CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter begins by providing an overview of the country's demands for the science and technology manpower and the education policy changes to accelerate the fulfillment of those demands. It is followed by an analysis on the reading difficulties encountered by Malaysian undergraduates when reading academic texts in the English language at tertiary level. The statement of problem, objectives, research questions, and significance of the study will be discussed next. Finally, definition of terms and the chapter summary will conclude this chapter.

1.2 Human capital development in science and technology

Malaysia's participation in the aggressively competitive globalized high-tech economy demands for proficiency in the English language and highly prizes advanced knowledge and skills in science and technology (S&T, hereafter) as well as higher level of thinking skills (Eighth Malaysia Plan, 2001; Ninth Malaysia Plan, 2006; p. 248; Rohani & Netty, 2004). Corollary to this and the shrinking demands for the huge number of Arts degree holders (Ain Nadzimah, 2004), the government has undertaken a number of drastic measures to alleviate the imbalance between the increasing demands for S&T professionals and the existing production of Malaysian workforce.

Acknowