in their failure to learn. Students in the focus group elaborated on their Learning Styles. Five identified themselves as visual learners who needed pictures and diagrams. One identified herself as a kinaesthetic learner who needed to do things as part of her learning. The other five agreed that they also found doing things beneficial. In the written feedback, six students identified themselves as visual learners. No students identified themselves as auditory learners.

4.2.6.10 Understanding – Does This Affect Your Ability to Write Reflectively?
Seven students wrote that if they understood the concept it would be easier to write reflectively about it. During class conversations, students expressed confidence in their understanding of mitosis. However, their writing generally indicated a low level of understanding. In the focus group, one student said that the more she understood a concept, the easier it was to write about it. Another commented, “You can’t write when it doesn’t mean anything”.

4.2.6.11 Discussion
During class conversations, students demonstrated their confusion between a class discussion and the teacher’s explanation of a concept to the class. Class discussion was an opportunity for quite a number of students to opt out. Class conversations indicated that they had no experience of structured group discussion. When asked to discuss specific ideas in small groups, most of the students rapidly veered off-task.

4.2.6.12 Teacher Explanations
In the minds of most students the teacher’s function was to explain. Thus, a class discussion was viewed as an opportunity for the teacher to repeat the explanation. If a
student asked a question, the teacher could set off again on much the same explanation. A frequently expressed view was that if the teacher explained it often enough then the students would understand it. Students commented:

- The teacher should explain it more.
- If we go over and over it I will get it.
- The teacher needs to explain it properly with words we understand.

Students in the focus group agreed that if the teacher explained a concept clearly enough students would be able to understand it. They made comments such as:

- I like class discussion because it makes it clearer and the teacher explains it so I get it.

4.2.6.13 Reflective Writing

The evaluation of student reflective writing against the writing criteria suggests that they found writing reflectively difficult to understand and difficult to do. Seven students, almost one third of the class, did not submit any writing at all. Another six who did submit writing copied from the text book because, as they explained later, they did not know how to begin or what to write. Seven who did submit their writing met fewer than half the writing criteria. Only four students were able to meet over half the criteria, and, of these, the maximum percentage met was only sixty-three per cent. Reflective writing in this class demonstrated a low level of understanding of mitosis. It also illustrated the students’ lack of confidence in their ability to think and to learn, and their dependence on the teacher as the provider of knowledge.

4.2.7 Conceptual Codes

The descriptive open codes have been conceptualised to identify a number issues related to reflective writing. The conceptual codes identified in the Year 10 data include:

- Learning in Science
- Literacy
- Metacognition
- Fear of Failure
4.2.7.1 Learning in Science

In the literature review, two models of learning were reviewed: the Transmission model and the Interpretation model. The view of learning held by Year 10 students in this class was based on the Transmission model, in which the teacher’s role is to provide knowledge by presenting it in the form of a lecture, a teacher-centred form of class discussion or a worksheet. The students’ work is not to participate actively in the learning process, but passively to copy down the correct information and memorise it for exams. These students expected little interaction with the teacher and had no concept of the teacher as a learning facilitator, who was there to interact with them as they took responsibility for their own understanding and learning. The students had no concept of social construction in small structured groups, or of how discussion and reflective writing could contribute to an understanding of concepts.

4.2.7.2 Literacy

Literacy can be defined as the ability to read, write, speak and listen. Some of the difficulties experienced by this Year 10 class depended on their lack of knowledge of vocabulary and their inability to use oral and written language to construct knowledge in Science. Thus, most of the students lacked basic literacy skills in Science.

4.2.7.3 Metacognition

Most of the students had never been taught how to think about any aspect of their own learning strategies. When presented with a learning challenge, such as writing reflectively, they generally became helpless because they lacked awareness of strategies they could use and also lacked awareness that problems could be approached strategically. Most had an awareness of an individual Learning Style, a concept which is not supported by a body of empirical research. Their personal Learning Style was interpreted as another responsibility for learning to be met by the teacher and did nothing to enhance their participation in the learning process. When faced with a challenge, the only options for these students were to look to the teacher for answers or to opt out of the lesson. They were unable to consider strategies that could address a learning problem, or to take responsibility for their own learning. Passivity was the accepted mode.
4.2.7.4 Fear of Failure
A large number of students in this class saw themselves as having failed as learners in Science. This had brought with it the humiliation of poor exam results and indifferent reports for Science, the perception of appearing to look “stupid” in front of teachers and their peers, the frustration of consistent failure to understand and the prospect of similar experiences to come. This was evident in the desire of one third of the class to absent themselves from learning by not handing in their work, and passively resisting involvement in the class by procrastinating and refusing to engage in activities. Confidence about their ability to learn was not high. Thus, it was particularly difficult for these students to change to a more independent form of learning where, assisted by the teacher, they could assume some responsibility for the construction of concepts in their own minds, including writing reflectively about them.

4.2.8 Emergent Categories and their Properties
A category is an overarching concept, analogous to an independent variable that emerges from the conceptual codes. The category which emerged from the Year 10 data was: A Transmission Model of Teaching and Learning, which had a particular subsidiary topic, “Fear of Failure”

These categories and their properties are discussed below.

4.2.8.1 A Transmission Model of Teaching and Learning
The teaching and learning experiences of these students indicated that they had been accustomed to a Transmission model of learning in Science. They regarded the teacher and the text book as the authoritative sources of information and placed little value in their own thinking or their ability to construct their own learning. They lacked confidence in their ability to think and contribute to the learning process and had no concept about participating in their own learning. They did not know how to use oral discussion in small structured groups or to how write reflectively to construct knowledge and thus lacked literacy skills in Science. These students had not been taught how to think metacognitively about the strategies they used when thinking and learning and therefore were unaware of learning and thinking strategies that they could use when faced with a
challenge. This provided them with little control over their learning and placed them at risk of failure so that they were likely to give up, opt out and become either defeatist or angry.

Fear of Failure
Many students in this class had failed to learn effectively in Science over the years. Excessive dependence on the teacher as the means through which students succeed, or fail to learn at school is a property of the Transmission model. Learning within this model, students have minimal contact and interaction with teachers. They are dependent on their ability to absorb information from the teacher, the text book, worksheets or copied notes. The only opportunity students have to discuss misconceptions is during a class discussion in which they may risk feeling that they are perceived as “stupid” by the teacher and/or their peers.

4.2.9 Disconfirming Evidence
Not all students in the class were afraid of failure. A small number of students had managed to memorise information and attain, in their view, satisfactory results in examinations. These students were, however, dependent on the teacher and anxious to receive correct information to memorise for examinations.

4.2.10 Emergent Theory
Hypotheses are induced from the emergent categories. These hypotheses are used to inform theoretical sampling and to develop the emergent theory.

Hypothesis 1
Students perceive the following difficulties when writing reflectively in Science:

• not having access to diagrams, the text book and correct information
• lack of technical terminology
• inability to spell the required words
• inability to construct understanding
• inability to think about the concept
• inability to remember the concept as a whole or in detail
• not knowing how to begin to write
• not knowing what to write

These problems largely result from a Transmission approach to teaching and learning.

4.3 YEAR 8 - A LESSON ON PHOTOSYNTHESIS
In this section results were recorded from the second sample, a mixed ability Year 8 class of 24 students studying their first topic, “Up the Garden Path”. To introduce the topic students were given some food derived from plants such as crushed sugar cane, currant buns and barley sugar. The first question they wanted to investigate was how and why plants made sugar. Thus the topic began with a study of photosynthesis. This was the first time they had been involved in a role play in Science and it was the first time they had written reflectively about their learning.

4.3.1 Theoretical Sampling and the Researcher’s Impressions
This Year 8 class was chosen because, like Year 10, it was a mixed ability class and had not previously taken part in a role play. By the time I conducted this lesson I had known the class long enough to establish rapport. I was confident that they would be able to take part in a role play and the structured small group discussion that was integral to it. Although these students had also experienced a Transmission approach to learning in Science, they were younger and more optimistic about their ability to learn. They tended
to approach their learning with enthusiasm and most were positive and trusting when asked to learn in different ways.

I was interested to find out if the Year 8 responses to reflective writing were similar to those of the Year 10 students and whether or not the role play addressed some of the difficulties perceived by the Year 10 students.

4.3.2 Aims
The lesson aimed to:

- present a simple model of photosynthesis which can be developed once a basic outline of the process has been learnt.
- investigate the influence of role play on students’ perceptions of reflective writing about photosynthesis.

4.3.3 Lesson Outline
At the beginning of the topic the students had observed leaves, revised the structure of plant cells, identified the structures of a leaf seen in cross section, including the cuticle, epidermal cells, palisade cells, mesophyll cells and stomates, and drawn a labelled diagram. They had also identified, drawn and labelled the structures of a root and stem from slides and diagrams.

Because the Year 8 students had not used a role play in Science, one lesson was required to introduce them to the concept of photosynthesis and to the processes involved in a role play. Using a large diagram of a plant and a pot plant, the teacher referred the students to the diagrams of leaf and root structure which they had learnt about previously. Photosynthesis was introduced as the process plants use to make food in the form of glucose using carbon dioxide from the air, water from the ground, and sunlight. Relevant technical vocabulary was written on the board: xylem, carbon dioxide, oxygen, glucose, chloroplast, chlorophyll and stomata. The word equation for photosynthesis was written on the board so students could see the ingredients and products of photosynthesis.
The function of the role play as a means of constructing an understanding of a scientific concept was carefully explained. The components of a role play such as the drawing, the storyline, the kinaesthetic activity and social construction were carefully outlined. Students require careful preparation if they are to participate effectively in social construction. First, the students were shown how to use roles in a structured group. Then they were shown how to speak to each other to minimize conflict and how to listen effectively to other students. The purpose of social construction and structured group discussion as a means to construct concepts, clarify ideas, learn technical vocabulary and verbalise concepts were explained. Several students were asked to demonstrate a role play about how chloroplasts in a plant cell trap light energy which is used to combine carbon dioxide and water to produce glucose and oxygen.

**Roles**

- Carbon dioxide, chlorophyll, water, glucose and oxygen – 5 students
- Narrator – teacher/student
- Light – white cardboard arrow
- The sun – 1 student
- Stomate – open doorway to the classroom

**Role Play**

A space in the front of the classroom was labelled *chloroplast*.

The open doorway was labeled *stomate*.

Four students each wore a large label easily seen by the class: *carbon dioxide, water, glucose, oxygen*.

The teacher narrated what was happening.

The two students representing *carbon dioxide* and *water* stood side by side.

The two students representing *glucose* and *oxygen* crouched behind them.

The student representing the sun carried the arrow labeled *light*. She threw it into the chloroplast where it was caught by the chlorophyll. The chlorophyll gave the light energy to the water.
The water then linked arms with the carbon dioxide and they crouched down as they changed to glucose and oxygen. At the same time the glucose and oxygen stood up.

The glucose remained in the chloroplast and the oxygen left the cell via the stomate represented by the open door.

The role play was repeated using a student narrator. During the role play, the teacher demonstrated questions that could be used at the stage of social construction in small structured groups such as:

- *Describe what is happening here. Check your ideas with your group.*
- *Explain to your partners how light is caught and trapped by the leaf.*
- *Work out what the light does and see if you agree with a person sitting close by.*
- *What is happening to the carbon dioxide and water? Make sure you agree with the other people in your group. How could you be sure that you are correct?*
- *What do people in your group think will be produced by the chloroplast? Why do you think this?*
- *What could the oxygen do? Where could it possibly go, being a gas? Discuss this with the person next to you.*
- *How could the plant use the glucose? Find out what two other people think and then make sure you all agree before you write your answer.*

During the following lesson, students were asked to work in structured groups of four to create and act out their own role play of photosynthesis. The students were told that after the performances of the role plays the information on the board would be erased and other resources put away. Then each student would be expected to think carefully about the process of photosynthesis, and describe it in writing.

To form the structured group, the roles of *director, reader, encourager* and *recorder* were negotiated by the students.

- The director’s role was to organise group members to plan the role play, collect materials and clean up at the end.
- The reader’s role was to read the instructions step by step to the group.
• The encourager’s role was to make sure everyone contributed and no one was left out or refused to contribute.

• The recorder’s role was to make a record of the role play they were to perform.

Instructions given to the students were:

Use information from the equation, the plant diagram, the textbook and your previous notes to create a role play to demonstrate the process of photosynthesis.

You must include:

• how the water enters the plant and is transported to the leaves
• how the carbon dioxide enters the leaves
• how light is trapped and used
• how oxygen might escape from the leaves

You will present your role play to the class. If, after 10 minutes, it is incomplete your group can perform what you have created in the time allocated.

As students created the role play, the teacher moved from group to group questioning students’ understanding and thinking about photosynthesis and their reactions to the role play. After each group had performed their role play and watched those of other groups, the board was erased and other resources put away as each student wrote reflectively about photosynthesis. They were instructed to include the word equation and a summary of the process.

### 4.3.4 Data Collection

After completing the reflective writing, all students answered questions in a written interview. During the lesson, conversations about the role play were held with each group of students and in the following lunch break six students from a range of academic ability were interviewed for fifteen minutes in a focus group using the questions outlined in Chapter 2. Lesson notes were written during and after the lesson.

Before the end of the lesson, students completed a written interview. It was difficult to follow the recommendations of Grounded Theory and ask only general questions related to the substantive issue. This was because Year 8 students had difficulty answering
general questions about learning and reflective writing, as most had not developed an awareness of their thinking or writing processes and were unable to relate to general questions. For example, when asked what they had done in this lesson to make learning easier, four students mentioned practical work, mind maps, and brainstorming, none of which had been used in the lesson. Most Year 8 students completed written interviews very quickly and had to be discouraged from copying what their friends wrote. In comparison, senior students could write more detailed answers and expressed a wish to do so.

4.3.5 Writing Criteria

The writing criteria were based on the instructions for the role play.

1. 

2. State that the plant obtains water from the soil and transports it up the stem to the leaves.

3. State that carbon dioxide enters the leaves through the stomates.

4. State that sunlight is trapped by chlorophyll in the leaves.

5. State that oxygen leaves the plant through the stomates.

6. Write a summary of photosynthesis from the equation.

4.3.5.1 Evaluation of Writing Criteria

The reflective writing was assessed according to the writing criteria. Written work scored 1.0 for each of the criteria met and 0.5 if it had been substantially met. For example, writing criterion 3 says, “State that carbon dioxide enters the plant through the stomates”. A student who wrote that carbon dioxide was collected from air by the leaves scored 0.5. To score 1.0 the movement of carbon dioxide into the leaves through the stomates must be included in the description.
In the following table the results of the evaluation of student reflective writing compared to the writing criteria are recorded. The student number is recorded in the left hand column. The writing criteria are listed in each of the columns. Each student’s score for a particular writing criterion is recorded in the designated column. The total score for each student is in the right hand column.
### Table 4.3.5.1.1

**YEAR 8 PHOTOSYNTHESIS**

Evaluation of Writing Criteria

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<th>1 Word Equation</th>
<th>2 Obtaining Water</th>
<th>3 Carbon Dioxide Enters</th>
<th>4 Sunlight is Trapped</th>
<th>5 How Oxygen Leaves</th>
<th>6 Summary of Photosynthesis</th>
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</tr>
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<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>4.5</td>
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<tr>
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<td>0.5</td>
<td>0</td>
<td>0</td>
<td>1.0</td>
<td>3.0</td>
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<tr>
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<td>0.5</td>
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<td>1.0</td>
<td>0.5</td>
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<td>0.5</td>
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<td>20</td>
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<td>1.0</td>
<td>5.5</td>
</tr>
<tr>
<td>24</td>
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<td>1.0</td>
<td>0</td>
<td>1.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>
The following table summarises the extent to which students met the writing criteria. The percentage of students meeting each condition is recorded in the left hand column. The percentage of the writing criteria met is recorded in the right hand column.

**Table 4.3.5.1.2**

**STUDENT RESPONSES TO WRITING CRITERIA**

<table>
<thead>
<tr>
<th>Percentage of Students</th>
<th>Percentage of Writing Criteria Met</th>
</tr>
</thead>
<tbody>
<tr>
<td>67</td>
<td>80-100</td>
</tr>
<tr>
<td>25</td>
<td>50-79</td>
</tr>
<tr>
<td>8</td>
<td>&lt;50</td>
</tr>
</tbody>
</table>

All the students in Year 8 were able to write reflectively about photosynthesis. All the students handed in their reflective writing and no one copied information from the text book. The students expressed little anxiety about the writing process although some mentioned in their written responses that they had found it difficult.

**Comparison**

The following table compares the extent to which Year 10 and Year 8 students met the writing criteria. The percentage of Year 10 and Year 8 students are recorded in the two left hand columns. The percentage of writing criteria met is recorded in the right hand column.

**Table 4.3.5.1.3**

**PERCENTAGE OF YEAR 10 AND YEAR 8 STUDENTS MEETING THE WRITING CRITERIA**

<table>
<thead>
<tr>
<th>Percentage of Year 10 Students</th>
<th>Percentage of Year 8 Students</th>
<th>Percentage of Writing Criteria Met</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>67</td>
<td>80-100</td>
</tr>
<tr>
<td>12</td>
<td>25</td>
<td>50-79</td>
</tr>
<tr>
<td>88</td>
<td>8</td>
<td>&lt;50</td>
</tr>
</tbody>
</table>
The table indicates that the Year 10 students experienced more difficulty writing reflectively than the Year 8 students.

4.3.5.2 Examples of Reflective Writing

The writing samples below represent the range from highest to median to lowest in the Year 8 class.

The following writing sample met the highest percentage of writing criteria in this class.

**Figure 4.3.5.2.1**

**WRITING SAMPLE WITH A SCORE 6/6**

Photosynthesis

IN

Carbon dioxide (CO2) comes in through the stomates.
Water (H2O) comes through the roots and up the stem through the xylem.
The chlorophyll traps the sunlight, it traps in all the colours of the rainbow except for green, which it reflects (that is how leaves appear green).

OUT

Glucose travels through the plant through the phloem.
Oxygen (O2) is transpired out through the stomates.
Photosynthesis makes glucose and oxygen with CO2, H2O and sunlight. The glucose is used as fuel for the plant and O2 is a waste product.

The following writing sample met the median percentage of writing criteria.

**Figure 4.3.5.2.2**

**WRITING SAMPLE WITH A SCORE 4/6**

Photosynthesis

Carbon dioxide is in the air and enters the plant through the stomata it’s water
comes into the plant by its roots.
Sunlight provides light for the chlorophyll to go green.
Photosynthesis makes glucose and oxygen. It converts carbon dioxide and water into glucose and oxygen.
The following writing sample met the lowest percentage of writing criteria.

**Figure 4.3.5.2.3**

**WRITING SAMPLE WITH A SCORE 2/6**

The plant gets what it needs for photosynthesis by using different parts of the cell to trap different things such as sunlight, carbon dioxide and water. Everything travels up the xylem tubes and into the plant to make glucose. Transpiration then turns food into energy and the plant grows. Photosynthesis makes oxygen and glucose from the sunlight, carbon dioxide and water.

4.3.6 Open Coding and Sorting

The open codes established in the Year 10 class were used as a basis to classify data from the Year 8 class. These codes were expanded to accommodate additional data from the Year 8 class. The additional codes were:

- Understanding – Does This Affect Your Ability to Write Reflectively?
- How Does Reflective Writing Affect Your Ability to Understand Concepts?
- What Makes Reflective Writing Difficult?
- Discussion and Role Play
- Role play and Understanding
- Role play and Remembering

The coded data from Year 8 were compared with similar data from Year 10.

4.3.6.1 Copying from the Board

The Year 8 students did not complain about writing reflectively about photosynthesis or mention that they would prefer to copy notes from the board. Copying notes from the board was not an issue in this class. They generally expressed confidence about writing reflectively about photosynthesis, making comments such as:

- If I write it in my own words I know what I am talking about.
Yes if you’re shown diagrams and really understand it’s easy to write about. (It’s easy) because I know what the whole process is and understand it fully.

Comparison
Although both the Year 10 the Year 8 students had experienced Transmission teaching and learning in Science, the Year 8 students did not hold such rigid expectations about how Science should be taught and learnt. The Year 8 students expressed a greater confidence in their ability to write reflectively.

4.6.3.2 Learning in Science

Earlier in the year, during a class discussion about their view of learning in Science, the Year 8 students commented that they did not like writing in Science. By “writing in Science”, they were referring to writing notes in their books or from the board or to summarising passages from the text book. They said that they did far too much writing and would prefer to do lots of practical work and games. They said that it was the teacher’s responsibility to provide them with correct information so that they could do well in exams and assessments. Their responsibility was to complete their homework and learn their work.

The Year 8 students were excited to create and participate in a role play although they had not learnt in this way before in Science. Most of the students viewed the role play as a type of game. During the role play, students in each group were involved and on task. Students enjoyed the structured groups and the access this gave them to the teacher. Comments were made such as:

The role play was fun and I learnt heaps.
It helped me sort out what was happening
It was good to have the teacher coming round.
It was a fun and absorbing way to learn.

A few students expressed anxiety about learning in a different way. They wanted to be sure that they had the correct information so they knew what they had to memorise. They said they felt confused and could not understand photosynthesis. Confusion was equated with a failure to understand, rather than a possible part of the process of understanding.
and learning. These students were anxious that they might leave the classroom feeling confused about the concept.

Three students in the focus group complained that they had to think too much. They asked why the information could not be provided by the teacher to save them time and effort. A number of students mentioned the importance of the initial presentation and explanation of the concept. This set the scene, introduced the technical words, and gave them an overview of the lesson’s central concepts on which they could build their understanding.

Comparison
There was an air of optimism in Year 8 that was not evident in the Year 10 class. The students believed they could learn and understand scientific concepts and most were able to trust the teacher to present information in a way which they could understand. The students wanted to be engaged in their work, there was no passive resistance and work was completed and handed in when requested. However, like the Year 10 students, the Year 8 students expressed a distaste for writing. For each class, writing was perceived as copying from the board, completing worksheets and summarising passages from the textbook. Neither class had any experience of reflective writing in Science. The Year 8 students did not depend on teacher explanations in the same way as the Year 10s but they did identify the initial presentation and explanation of the idea as important. Unlike the Year 10s, the Year 8 students learnt to work in small structured groups. In both classes, only a few students took part in class discussions. Unlike the Year 10 students, few Year 8 students had heard of Learning Styles, but those who had thought that the teacher should match the presentation of concepts to their preferred modality. By the end of two lessons most of the Year 8 students could construct their learning using role play, discussion and reflective writing and they had some awareness of the learning strategies they had been using.

4.3.6.3 Having the Correct Information
Only two students were concerned that they were not given the correct notes to copy. During the lesson, all students had opportunities to check their notes with the teacher and their peers. In addition, they had access to resources on the board and the text book. However, most of the students were concerned about having the correct information by the end of the lesson. One student wrote:

I can do this (write reflectively) because I learnt all this (photosynthesis). It is sometimes easier (to write in your own words) but it is good to know it properly so that you know it is definitely right.

Other students in the focus group said that:

Sometimes it was a bit confusing but we could check with the text book and ask so we thought we worked it out OK.
It was good because we could check what we had written afterwards with the instructions.

Comparison
The Year 10 students worried that the information they wrote was incorrect. However, the Year 8 students were much more confident that they could write correct information. Unlike the Year 10 students they were aware of the resources available for learning in the classroom and could use them to ensure that the information they wrote was correct. They were able to discuss in structured groups, ask the teacher for assistance and refer to their text books and information written on the board.

4.3.6.4 Technical Terms
In conversations around the classroom, problems with the technical words such as chloroplast, stomata, xylem and chlorophyll were not mentioned. Students used the words as they created and acted the role plays. Students in the focus group were surprised that I asked about the technical words. They thought they understood all the technical words used in the lesson. When they were asked how they thought they learned the words, they said it was helpful to see the words at the beginning of the lesson and after the first role play they must have known them because, from then on, they used them without thinking. Two students remembered hearing some of the words when they had learnt about plant cells in Year 7.
Comparison
Both classes found a list of technical words assisted their learning. For Year 10, the use of vocabulary that they were unable to understand was seen as an impediment to learning and to writing reflectively. The Year 10 students had no experience of actively using scientific vocabulary as they completed learning activities in class. The Year 8 students did not experience the same difficulty with technical language as Year 10s because they were able to use the words in context during the activities in class.

4.3.6.5 Writing Reflectively – Easy or Difficult?
In the written interview, students were asked how easy or difficult it was to write about photosynthesis. The following table is a summary of their responses. The ratings of the students are listed in the left hand column. In the right hand column are the numbers of students who selected each rating.

<table>
<thead>
<tr>
<th>Ratings</th>
<th>Student Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>3</td>
</tr>
<tr>
<td>Fairly easy</td>
<td>12</td>
</tr>
<tr>
<td>Fairly difficult</td>
<td>4</td>
</tr>
<tr>
<td>Difficult</td>
<td>1</td>
</tr>
</tbody>
</table>

Seventy-five per cent of students found writing about photosynthesis in the easier range while twenty-five per cent found it in the difficult range. That most students record reflective writing in the “fairly easy” range indicates that it still presents some challenge. Students made statements such as:

- I had a good understanding of photosynthesis.
- I had to rethink some answers.
- It was easy once I knew the formula but before that it was quite challenging.
- We had just covered it in class so it wasn’t too difficult.
- We had done a lot of work on it. This made it easier but I had to remember what each thing did.
Students commented on the difficulties they encountered when writing reflectively:

It was a bit difficult remembering the equation for photosynthesis.
It was challenging and I had to think.
Sometimes things weren’t explained very good.
Different (student) explanations made it confusing. The (group) role play confused me.

In addition to those perceived by Year 10 students, two Year 8 students identified the following difficulties: explanations suggested by different students during role plays could be confusing; sometimes the teacher’s explanation was not clear enough; during a role play effort was required to think about the concept, and at times a student could fail to understand a concept.
4.3.6.6 What Makes Reflective Writing Easy?

Students were asked to identify the strategies they used that made reflective writing easier. Their responses are recorded in the following table. The strategies used are recorded in the left hand column. The number and percentage of students who identified each strategy are recorded in the right hand column. In their feedback students confused whole class discussion with group discussion and therefore the term *discussion* in the table does not discriminate between these two forms of discussion.

**Table 4.3.6.6.1**

<table>
<thead>
<tr>
<th>Strategies that made Reflective Writing Easier</th>
<th>Number of Students</th>
<th>Percentage of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Referring to the textbook during discussions</td>
<td>2</td>
<td>10%</td>
</tr>
<tr>
<td>Explanation about photosynthesis before the role play</td>
<td>4</td>
<td>20%</td>
</tr>
<tr>
<td>Seeing and discussing the equation a number of times with the teacher and in student groups</td>
<td>5</td>
<td>25%</td>
</tr>
<tr>
<td>Role Play</td>
<td>9</td>
<td>45%</td>
</tr>
</tbody>
</table>

In the focus group students said:

The role play helped me remember photosynthesis because I could think back to what we did.

The group discussion was good because we worked it out together and when I was writing I could remember about it.

All that learning we did helped me understand. Then I could write easier.

**Comparison**

The Year 10 students thought that multiple explanations by the teacher and access to visual resources such as diagrams and pictures made reflective writing easier. On the other hand forty-five per cent of the Year 8 students found that role play made reflective writing easier. The equation which was part of the explanation before the role play and other aspects of the initial explanation were indicated by another forty five per cent of
students. A much smaller percentage of students used the text book as a resource during discussions.
4.3.6.7 What Makes Reflective Writing Difficult?

Seventeen students said that nothing in the lesson made reflective writing difficult. Apart from the two students who said they were confused by different points of view in the group discussion, others wrote that reflective writing was difficult because there were so many things to think of and remember at once. They wrote:

We had done a lot of work on it but I had to remember what each thing did.
Writing is pretty easy but sometimes it’s hard to remember everything.

4.3.6.8 A Picture in Your Mind?

Students were asked in the written interview if it was easier to write if they had a picture of the concept in their mind. Seventeen said it made it easier to write and one replied that this sometimes was the case. Five students in the focus group said that the role play helped them to imagine the process of photosynthesis. One said that she could picture the water and carbon dioxide joining up inside the plant cell and making a bigger particle called glucose. This made it easier to remember.

Students were asked if it was easier to write if they had access to a diagram. The following comments were recorded in their written interviews:

I like diagrams because you can see what happens and understand it better.
I like diagrams and did some diagrams in my book for notes.
(I like to use diagrams) especially if the concept is difficult. The role play helps.
Diagrams and actually looking at the plant are helpful.
I like to see the original diagram

Students in the focus group said that the role play helped to make the diagram come to life. They said that, without a diagram, it could be hard to imagine what was happening to the particles and light energy all at the same time.

Comparison

Students in both classes agreed that visual resources such as diagrams and pictures helped them to learn and to write reflectively about concepts. The Year 8 students said that the role play helped them to imagine the photosynthesis and this made it easier to write.
4.3.6.9 Learning Styles
This was not an issue in Year 8. Most students were unaware of ideas about preferred Learning Styles. According to the analysis of research into learning styles by Coffield, Moseley, Hall and Ecclestone (2004) the concept of Learning Styles has not been validated by empirical research.

4.3.6.10 Understanding – Does This Affect Your Ability to Write Reflectively?
Students perceived a relationship between the ability to understand a concept and the ability to write about it. Comments included:

A good understanding makes writing very easy.
If you are shown diagrams and really understand it is easy to write about.

Students in the focus group said that it was obvious that if they understood something it would be easier to write about it.

Comparison
Students in both classes thought that understanding made reflective writing easier, although many Year 10 students were unclear about the nature of reflective writing.

4.3.6.11 How Does Reflective Writing Affect Your Ability to Understand Concepts?
Although this was their first experience of reflective writing, ninety per cent of the class made positive comments in their written feedback about the way in which reflective writing helped them to understand the concept they were learning. The following are examples of their comments:

I like it (reflective writing) because I can understand the work more.
(5 students)
My own writing that I do – I can understand it more.
Yes I like writing in my own words as the text book or other notes are more complicated. My words are simple and I can understand the process.
If I write in my own words I know what I am talking about.
Yes (I like reflective writing) because I understand it when I explain it.
Yes because I know what the whole process is and understand it fully (when I write reflectively).
It makes sense to me.
Students in the focus group were equally positive about reflective writing. They commented that it could be difficult because they had to organise their thinking and think about the concept so they “got it right”. One student explained that “the bits you really get are the easiest to write about but sometimes you get stuck because you’re not quite sure about one part”. The two students who did not find reflective writing helpful wrote:

I like to memorise the main points and write them down as I remember them.
Other words make more sense to me.

Comparison
Although their understanding of reflective writing was questionable, several students in Year 10 commented that reflective writing contributed to an understanding of a concept. Ninety per cent of Year 8 students said that reflective writing helped them to understand photosynthesis.

4.3.6.12 Role Play and Discussion
Discussion is an integral part of a role play. Students cannot avoid discussing the concept when they create a role play about it. Social construction of the concept takes place during the discussion amongst students in each group and/ or with the teacher.

Comparison
Unlike the Year 10s, the Year 8 students were able to take part in the structured discussions embedded in their role play.

4.3.6.13 Role Play and Understanding
Students were not asked specifically about role play in the written interview but it was mentioned by nine students who commented that it made the process of photosynthesis easier to understand. They made comments such as:

It made it (the concept) seem simpler.
It was good. I learnt heaps. If I write in my own words I now what I am talking about after I’ve done it.
Yes if you’re shown diagrams you act it out and really understand it and it’s easy to write about.
(It’s easy) because I know what the whole process is and understand it fully and can see our group all doing it.

4.3.6.14 Role Play and Remembering
The role play helped students remember aspects of the concept, because they could remember acting it. Students in the focus group said:

I remembered it easier after the role play.
You can feel yourself doing all the things with light and water and that and it’s easier to remember all those things.
When we do the role play it’s easier to remember. There’s lots to remember.

Although they were not specifically asked, five students wrote that the role play helped them remember what happened during photosynthesis.

4.3.7 Conceptual Codes
Conceptual codes are derived from the open descriptive codes. They conceptualise the issues and classroom practices that relate to the substantive issue. The following conceptual codes were identified in the Year 8 data:

Learning in Science
Interpretation Learning
Literacy
Metacognition
Fear of Failure
Visualisation

4.3.7.1 Learning in Science
Although the Year 8 students’ experience of learning and teaching in Year 7 Science had been essentially a Transmission approach, their view of role play as a game led them with little effort into Interpretation learning. Most found it easy to understand the implications of social construction and worked effectively in structured groups. The Year 8 students were excited to learn interactively. They became less dependent on the teacher as the
authoritative source of knowledge. In their groups they referred to their text book and each other and depended on the teacher to resolve confusion through individual or small group discussion. Most students enjoyed using role play to learn and found it motivating. Although they had not used reflective writing in Science before, they were confident when asked to write in this way.

Comparison
Unlike the Year 10 students, Year 8 students adapted readily to Interpretation teaching and learning. Only a few of the Year 8 students found this transition difficult. They were able to meet a greater percentage of the writing criteria than the Year 10s (See table 4.3.5.1.2)

4.3.7.2 Interpretation Learning
After the initial explanation at the beginning of the lesson, Year 8 students involved themselves in interactive learning and adopted an Interpretation model of learning. They were able to take responsibility for their own learning and use the resources available in the classroom. Apart from the introductory explanation, viewed as an important part of the lesson, students no longer depended only on teacher explanations for their understanding. All the difficulties perceived by students to make reflective writing difficult were, to a large extent, resolved by the activities within the role play such as social construction, structured group discussion, drawing and story telling.

Comparison
In this lesson the Year 8 students were able to move away from the Transmission model utilised by the Year 10s to an Interpretation model which resulted in positive learning results for over 90 per cent of the class.

4.3.7.3 Literacy
The initial list of technical words and the opportunities to use them in the lesson removed the issue of technical words as a difficulty for reflective writing. The Year 8 students
were using reading, speaking, writing and listening to construct learning for themselves. In other words they were acquiring literacy skills in Science.

**Comparison**

Unlike the Year 10 students, the Year 8 students were reading, listening and discussing in small structured groups and writing reflectively in order to construct knowledge. Most of the Year 10 students were not literate in scientific language. They experienced difficulty listening to information, asking pertinent questions and listening actively to the answers, entering into discussion about scientific concepts, reading information from their textbooks effectively and writing reflectively about the concepts they were learning. This inability to use scientific language effectively aurally, orally or in order to comprehend written material or to express concepts in writing, represented a huge impediment to their learning.

**4.3.7.4 Metacognition**

Initially students in Year 8 had little awareness of how to think about their own learning strategies, or of why they thought as they did about the concepts they were learning. During discussion after the lesson, most were able to identify strategies that had helped them to think, remember and write about photosynthesis. They identified strategies such as: drawing so they could see details of photosynthesis; discussing aspects of the process within their groups to clarify things they did not understand and acting out the role play so they could remember what happened. The role play and the discussion helped them to imagine the process of photosynthesis and this helped them to understand and to remember it.

**Comparison**

During the lesson the Year 8 students began to think metacognitively about the strategies they had used to help themselves think, learn and write. The Year 10 class was not able to understand the relevance of this approach to their learning or to think in this way. They
experienced fundamental difficulties thinking about aspects of the process of mitosis. Questions about why they thought in the way they did were, to a large extent, met with a sense of confusion. Any answers were to be found inside the teacher’s head, or if she refused to tell, then they could be reluctantly extracted with greater exertion in some manner from the textbook.

4.3.7.5 Fear of Failure

Although the fear of failure did not dominate in the Year 8 class, it was still an issue to be considered. A few students were anxious when they experienced feelings of confusion during the learning process. They were anxious that they would not be able to understand the concept or have the correct information by the end of the lesson and would, therefore, perform badly in the assessment. Most students expressed the need to understand the concepts they were learning in class and to feel that they had the positive support of the teacher while they were learning.

Comparison

In Year 10 many students had a history of failure to learn in Science and tried to avoid a similar situation by opting out of learning. Some Year 8 students became anxious as they changed from a Transmission to an Interpretation model of teaching and learning. However the Year 8 students demonstrated a greater degree of optimism and confidence in their ability to learn and participate successfully in classroom activities.

4.3.7.6 Visualisation

Year 8 students said that visualisation in the form of diagrams or a picture in their mind made reflective writing easier because they could see an image of the process. This gave the concept structure and made it easier to know how to begin the writing. Without some form of visualisation it was difficult to imagine an abstract process such as photosynthesis. The role play as an example of the enactment effect helped them visualise the process and this made it easier to remember and understand. The role play promoted social construction through discussion and helped students to verbalise the
concept. Thus the role play provided an opportunity for both the visualisation and verbalisation, which greatly assist learning, to take place.

Comparison
Although many Year 10 students considered that visualisation was important for learning, apart from the use of diagrams, they were unaware of how to achieve it and most were no longer inclined to make further attempts to learn. Most of the Year 8 students could visualise the concept after completing the role play due to the enactment effect. This visualisation helped them to understand, remember and write reflectively about the concept.

4.3.8 Emergent Categories and their Properties
A category is an over-arching concept, analogous to an independent variable that emerges from the conceptual codes.

The following categories were identified in the Year 8 data:

- A Transmission Model of Teaching and Learning
- An Interpretation Model of Teaching and Learning
- Role Play

These emergent categories are discussed below.

4.3.8.1 A Transmission Model of Teaching and Learning
The Year 8 students effectively began to make the transition from Transmission learning to Interpretation learning. This was aided by careful guidance from the teacher who explained to students how, after an initial introduction from the teacher to a concept, their learning would benefit from the different forms of social construction included in role play, such as group drawing and labeling, structured group discussion, the acting of roles, story telling, and individual reflective writing. The teacher explained to students that the rote learning of notes provided by the teacher, without additional social construction and reflective writing, would be less likely to result in individual learning at a deeper level.
4.3.8.2 An Interpretation Model of Teaching and Learning
The Interpretation model is an alternative approach to teaching and learning in which students take a greater responsibility for their learning and, after an initial introduction to a concept, are actively engaged in the construction of this learning using various forms of social construction and discussion in small structured groups with assistance from the teacher. This is followed by individual reflective writing. Students become literate in scientific language through discussion and reflective writing. The role of the teacher is to facilitate learning by planning activities such as role play and by structuring discussion to differentiate learning and by taking part in these discussions with students. By encouraging students to construct their own learning and by using class discussion which includes every student, the teacher demonstrates that she values student thinking and ideas as part of the learning process. In this way, each student’s contribution to thinking about a concept is affirmed and students come to understand that they and every other student can make valued contributions to class deliberations about a concept.

4.3.8.3 Role Play
Role Play is a property of Interpretation learning as it involves students in the construction of their own learning. To carry out role play, students become involved in social construction during discussion. Role play helps students overcome some of the difficulties they perceive when writing reflectively, such as not having access to diagrams, the text book and correct information and an inability to learn the technical words, construct understanding, think about the concept, remember the concept, or know how to begin to write, or know what to write about it.

4.3.9 Disconfirming Evidence
Three out of twenty-four students experienced some difficulty changing to an Interpretation model of learning. Their expectations related to a Transmission model of teaching and learning. Therefore they became anxious when precise notes to be rote learned were not provided by the teacher. They felt confused by Interpretation teaching and learning methodology and needed time to understand how to use small group discussion to resolve confusion as part of the construction of understanding. This
highlights the need for the teacher to be aware that some students need time and support as they readjust to a new form of learning and teaching and develop confidence in their ability to learn at a deeper level and in a different way.

These students commented that they found the change to Interpretation learning and role play difficult for the following reasons: they were confused by the different explanations put forward by students during the role play; they found that the teacher’s explanations were not clear enough at times; sometimes they could not understand the concepts and an effort was required to think about them.

4.3.10 Emergent Theory

Hypotheses are induced from the emergent categories. These hypotheses are used to inform theoretical sampling and to develop the emergent theory. The following two hypotheses have been induced from analysis of the Year 8 data. Hypothesis 1 was induced from the Year 10 data and is recorded at the end of the analysis of the Year 10 data.

**Hypothesis 2**

Interpretation learning, which includes role play, helps to overcome the difficulties listed in Hypothesis 1. In addition it diminishes the fear of failure and builds students’ confidence in their ability to learn.

**Hypothesis 3**

Role play is a form of interactive learning that allows the social construction of meaning through small group structured discussion. This enables students to verbalise a concept as it is clarified. The physical nature of role play also enables students to visualise a concept automatically through the enactment effect. Both help students to think about the concept and understand its sequence. Role play provides a concrete model of an abstract concept which enables students to visualise and understand abstract concepts.
4.4  YEAR 11 PHYSICS – HERTZSPRUNG-RUSSELL DIAGRAM

In this section results were recorded from the third sample, a mixed ability Year 11 Physics class of nine students studying the Hertzsprung-Russell Diagram. The students had participated in a number of role plays. Two of the nine students were chronically ill and absent from this lesson.

4.4.1  Theoretical Sampling and the Researcher’s Impressions

By the time I conducted this lesson I had known the class long enough to establish rapport. I was confident that they would be able to take part in a role play and the structured small group discussion that was integral to it. All the students found concepts in Physics challenging. Prior to this lesson they had participated in several role plays which, they claimed, helped them to learn complex and abstract concepts more easily. After each role play students wrote reflectively about the concepts they were learning. Although the students had been used to the Transmission model of learning they had readily adapted to an Interpretation model and therefore copying from the board and other aspects of Transmission teaching were no longer an issue in the class.
The analysis of data from the previous two classes determined the issues that required further clarification. Some of the difficulties perceived by students in the previous two classes had been identified and perceived difficulties from this class were also canvassed. In this class, the focus was on components of role play, such as small group structured discussion and visualisation to determine whether or not they can improve students’ ability to write reflectively about scientific concepts.

4.4.2 Aims
The lesson aimed to:

- provide students with a clear understanding of the Hertzsprung-Russell Diagram using a role play and reflective writing.
- investigate whether components of role play such as structured discussion and visualisation, can improve students’ ability to understand, remember and write reflectively about a scientific concept.

4.4.3 Lesson Outline
During this lesson students studied the Hertzsprung-Russell Diagram (referred to as an H-R Diagram). Initially students were shown a large H-R Diagram on the whiteboard. The scale on the Y axis referred to the luminosity of stars. On the X axis scales referred to both the temperature and the colour of the star. Students took turns to identify the position of different types of stars on the H-R Diagram, such as the hottest stars, main sequence stars, the largest stars, red giants, white dwarfs and the largest and smallest stars. They were able to ask questions at any time and there was continual interaction between the teacher and the students and between the students themselves.

After the initial presentation of the concepts on which the H-R Diagram is based, the role play was prepared. A graph was constructed from labeled paper axes attached to the floor. Each axis was two metres long. This graph was large enough for the students to walk into. The students chose which star they would play and then described their intensity, colour, size and temperature. If they did not know some of the information,
they looked it up in their text book or discussed it with the teacher. They dressed up as the star they had chosen using appropriately coloured crepe paper. They pinned on one of the following labels to identify which star they were playing

- Large white star
- Large blue star
- Main sequence star
- The Sun
- White dwarf
- Red dwarf
- Red Giant
- Brown dwarf

**The Role Play**

1. The students walked to their place on the graph of the H-R Diagram according to their size, luminosity, colour and temperature. During this process there was some discussion amongst the students.

2. Students took turns to describe their star by relating their luminosity to their temperature, size and colour. For example, one student said, “I am a large blue star. I am very luminous, around -2. I emit a lot of energy because I am large and hot. My temperature is 25000K and because I’m on the Main Sequence I fuse hydrogen.”

3. At the end of each description there was further discussion and question amongst members of the class including the teacher.

When everyone had described their star and there were no further questions, the diagram was removed from the floor, the students took off their colours and sat down to write reflectively about the Hertzsprung-Russell Diagram.

### 4.4.4 Data Collection
During the lesson data were collected from class conversations and the students completed a written interview. They were also asked to identify what made reflective writing difficult in Physics. Owing to its small size, the class became the focus group. Class notes and observations were written up during and after the lesson.

4.4.5 Writing Criteria

The following writing criteria were based on the following concepts in the role play which were related to stars.

1. Relate luminosity to temperature
2. Relate luminosity to size
3. Relate temperature to colour
4. Relate hydrogen fusion to stars situated on the main sequence
5. Describe the relationships in 1-3 for stars not found on the main sequence

4.4.5.1 Evaluation of Writing Criteria

The reflective writing was scored according to the criteria. Written work scored 1 for each of the criteria met and 0.5 if it had been substantially met, as in the previous samples. In the following table the results of the evaluation of student reflective writing compared to the writing criteria are recorded. The student number is recorded in the left hand column. The writing criteria are listed in each of the columns. Each student’s score for a particular writing criterion is recorded in the designated column. The total score for each student is in the right hand column.

<table>
<thead>
<tr>
<th>Student</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminosity to Size</td>
<td>Luminosity to Size</td>
<td>Temperature to colour</td>
<td>Fusion and main sequence</td>
<td>Stars not on main sequence</td>
<td>/5</td>
<td></td>
</tr>
</tbody>
</table>
The following table summarises the responses of students to reflective writing and the extent to which they met the writing criteria. The percentage of students meeting each condition is recorded in the left hand column. Each column records a possible student response to reflective writing.

Table 4.4.5.1.2

| THE PERCENTAGE OF STUDENTS MEETING DIFFERENT LEVELS OF WRITING CRITERIA |
|-------------------------------|-------------------------------|
| **Percentage of Students** | **Percentage of Writing Criteria Met** |
| 29                          | 90                            |
| 42                          | 80                            |
| 29                          | 70                            |
| 71                          | >80                           |

Comparison
Almost the same percentage of students in Years 8 and 11 met between 80 and 100 per cent of the writing criteria. However, no Year 11 students met less than 70 per cent of the writing criteria. Although most of the Year 11 students maintained that reflective writing in Physics was a challenge, the extent to which their reflective writing met the writing criteria indicates that they were able to meet this challenge.

### Table 4.4.5.1.3

**PERCENTAGE OF WRITING CRITERIA MET IN EACH SAMPLE**

<table>
<thead>
<tr>
<th></th>
<th>Percentage of Scripts Submitted</th>
<th>Percentage of Scripts Written by Students</th>
<th>Met Over 80% of Writing Criteria</th>
<th>Met Under 50% of Writing Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 10</td>
<td>70%</td>
<td>46%</td>
<td>0%</td>
<td>64%</td>
</tr>
<tr>
<td>Year 8</td>
<td>100%</td>
<td>100%</td>
<td>67%</td>
<td>16%</td>
</tr>
<tr>
<td>Year 11</td>
<td>100%</td>
<td>100%</td>
<td>71%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Compared to the Year 10 class, the Year 8 and Year 11 class all wrote and submitted their scripts and approximately seventy per cent attained over eighty per cent of the writing criteria.

#### 4.4.5.2 Examples of Reflective Writing

Two examples of reflective writing are recorded below. The writing samples represent the range from highest, to median to lowest in the Year 11 class. The following writing sample met the highest percentage of writing criteria in this class.

**Figure 4.4.5.2.1

**WRITING SAMPLE WITH A SCORE 4.5/5**

Hertzsprung-Russell Diagram

The Hertzsprung-Russell Diagram shows the luminosity and temperature of stars. It was developed by Hertzsprung and Russell at the same time in two different countries. The diagram also tells astronomers what colour the stars are likely to be.

Main sequence stars are those that are located diagonally through the centre of the diagram. The main sequence stars are those that are “burning” hydrogen. They include stars that are blue, orange, yellow, red and brown. The sun is also included in the main sequence and has a luminosity of 1. The luminosity is located on the vertical axis of the diagram and the temperature on the horizontal axis. The temperature is measured in degrees Kelvin (K). Blue stars are located on the top left hand corner. They are hotter and more luminous.

White dwarfs are located in the bottom left hand corner of the Hertzsprung-Russell Diagram. This means that they are very hot, but not very luminous. White dwarfs are not part of the main sequence.
Red giants are in the top right hand corner of the diagram. They too, like white dwarfs are not part of the main sequence. Their positioning tells us they are not very hot, but they are very luminous. Luminous stars are also very large, which means red giants are very large.

The Hertzsprung-Russell Diagram is therefore very helpful to astronomers. They can use it to determine the luminosity, temperature, colour and size of stars as well as determining whether a star “burns” hydrogen if it is part of the main sequence.

The following writing sample met the lowest percentage of writing criteria in this class.

**Figure 4.4.5.2.2**

**WRITING SAMPLE WITH A SCORE 3.5/5**

Report – Hertzsprung-Russell Diagram

The Hertzsprung-Russell Diagram shows the luminosity, temperature, size and colour of main sequence stars (blue → red, infra red) white dwarf, red giants etc. The above can all be determined from this diagram.

The main sequence stars consist of blue stars which are around 25,000K. They have a high luminosity and are very big. Next are the yellow stars or the sun which has a luminosity of 1. The luminosity scale is worked around the sun. The sun is not as hot as a blue star and is reasonably big. Next in the sequence are red stars. They are not very hot, have little luminosity and are not very big. Finally, there are the brown dwarfs (infrared) which are very tiny, have hardly any luminosity and are not very hot at all.

White dwarfs are very hot, yet quite tiny. They are not very luminous and of course they are white.

Red giants are red and extremely large stars. They have high luminosity and are not very hot at all.

Astronomers can use this diagram to identify temperature, luminosity, size and colours of certain stars.

### 4.4.6 Open Coding and Sorting

The open codes established for data collected from the previous classes were used to analyse data from the Year 11 class. These codes were expanded to accommodate additional data from the Year 11 class and include:

- Copying from the Board
- Learning in Science
- Having the Correct Information
- Technical Terms
- Writing reflectively – Easy or Difficult?
What Makes Reflective Writing Easy?

What Makes Reflective Writing Difficult?

A Picture in Your Mind?

What Helps You Understand?

Structured Group Discussion

Role Play and Remembering

Role Play and Visualisation

Role play and Reflective Writing

4.4.6.1 Copying from the Board

Students expressed no wish to copy notes from the board and nor did they make any comments about this issue. The students expected to write reflectively about the H-R Diagram and they were aware that copying from the board was not an option.

4.4.6.2 Learning in Science

Although they had been accustomed to a Transmission approach to teaching and learning in previous years, the Year 11 students adjusted to an Interpretation approach to learning with little difficulty. Role play, structured discussion and reflective writing helped them to construct the complex, abstract concepts frequently encountered in Physics. They often requested role play to help them understand the concepts they found difficult in Physics.

4.4.6.3 Having the Correct Information

Only one student expressed some anxiety about acquiring the correct information during this lesson. She wrote:

I prefer reading information from the text book or handouts to properly describe what we experienced.

In the focus group, this student revealed that she was under pressure from her parents who considered that memorising information from her notes and the text book was the best way to learn.

Comparison
As students participate in an Interpretation model of learning and gain confidence, they become less anxious about how they will acquire the correct information. Some students in the class have pressures on them that relate to factors outside the classroom and beyond the learning model. Teachers need to be aware of the possibilities as these students may require individual encouragement.

4.4.6.4 Technical Terms
This did not emerge as an issue in this class because, as students in the focus group said, the technical words were defined in the initial presentation of the H-R Diagram. They were then a part of the role play and were therefore constantly used by students during the lesson.

4.4.6.5 Writing Reflectively – Easy or Difficult?
In the written feedback about reflective writing students commented:

- It is one of the hardest things to do in Physics.
- This can be challenging - putting your experiences into words.
- No it is not easy but the activities we do in class made it easy.
- Writing is always difficult whether you know the subject and are really good at it.

In the focus group, writing reflectively about new concepts in Physics was generally seen as challenging because it requires effort to think precisely about the concept. Students commented that reflective writing was easy when the concept was easy to understand. They said that when they wrote, they became aware of gaps in their understanding and areas of confusion that they needed to address.

Comparison
In each of the classes those involved in Interpretation learning, including role play, found it easier to write reflectively than those committed to the Transmission model. Although reflective writing remained challenging for these students, the role play and the activities within it helped with understanding, making it easier to reflect on a concept and to write about it.
4.4.6.6 What Makes Reflective Writing Easy?

The table below records the written responses of Year 11 students to this question. The left hand column lists students’ perceptions of what makes reflective writing easier. The number of students who responded positively in each instance is recorded in the right hand column. The table indicates that Year 11 students considered role play and visualisation made reflective writing easier than did structured discussion.

Table 4.4.6.6.1

STUDENT RESPONSES TO WHAT MAKES REFLECTIVE WRITING EASIER?

<table>
<thead>
<tr>
<th>What Makes Reflective Writing Easier?</th>
<th>Number of Positive Written Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Role Play</td>
<td>100%</td>
</tr>
<tr>
<td>Visualisation</td>
<td>100%</td>
</tr>
<tr>
<td>Structured Group Discussion</td>
<td>63%</td>
</tr>
</tbody>
</table>

Comparison

The table below provides a comparison of responses from each class to the question, “What makes reflective writing easier?” The left hand column lists students’ perceptions of what makes reflective writing easier. The number of positive written responses from students in each of classes is recorded in the three columns on the right hand side of the table.

Some students in each class also mentioned the following:

- Initial explanation by the teacher
- Use of the text book

Table 4.4.6.6.2

WHAT MAKES REFLECTIVE WRITING EASIER? –
<table>
<thead>
<tr>
<th>What Makes Reflective Writing Easier?</th>
<th>Percentage of Positive Written Responses Year 10</th>
<th>Percentage of Positive Written Responses Year 8</th>
<th>Percentage of Positive Written Responses Year 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding</td>
<td>65</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Ability to remember</td>
<td>55</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>Role Play</td>
<td>n/a</td>
<td>45</td>
<td>100</td>
</tr>
<tr>
<td>Visualisation</td>
<td>55</td>
<td>86</td>
<td>100</td>
</tr>
<tr>
<td>Discussion</td>
<td>0</td>
<td>45</td>
<td>63</td>
</tr>
</tbody>
</table>

### 4.4.6.7 What Makes Reflective Writing Difficult?

In addition to the difficulties experienced by the Year 10 and Year 8 students when they wrote reflectively about concepts, the Year 11 students identified the following:

- It is difficult to remember all the details about the concept.
- Getting it all together and understanding the concept as a whole is a challenge.
- Things you don’t quite understand are difficult to reflect and write about.
- Planning and sequencing the writing is hard when you are trying to think the concept through.
- Organising experience and ideas into words and write about them is quite difficult.
- Having to think precisely about concepts makes writing quite hard.

### 4.4.6.8 A Picture in Your Mind?

All the students linked the role play to their ability to visualise the concepts expressed in the H-R Diagram. Students wrote:

- Acting out is very good because it helps us see how particular things work.
- Acting out helped me gain a visual image of what was taking place.
- Physically doing it gives me a clear picture in my head of the enactment and what was said and done.

In the focus group, all the students agreed that visualisation helped them to understand, to remember and to write reflectively about the H-R Diagram. The experiences of these students support the enactment effect, in which the enactment of a concept assists with an ability to visualise and remember it.
Comparison
Most students in each of the classes acknowledged that visualisation contributes to their understanding and ability to remember a concept and to their ability to write about it to some degree. This was observed least in the Year 10 class as many students in that class were unable to participate in activities that would promote visualisation. The more involved the class was in Interpretation learning, the more aware they became of the learning strategies they used. This increase in metacognitive awareness of learning strategies resulted in students in Year 11 in particular choosing strategies which they considered would assist their learning. Role play with its attendant visualisation was an example of one such activity.

4.4.6.9 What Helps You Understand?
Students wrote that the following helped them to understand the H-R Diagram:

- A clear visual explanation
- Talking about it with someone else
- Writing in my own words helped me understand it much more
- Acting out or drawing makes concepts clearer and they mean more than just copying notes down (all students)
- After acting out I can write about it (H-R Diagram) without worrying that what I have written is completely wrong

The Year 11 students found that role play which includes visualisation, discussion, and drawing helped them to understand the H-R Diagram. In addition, they all acknowledged the assistance of reflective writing in deepening their understanding of the concept by requiring them to organise their thinking in a precise way.

4.4.6.10 Structured Group Discussion
The focus group acknowledged structured discussion to be an integral part of role play and an opportunity for everyone in the class to learn from each other and to verbalise the concept. The structure of the discussion led them through the concept and made it easier for them to understand the concepts involved and to organise them in their minds. One student wrote:

- Talking about concepts helps me to organise answers. Sometimes I am unsure about a concept until I have talked it through.
Students found the discussion more difficult to carry out than other aspects of the role play because it required concentration and effort, as they sorted through their own confusion and constructed the concept. The teacher needed to plan the group discussion carefully to ensure that it led students through the concept. Otherwise the discussion could be unfocused and ineffective.

**Comparison**

For the Year 10 students, class discussion was an opportunity for the teacher to repeat an explanation. Both the Year 8 and Year 11 students used the discussion in structured groups to clarify aspects of the concept, to organise information, to verbalise the concept and to construct an understanding of it themselves. The Year 11 students developed the greatest metacognitive awareness of both structured groups and discussion as strategies they could use to construct their learning.

**4.4.6.11 Role play and Remembering**

In their written feedback, all the students connected role play to their ability to remember a concept. They wrote:

(After the role play) I can grasp the concept more firmly and am less likely to forget it.
Acting out is the easiest way to remember for me. (3 students)
Acting out makes it easier to remember than highlighting a sheet or hearing what happens.
It is easier to retain information because I can actually remember doing the idea.

**Comparison**

Year 10 students were not able to use a model adequately or to attempt a role play.
Year 8 students linked role play with its use of diagrams, acting out and seeing the equation to their ability to remember the concept. In Year 11 most students linked their ability to remember to the role play. The experiences of the year 8 and year 11 students are supported by the enactment effect.

**4.4.6.12 Role Play and Visualisation**
The Year 11 focus group acknowledged that role play contributed to their ability to visualise the concept. Students wrote:

- Acting out really helped me gain a visual image of what was taking place. It was also enjoyable.
- All I have to do is think about what we did and I have it there.

**Comparison**

Year 8 and year 11 students linked role play to their ability to visualise the concept. Year 8 students also linked diagrams to visualisation. Again their experience is supported by the enactment effect.

### 4.4.6.13 Role Play and Reflective Writing

The students in Year 11 preferred to use role play where possible as they found it made reflective writing easier. Students wrote:

- It’s hard to write about something after it is explained on the board, but in prac (role play) you have to think about what you are actually doing.
- Acting out the concept gives me a visual aid to use when I write about it.
- Physically acting out helps me to write as I can clearly put it into my own words having acted it out.

In the focus group students said that role play provided opportunities to visualise and verbalise and this helped them to understand and remember the concept and to write reflectively about it. The role play also gave them the opportunity to become aware of misconceptions and to clarify them during the learning sequence.

**Comparison**

Year 11 students were more articulate about the connection they perceived between role play, visualisation and writing. They were also more aware of their use of discussion and its value as a learning tool. However, most Year 8 students also recognised the increased ability to write about a concept after having completed a role play.

### 4.4.7 Conceptual Codes
Data analysis from the open codes is combined, conceptualised and recorded as conceptual codes. The records of codes which have appeared before and have reached saturation are not repeated. The conceptual codes identified in the Year 11 data include:

- Learning and Understanding in Science
- Reflective Writing through Role Play

4.4.7.1 Learning and Understanding in Science
The Year 11 students had adapted readily to an Interpretation model of learning. They had become more responsible for their own learning and had acquired a metacognitive awareness of some effective learning strategies which they could choose to use. They used the teacher as a learning resource, participated effectively in role play, which included acting out and social construction using structured group discussion followed by individual reflective writing. There was little evidence of anxiety or fear of failure in the classroom.

Comparison
By using an Interpretation model of teaching and learning most of the problems listed by the students in each class, such as not understanding technical words and concepts, having incorrect information or leaving the classroom feeling confused, could be overcome. As students became more experienced with the learning strategies embedded in role play and Interpretation teaching and learning, they became more confident in their ability to use role play, as well as other classroom resources such as the textbook and the teacher, as they constructed understanding and clarified areas of confusion. This trend became more apparent from Year 10 through Year 8 to Year 11, as students were able to participate more fully in the process and become more experienced in its use for learning.

4.4.7.2 Reflective Writing through Role Play
Role play consists of a number of interacting factors that can all contribute significantly to the ability of students to write reflectively about a concept they are learning. Role play
itself automatically stimulates visualisation through the enactment effect and this contributes to the ability to understand and to remember concepts. Structured group discussion provides an opportunity for the social construction of concepts, the clarification of misconceptions, and it enables students to verbalise the concepts they are learning.

**Comparison**

The ability to meet the writing criteria of each lesson increases when students take part in a role play. For example, the Year 10 class was unable to use aspects of role play such as acting out, model making, discussion and drawing during the process of learning. The Year 8 and Year 11 classes were able to use these strategies to some degree and were able to meet a greater percentage of the writing criteria.

### 4.4.8 Emergent Categories and Their Properties

The conceptual codes are linked to form categories which are analogous to independent variables. The following categories which have emerged from a comparison of the conceptual codes were identified in the Year 11 data:

- An Interpretation Model of Teaching and Learning
- **Role Play**
  (the latter with attendant properties: “Structured Group Discussion”; “Visualisation and Remembering”; “Understanding”).

#### 4.4.8.1 An Interpretation Model of Teaching and Learning

By adopting this model of teaching and learning, students develop a different learning relationship with the teacher. They learn to use strategies that enable them to construct concepts and they begin to assume responsibility for their own learning. They can reflect on the strategies that help them to learn and write reflectively. This metacognitive awareness contributes to the development of their cognition. Their ability to become literate in scientific language develops through the use of social construction and reflective writing. By listening to their discussion and by reading their writing, the teacher can assess their level of understanding. Because they are actively involved in
their learning, students are more likely to understand, and less likely to learn superficially or to opt out of learning Science altogether.

4.4.8.2 Role Play

The components of role play interact to provide effective learning. Through the enactment effect, role play automatically stimulates visualisation which helps students to understand and remember concepts. Role play contributes to the development of aural, oral and written literacy in scientific language through social construction and reflective writing. Through story telling, and a sequence of physical events, role play organizes concepts into a sequence that enhances recall. Structured group discussion provides opportunities to clarify concepts and enables students to verbalise them. In addition, students are actively involved in the lesson and many say they enjoy this and find it motivating. Physical activity is also known to enhance learning.

It is not possible to divide the properties of role play into separate entities, as they all interact to provide a learning process. For example, the enactment effect automatically stimulates visualisation and memory for action. Understanding is assisted by visualisation and physical activity. Visualisation contributes to the ability to conceptualise and to discuss concepts and this again contributes to understanding, as do enjoyment and motivation. These components have, however, been discussed separately for the purpose of data analysis.

Structured Group Discussion

Structured group discussion provides students with roles so that they are more likely to participate and no one person is likely to dominate. This type of discussion is part of a role play and can be carefully planned by the teacher to direct the students towards an understanding of the concept. By taking part in social construction, students verbalise and sequence the concept as they clarify it. The ability to verbalise contributes to the ability to write reflectively, particularly about abstract concepts. Students may find structured discussion difficult as it is focused and requires concentration and effort. Small group discussion may be extended to a class discussion in which, using a policy of no-hands-up,
all students are expected to contribute. This provides the teacher with opportunities to use contributions made by any student as part of the discussion. In this way, student thinking is valued, affirmed and woven into the learning experience of the class. This builds students’ confidence in their own thinking process.

**Visualisation and Remembering**

Role play stimulates visualisation through the use of diagrams and physical action. Visualisation contributes to recall and understanding, particularly of concrete concepts. Role play is therefore useful for students who have difficulty visualising. As a result of the enactment effect, students participating in a role play visualise and remember automatically.

**Understanding**

Concrete concepts are generally easier for students to understand than abstract concepts. A concrete model is useful for all learners and particularly for those whose cognitive development is still at the late concrete operational stage. Role play converts an abstract concept such as photosynthesis, or the H-R Diagram, into a concrete model which is easier for students to understand. Role play stimulates visualisation, which also contributes to understanding.

**4.4.9 Disconfirming Evidence**

Even after participating in a role play, students were not able to meet all the writing criteria. When students were asked about this, they would either say that they knew it but had forgotten to include it, or that they did not completely understand an aspect of the concept. However, in this research project Year 10 could not attempt role play, Year 8 was using it for the first time, and it was a new approach to learning for Year 11. In addition, in previous years none of the students in these classes had ever written reflectively in Science classes.

Sometimes students may experience influences from outside the classroom such as family pressure or illness that may impinge on their learning in class. Teachers need to be aware of this possibility. The expertise of the teacher may also affect the degree to which
the students can meet the writing criteria. The students did not have access to the writing criteria and therefore the lesson had to be delivered so that students had an opportunity to learn the criteria they were expected to express in their writing.

4.4.10 Emergent Theory

Hypotheses are induced from the emergent categories to develop the emergent theory.

Hypothesis 4

Role play is a form of Interpretation learning that provides social construction through small group structured discussion. Structured discussion enables students to verbalise the concept as it is clarified. The physical nature of role play enables students to visualise and remember the concept automatically through the enactment effect. Visualisation and memory help students to think about the concept and understand it at various levels of detail. Role play provides a concrete model of an abstract concept, making it easier for students to visualise and understand abstract concepts.
4.5 YEAR 8 - TRANSPERSION

In this section data were recorded from a second Year 8 lesson. In this lesson the students were studying transpiration from their first topic, “Up the Garden Path”. This class had previously used a role play to study photosynthesis and therefore this was to be the second role play they had used in Science.

4.5.1 Theoretical Sampling and the Researcher’s Impressions

Role play emerged as a core category in the Year 11 Physics lesson where it was linked to social construction e.g. discussion and verbalisation, the enactment effect which automatically stimulated visualisation and memory, and understanding. All of these factors contributed to students’ ability to write reflectively about the concepts they were learning. Theoretical sampling in this Year 8 class was used to clarify further the relationship between role play, its properties of understanding, remembering, visualisation, structured discussion and reflective writing.

4.5.2 Aims
The lesson aimed to

- present a simple model of transpiration.
- observe the relationship between role play and its properties and the ability of students to write reflectively about transpiration.

### 4.5.3 Lesson Outline

In previous lessons, the students had identified root hairs, roots, xylem, stem, leaves and stomates. In this lesson, they were given a list of technical words and their meanings. The concept of transpiration was introduced by the teacher using a two metre diagram of a plant and a pot plant. Several students came up and used the diagram and the pot plant to demonstrate to the class the passage of water up the plant from the root hairs through the xylem into the leaves and out through the stomates.

**Role Play**

The students were then asked to organise themselves into structured groups. Using butcher’s paper and pens they were given ten minutes to draw a large, two metre diagram of a plant. They drew and labelled the root hairs, roots, xylem, stem, leaves and stomates. In each group, students took turns to be a water particle. The water particle walked through the diagram from the soil, into the root hairs, across into the xylem, up the xylem in the stem, into the leaves and out through the stomates. As each student moved through the plant, she told the story about what was happening to her as a water particle. The other members of the group listened and asked questions to clarify their ideas. Each member of the group carried out the role play while the others listened and asked questions in their turn. During this time the teacher moved from group to group listening carefully to the students and responding to their questions. The teacher also asked questions to stimulate student thinking. On completion, students were asked to fold their diagram away. They were then asked to draw a labelled diagram of transpiration in their books and to write reflectively about the process of transpiration.

### 4.5.4 Data Collection
Data were collected from conversations with groups of students and with individual students and from a written interview completed by all the students. During the following lunch break a focus group of six students from a range of abilities was interviewed about aspects of the lesson using questions outlined in Chapter 2. The students in the focus group were asked to reflect on the strategies they had used during the lesson about transpiration. Research notes were recorded during and after the lesson.

4.5.5 Writing Criteria

The following writing criteria were based on the concepts in the role play

1. The absorption of water from the soil through the root hairs.
2. The path of water through the roots to the xylem, up the stem and into the leaves.
3. The path of the water out of the plant via the stomata.
4. The relationship between transpiration and evaporation or photosynthesis.
5. A clear diagram showing the path of water through the plant and labeled the root hairs, xylem and stomates.

4.5.5.1 Evaluation of Writing Criteria

The reflective writing was scored according to the criteria. Written work scored 1 for each of the criteria met and 0.5 if it had been substantially met, as in the previous samples. In the following table, the results of the evaluation of student reflective writing compared to the writing criteria are recorded. The student number is recorded in the left hand column. The writing criteria are listed in each of the columns. Each student’s score for a particular writing criterion is recorded in the designated column. The total score out of five is located in the right hand column.

<table>
<thead>
<tr>
<th>Student</th>
<th>1: Absorption of Water</th>
<th>2: Path of Water Up Plant</th>
<th>3: Path of Water Out of Plant</th>
<th>4: Transpiration - Evaporation or Photosynthesis</th>
<th>5: Labelled Diagram</th>
<th>Total /5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>
The following table summarises the extent to which students in this Year 8 class met the writing criteria. The number and percentage of students meeting the writing criteria are recorded in the left hand columns. The percentage of writing criteria met is recorded in the right hand column.

Table 4.5.5.1.2

<table>
<thead>
<tr>
<th>FREQUENCY AT WHICH WRITING CRITERIA WERE MET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Students</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>11</td>
</tr>
</tbody>
</table>
### Table 4.5.5.1.3

**PERCENTAGE OF WRITING CRITERIA MET IN EACH SAMPLE**

<table>
<thead>
<tr>
<th></th>
<th>Percentage of Scripts Submitted</th>
<th>Percentage of Scripts Written by Students</th>
<th>Percentage of Students Meeting Over 80% of Writing Criteria</th>
<th>Percentage of Students Meeting Under 50% of Writing Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 10</td>
<td>70</td>
<td>46</td>
<td>0</td>
<td>64</td>
</tr>
<tr>
<td>Year 8:1</td>
<td>100</td>
<td>100</td>
<td>67</td>
<td>16</td>
</tr>
<tr>
<td>Year 11</td>
<td>100</td>
<td>100</td>
<td>71</td>
<td>0</td>
</tr>
<tr>
<td>Year 8:2</td>
<td>100</td>
<td>100</td>
<td>83</td>
<td>4.5</td>
</tr>
</tbody>
</table>

An increased percentage of students in this class met between 80-100 percent of the writing criteria. A small percentage scored below 50 percent. With increasing awareness of the difficulties students perceive when writing reflectively and of how role play can address these difficulties, students who have adapted to Interpretation learning and participated in role play appear to find reflective writing easier.

#### 4.5.5.2 Examples of Reflective Writing

Three examples of reflective writing are recorded below. The writing samples represent the range from *highest* to *median* to *lowest* in the Year 8 class. The following writing sample met one hundred per cent of writing criteria for this class.

**Figure 4.5.5.2.1**

**WRITING SAMPLE WITH A SCORE 5/5**
The water collects in the soil and the root hairs soak up the water. The water enters the plant through the root hairs and travels up the roots, stem and branches into the leaves through the xylem cells. When in the leaves it evaporates out of the stomates and leaves the plant.
The following writing sample met the median percentage of writing criteria, eighty percent.

**Figure 4.5.5.2.2**

WRITING SAMPLE WITH A SCORE 4/5

```
exploration

The water, which comes from the soil travels through the root hairs, then through the roots. It then travels up the xylem vessels to the leaf. It then exits through the stomates.
```
This following writing sample met the lowest percentage of writing criteria in this class, sixty per cent.

Figure 4.5.5.2.3

WRITING SAMPLE WITH A SCORE 3/5
4.5.6 Coding for the Core Category and its Properties

Transpiration is when water goes into the plant through the root hairs of roots. It then travels up the xylem into the leaves, and then out again through the stomates.
Role play and its properties were identified as the emergent core category in this research project. Thus data from the Core Category, role play were sorted into the following properties:

- Role Play and Structured Group Discussion
- Role Play and Visualisation
- Role play and Remembering
- Role play and Understanding

Role play and its properties were analysed in relation to learning, understanding and reflective writing.

### 4.5.6.1 Role Play and Structured Group Discussion

Each group of students remained on task during the structured group discussion which included working in a structured group to organise the drawing of transpiration and to work through the structure of the role play. These two activities directed the social construction and discussion. During the discussion, students asked the teacher questions and some consulted the text book. They said that they were confident about their learning because the teacher was available to ask and answer questions. They now had a greater awareness of the purpose of the discussion and they knew that their verbal interchange represented a discussion. They wrote that:

> It (the discussion) helped me to understand by me being able to describe the process in my own words and that of my friends in a fun, story telling way.
> It helps because your peers tell you if you’re right, it’s also fun.
> When we talk in our group we have different ideas and this makes us ask which one is right.
> I hadn’t thought of some of the things people in my group were saying.

**Comparison**

These students confirmed the observations of structured group discussion made by students in the first Year 8 class and in Year 11. They maintained that it helped them to sort out confusion about concepts as they expressed the concept in words and understood it more clearly.

### 4.5.6.2 Role play and Visualisation
Twenty three of the twenty four students said that the role play helped them to visualize transpiration. They said:

- The role play helped me by showing how and where the water went.
- It helped me analyse and visualise the process.
- Visual things (such as role play) help me learn.
- Very well because I could visually and physically see what happens in the process of transpiration.
- It helped me because I got to see and understand transpiration.
- It showed me how it happens.

Four students said that the diagram alone helped them to visualise transpiration clearly enough to write reflectively about it. Two students wrote:

- We drew the picture and could picture it in our own heads so didn’t need to do the role play.
- It helped and assisted me because I can see the diagram to tell my story

Some students said that drawing and labeling also helped them to understand the concept. They wrote the following comments:

- Yes it helped me understand in a simple way.
- Definitely! I understand it more, it’s much clearer.
- Yes, I thought it was much easier to understand transpiration with our diagrams.

Students said that visualisation helped them to recall the concept as a whole and in detail and made it easier for them to write reflectively about it. They commented:

- Yes because I visualised transpiration from the diagram.
- Yes, I think it did because I know where things are located.
- Yes because as I was writing about it I thought of going up the plant at the same time.
- Yes, I could see the image when I was writing about it.

Students in the focus group made similar comments such as:

- It is easier when you can see the plant and the little particles of water traveling in through the root hairs and up to the leaves.
- It was helpful because when I was writing I could see the whole thing and it was quite easy.
These comments are supported by the enactment effect outlined in the literature review (Engelkamp, 1998). The Year 8 students had become more aware of the strategies they were using for learning and how role play could cause visualisation to automatically occur, and that careful discussion and observation of diagrams could also contribute to the visualisation process. The students were developing a metacognitive understanding of learning strategies which they could consciously decide to use. For these students, role play and the attendant visualisation, and in this case the use of diagrams, contributed to the process of understanding and remembering necessary for reflective writing.

**Comparison**

Students in this class confirmed the observations made by the Year 8 and Year 11 classes relating role play to the ability to visualise a concept and then to understand and remember it. In these ways, the properties of role play contributed to students’ ability to write reflectively about a concept. In addition, each class commented that reflective writing itself contributed to the ability to visualise, understand and remember a concept. It seemed that each aspect of role play and reflective writing interacted with and reinforced the other.

**4.5.6.3 Role Play and Remembering**

Twenty three of the twenty four students wrote that the role play helped them to remember the process of transpiration. Specifically they wrote:

- It assisted me as creativity allows you to remember things.
- It helped me because acting the part of the water made me remember it better.
- Yes, I can see an image of the process.
- Yes, very much. I could remember it after we did the role play.
- Yes, I could see the image as I was writing about it.
- Yes, getting a visual picture in my mind makes it easier.
- You just have to think about it and you can see what happens and remember it.
- I just think about what I did and it all comes back.
- I can see a picture of the water particles and can remember what I did.

Students said in the focus group that it was easier to remember after the role play than after listening to the teacher explain a concept. The students’ observations are supported
by the enactment effect which maintains that role play automatically stimulates the memory.

**Comparison**

Students in the Year 8 and Year 11 classes previously sampled commented that role play enabled them to remember the scientific concept and its details more easily. When they could recall aspects of the concept, it made it easier to reflect upon it and write reflectively about it.

**4.5.6.4 Role Play and Understanding**

Ninety-one per cent of Year 8 students in this class wrote that aspects of role play helped them to understand transpiration more easily. They wrote comments such as:

- It helps because your peers tell you if you’re right, it’s also fun.
- It made sure I knew what happened in transpiration.
- It helped me a lot. I learn by doing or using bright colours so I felt that I learnt about transpiration well.
- It helped because I could see what was happening after I did it.
- Yes it helps us understand the process better.
- It helped me understand the process thoroughly. I learn something more when I teach it to someone else e.g role play.

Students expressed confidence in their understanding of transpiration both in their written questionnaires and in their answers in the focus group. These Year 8 students were motivated by the activities within the role play and they were excited by the fact that they were mostly sure that they could understand what occurred during the process of transpiration. They expressed less negativity about writing reflectively about a scientific concept. In fact, there was no reluctance to write observed by the teacher in this instance.

**Comparison**

<table>
<thead>
<tr>
<th>Table 4.5.6.4.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERCENTAGE OF POSITIVE RESPONSES THAT</td>
</tr>
</tbody>
</table>
This table indicates that as students become more conversant with role play, the more they perceive it to be helping them to understand a concept. Students commented that the more they understood a concept, the easier it was for them to reflect on it and write about it.

### 4.5.7 Disconfirming Evidence

Only one student commented that she continued to find the discussion within the role play confusing. She insisted that she would prefer notes from the teacher which she could learn as this was her expectation of learning for assessments. She said that listening to different points of view was confusing and made it difficult for her to understand the concept. It would have been interesting to give notes to this student when learning another concept to monitor her reaction and her participation in the group and in the role play.

### 4.6 EMERGENT THEORY

The data analysis from the second Year 8 class or Sample 4 confirmed the findings from the other samples without adding a large amount of new information. Students confirmed the enactment effect by which role play enabled them to visualise and remember more easily. Every student, except one, acknowledged that the discussion embedded in role play within the structured group and between the group and the teacher could enhance their ability to comprehend a concept.

Below are the hypotheses derived from the data analysis of the four samples to address the substantive issue of how role play addresses the difficulties students perceive when writing reflectively about the concepts they are learning in Science.

**Hypothesis 1**
Students perceive the following difficulties when writing reflectively in Science:

- not having access to diagrams, the text book and correct information
- lack of technical terminology
- inability to spell the required words
- inability to construct understanding
- inability to think about the concept
- inability to remember the concept as a whole or in detail
- not knowing how to begin to write
- not knowing what to write

These problems largely result from a Transmission approach to teaching and learning.

**Hypothesis 2**

Interpretation learning, which includes role play, helps to overcome the difficulties listed in Hypothesis 1. In addition it diminishes the fear of failure and builds students’ confidence in their ability to learn.

**Hypothesis 3**

Role play is a form of interactive learning that allows the social construction of meaning through small group structured discussion. This enables students to verbalise a concept as it is clarified. The physical nature of role play also enables students to visualise a concept automatically through the enactment effect. Both help students to think about the concept and understand its sequence. Role play provides a concrete model of an abstract concept which enables students to visualise and understand abstract concepts.
CHAPTER 5
THE EMERGENT THEORY

5.1 EMERGENT THEORY-DISCUSSION

In Chapter 4, data analysis revealed an emergent theory defined by three hypotheses. In this chapter the substantive issue is discussed in relation to these hypotheses which are summarised as follows:

- The difficulties students perceive when writing reflectively in Science have largely resulted from a Transmission approach to teaching and learning.
- Interpretation learning helps to overcome these difficulties.
- Role play, as a form of interactive learning, which includes kinaesthetic activity, discussion and visualisation, provides students with opportunities to construct concepts and to remember them, and thus the skills to write reflectively about them.

During the investigation students identified the difficulties they perceived when they attempted to write reflectively about the concepts they were learning. The table below presents this information which has been derived from analysis of the data. General areas of difficulty are listed in the left hand column and specific difficulties related to these areas are listed in the right hand column.

Table 5.1
DIFFICULTIES STUDENTS PERCEIVED WHEN WRITING REFLECTIVELY

<table>
<thead>
<tr>
<th>Area of Difficulty</th>
<th>Specific Difficulty when Writing Reflectively</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary</td>
<td>knowing the technical words and their meanings</td>
</tr>
<tr>
<td></td>
<td>knowing how to spell the technical words</td>
</tr>
<tr>
<td>Understanding</td>
<td>constructing and understanding the concept as a whole</td>
</tr>
<tr>
<td></td>
<td>not quite understanding parts of the concept</td>
</tr>
<tr>
<td>Remembering</td>
<td>remembering the concept as a whole</td>
</tr>
<tr>
<td></td>
<td>remembering details of the concept</td>
</tr>
<tr>
<td>Thinking</td>
<td>thinking about the concept</td>
</tr>
<tr>
<td></td>
<td>thinking how to construct the concept more precisely</td>
</tr>
</tbody>
</table>
It has been established that most students in Science classrooms in Australia experience a Transmission approach to learning wherein information is copied from the teacher in some form and memorised so that it can be repeated in an examination. The emergent theory indicates that, in this study, the difficulties perceived by students when they attempted to write reflectively largely resulted from such an approach to teaching. For example, in the Year 10 classroom, during teaching and learning, there was little interaction between members of the classroom, no social construction of concepts or individual reflective writing to further structure and deepen the construction of understanding. This resulted in the students having such a superficial understanding about mitosis that, even the most able students were not able to write well about the concept whilst some were unable to write about it at all.

Many of the Year 10 students required access to resources such as diagrams and the textbook in order to have information to include in their reflective writing. On the other hand, after using role play students in both the Year 8 classes and the Year 11 class did not require such access to diagrams or their textbook when they came to write reflectively. This is because role play is a form of Interpretation learning. In it students are provided with opportunities to construct their own learning through different forms of interaction with the concept, such as kinaesthetic experiences, drawing, labeling and finding information in the text, the use of technical vocabulary, verbalisation through structured group discussion and individual reflective writing which provides additional structure to conceptual understanding. The kinaesthetic experiences of role play draw on the enactment effect which automatically stimulates visualisation and recall. Thus, all the difficulties perceived by the students in this investigation could be addressed by aspects of role play.

Students in the Year 10 Transmission classroom experienced difficulty in learning the technical words and how to spell them because, apart from copying them into their notes,
no opportunities were provided for them to practise these words. Role play addresses difficulties with technical vocabulary and spelling by providing opportunities for words to be used frequently in discussion, reading and writing. Thus students learn vocabulary and spelling through usage, and in this way the words are incorporated into the students’ vocabulary.

Role play can address difficulties students have in understanding concepts by providing them with experiences that allow them to construct understanding. The structured group provides the focus required for discussion, verbalisation and social construction of the concept. Verbalisation is considered necessary for the construction of abstract concepts which are thought to be coded verbally in the brain. Each student has a role, which ensures that there is a purpose to the discussion and a goal to achieve within a certain time. The teacher in this situation structures the discussion so that students are led through the concept as, for example, when they draw, discuss and relate the journey of a water particle through the process of transpiration in a plant. By drawing and labelling diagrams the students have their attention drawn to both the technical vocabulary and the visual details of a concept. Visualisation is considered necessary for the construction of concrete concepts, which are thought to be encoded visually in the brain. Students who are unable to visualise a concept will have an incomplete understanding of it, while those who visualise a concept well will be able to understand it more completely.

Role play itself can provide a concrete model of an abstract concept. For students at the late concrete stage of cognition a concrete model is necessary if they are to construct concepts of abstract ideas and processes. They may be able to rote learn abstract information, but they will not be able to construct this knowledge for themselves unless the structures that enable this to occur have developed in the brain. The kinaesthetic nature of role play produces the enactment effect, which enables students to automatically visualise and remember information within the role play, thus enhancing their ability to construct and understand a concrete model of the concept. On the other hand, abstract concepts are thought to be encoded verbally. During the structured discussion of social construction, which is a part of all role play, students have
opportunities to verbalise concepts. This provides them with further opportunities to construct an understanding of abstract concepts. Visualising and verbalising have been shown to be essential elements of comprehension and writing, and both are a fundamental to role play.

Role play furthermore addresses difficulties students may experience when they try to remember concepts or parts of them. Most students in the Year 10 class had little more than a superficial understanding of mitosis gained from Transmission learning, and were therefore unable to remember very much about the concept. However, the kinaesthetic action of a role play results in the enactment effect, in which both visualisation and recall automatically occur. Both the kinaesthetic activity and the visualisation contribute to effective recall. Thus the acting out of a concept, which is so fundamental to role play, provides students with not only the ability to visualise the concept as a whole and in detail, but also to remember it. The extent to which a concept is visualised affects both the depth of understanding of the concept and the ability to recall it.

The difficulty students experience when thinking about concepts is also addressed by role play. In a transmission classroom most students are unlikely to have constructed enough understanding of a new concept to think about it. Without opportunities to construct understanding, students will fail to visualise and verbalise the concept or elements of it. For these reasons they will experience difficulty when they try to think about it. Thinking is grounded in physical schema which develops into visual images. The kinaesthetic aspect of role play, which stimulates visualisation provides a mental resource for thinking about concrete ideas. Similarly the discussion within role play provides a verbal resource for thinking about abstract ideas. When considering the kinaesthetic aspects of role play and visualisation, it is important to emphasise that this in no way relates to ideas about Learning Styles and preferred modalities of learning. All students need to visualise if they are to construct a deep understanding of concrete concepts and think about them. The kinaesthetic activity of role play has been shown from the literature and the data analysis to be a very effective way to produce visualisation of a concrete concept for all learners.
Role play addresses the difficulty students experience when planning and sequencing writing. The sequential nature of a role play provides students with a story line which they can use when planning their writing. This narrative characteristic of role play, together with visualising and verbalising, helps students to organize their experience and ideas into words. Thus, role play addresses the problem of knowing what to write. The sequential nature of role play and the visualising and verbalising that result from taking part in it ensure that students understand the concept, both as a story line and as an image or sequence of images. Having constructed an understanding of the concept in these ways it is not difficult for them to know where to begin and what to write.

A further positive outcome of role play is that it provides students with an opportunity to think metacognitively about the strategies they are using in their learning, thinking and then reflective writing. Metacognition refers to the ability to think about concepts, and the strategies used to learn or construct them for oneself. For example, in the answers to questions about their experience of learning through role play, many students acknowledged that the kinaesthetic activity helped them to visualise effectively and that visualisation was a strategy that helped them to understand, remember and think about concrete concepts. Thus, in Interpretation teaching and learning, the development of metacognition is involved in the learning process. This function of role play is extremely valuable, as metacognitive awareness gives students the ability to choose effective learning strategies when faced with a challenge, such as reflective writing. What is more, metacognition has been shown to drive cognitive development.

Role play is student-centred and provides opportunities for students to address their learning needs. By providing access to the teacher, feedback is readily available between all students in a classroom during a lesson as the teacher moves from group to group. In addition, role play brings scientific concepts into a context in which all students can participate. For many students, this appears to increase the motivation to learn (Van Ments, 1999:13). Furthermore, recent developments in cognitive science and linguistics indicate that thought, perception, action and language are closely connected, both as cognition develops and as we interact with our environment. These observations support
the thrust of this investigation underlining the important influence that both action and language can have on perception and thinking (Clark, 1997: 36; Gibbs, 2006:80)

It is highly desirable for students to be able to reason at the formal operational level in order to understand many scientific concepts. Without this level of reasoning students will not be able to process multivariate data, relate multiple causes to an effect and vice versa, understand probability, ratio, or use a formal scientific model. In the description of scientific practice outlined by Ford and Forman (2006) in which students play the roles of “constructor of claims” and “critiquer of claims”, student reasoning is an explicit and significant part of a lesson. Because role play contributes to the construction of concepts and to metacognition, it contributes to the development of student reasoning in two ways:

- It provides opportunities for students to participate effectively in scientific argument and debate.
- It encourages metacognition, or the conscious awareness of learning strategies, and thus contributes to cognitive development.

During the role plays analysed in this investigation, students had access to resources which enabled them to evaluate the ideas of their peers. The discussion within the role play, the individual writing and the evaluation of structured group work provided evidence of student involvement in the learning process and of the knowledge they had acquired by the end of the process (Ford and Forman, 2006: 10).

The issue of levels of cognition and cognitive development run parallel to this investigation. Findings have shown that for any one age group some of the curriculum demand will be cognitively mismatched to a percentage of the students. This emphasizes the importance of this investigation in a number of ways. Firstly it is important that the cognition of students is developed explicitly so that they are provided with the opportunity to understand multivariate and abstract scientific concepts. The use of metacognitive thinking in structured discussion and reflective writing will contribute to cognitive development. Furthermore, role play and reflective writing provide evidence of the level of thinking and depth of understanding of individual students. Rather than
provide information about what students can learn by rote, the kinaesthetic, oral and written components of role play provide both teacher and student with an assessment of their depth of understanding of a concept. Although students may not have constructed and understood every aspect of a concept on completion of role play and individual reflective writing, they will have an understanding which is broad and deep enough to allow them to write reflectively about most, if not all aspects of the concept. Reflective writing exposes the extent to which each student can understand the concept and thus becomes a valuable strategy with which to assess their learning. This assessment can be used by both teacher and student to further enhance the student’s understanding. Teachers can use this information to assess the level at which students are learning so that they can pinpoint the Zone of Proximal Development for each student and thus plan and differentiate lessons more incisively.

The findings of this investigation raise questions about the function of literacy in Science classes, in particular the function of oral and written language in the construction of scientific conceptual understanding. For the purposes of the current NSW Science Syllabus students are expected to write in a number of specific genres, not to construct scientific knowledge so much as to communicate it. For example, students must be able to use report, discussion and expository genre to communicate understanding. However, a significant problem for Science teachers is the frequent inability of students to construct an understanding of scientific concepts. Within the Syllabus documents, there is no mention of how fundamental literacy, in the form of reading, listening, speaking or writing, is to the construction of conceptual knowledge in Science. This investigation has demonstrated that students do not require the specific but inadequately identified genres, claimed by genre theorists, for the construction of an understanding of scientific concepts. Rather, it has been shown that students can use their own oral language and reflective writing to construct scientific concepts in class. They do not require a rigidly scaffolded generic form to construct conceptual understanding. Role play has been shown to be effective in providing students with opportunities to use both oral and written language for the construction of conceptual understanding in Science. In this investigation students have demonstrated how they can use their own oral and written
language to construct meaning. Once an understanding of a concept has been achieved, then different linguistic genres can be learnt and used as required.

At the conclusion of an investigation using Grounded Theory the emergent theory, based on the three hypotheses discussed here, must be shown to work. For the emergent theory to work, it must meet the following criteria. It must:

- ‘fit’ the data
- be workable
- have relevance
- be modifiable

To ensure its validity, the emergent theory must ‘fit’ the data so that it can be used in classrooms. Data analyses have demonstrated that role play as a form of interpretation teaching and learning can be used as a teaching strategy in secondary school Science classes, and that students are then able to construct an understanding of scientific concepts in this way. When students are taught using a Transmission model it is unlikely that they will be provided with the opportunities required for the construction of understanding.

The emergent theory must address the concerns expressed in the substantive issue and provide suggestions about how the proposed method can address the problem – in other words it must be ‘workable’. By demonstrating that both teachers and students can use role play to address the difficulties outlined in the substantive issue, and by providing a teaching sequence that addresses these difficulties, the emergent theory has been shown to be ‘workable’.

Furthermore, the emergent theory must address a problem that is generally recognized as such by teachers, and that the suggested solutions must be worth trying. It must have relevance to both teachers and students. The problem addressed by the emergent theory is defined in the substantive issue. This problem is not in itself recognized as significant by most Science teachers because neither role play nor reflective writing are commonly used in Science classrooms. According to the research literature most Science teachers use
transmission teaching and learning, and therefore reflective writing is not a significant issue for them. The significant issue for Science teachers is that many of their students experience difficulties constructing an understanding of scientific concepts. Thus the emergent theory is relevant because it identifies some of the reasons why students are unable to do this and suggests solutions, namely the use of role play, structured discussion and reflective writing.

The emergent theory must also be ‘modifiable’. If new data emerges it must be able to accommodate it. For example, in this investigation the emergent theory is based on data analyses of four classes of students from Years 8 – 11 in a girls’ school. If the theory were applied in a boys’ school new data that did not support the present theory may emerge. An addendum to the theory could then emerge and the theory could be modified to accommodate the new data. In such a case some of the classroom practices used with girls may require modification for use with boys. However, unless boys were found to be unable to write reflectively after role play, such modifications would be easily accommodated and would in no way invalidate the emergent theory.

This study investigated how role play addresses the difficulties students perceive when writing reflectively about the concepts they are learning in Science. With each successive sample further aspects of role play were investigated. Role play processes information kinaesthetically, orally and visually, all which contributes to deeper processing, repetition and connectivity within the brain. Role play uses literacy, with an emphasis on speaking, listening and reflective writing and, in this investigation, demonstrates that it is by the use of speech and reflective writing that both students’ literacy and their confidence in their ability to participate develop. Role play has been shown to address all of the difficulties students in this investigation perceived when writing reflectively about the concepts they were learning in Science.

5.2 LIMITATIONS OF USING ROLE PLAY IN THE CLASSROOM
If, as Goodrum, Hackling and Rennie (2001) report, “chalk and talk” is the predominant teaching strategy used in Science classes, one limitation of role play could be the ability
of teachers to implement it effectively as a teaching strategy. Effective role play involves the ability to teach students how to participate effectively in structured group discussion, to present students with sufficient information to enable them to plan and discuss a role play and to take part in social construction that will lead to the learning and the construction of relevant concepts. The lesson must be carefully planned and facilitated by the teacher to enable students to remain involved in the task and clarify the concept. Teachers also need to be aware of metacognition, its implications for learning and cognitive development and to develop it using role play. A poorly planned role play can lead to student misinterpretation and confusion. They also need to understand the importance of oral discussion and of individual reflective writing as part of the learning process and the assessment of the progress in their learning.

Role play cannot be applied to all concepts. Both students and teachers choose it when it is seen as appropriate. Variety is desirable in a classroom so it would not be appropriate to use role play for all learning. For example, teachers could use ICT programs as part of a learning sequence. Instead of writing in their journals or books, students could write a blog or take part interactively using Wiki technology. However, these technologies also depend on the level of teacher expertise in using these technologies as effective learning tools. For example, if a teacher is unable to involve students interactively in a lesson without the use of ICT, it is unlikely that an interactive lesson will be carried out effectively with technology. This technology can enable students to explore and explain scientific concepts collaboratively. However, to be effective, teachers require a metacognitive understanding of the strategies they are using and how these strategies contribute to effective learning outcomes.

5.3 LIMITATIONS OF THE STUDY

This study was carried out in only one setting, a Catholic girls’ school in the mid socio-economic range. It is thus difficult to generalise the results of the investigation to schools catering for different socio-economic groups, gender or culture. The classes researched were taught by the same teacher who was also the researcher. Future research directions
could attempt to replicate the results of this investigation in Science classes catering for different socio-economic groups, gender and cultures.

5.4 FUTURE RESEARCH DIRECTIONS

Research into the effectiveness of role play in schools from lower or higher socioeconomic groups, boys’ schools and co-educational schools could further modify the emergent theory described in this investigation. In addition, research could be conducted into the skills required by Science teachers in order to use role play successfully in a Science lesson and the extent to which these skills are currently used in Science classrooms.

The attitudes of teachers to the use of aspects of role play such as structured group discussion, social construction, metacognition, and individual reflective writing would also be possible directions for further research.
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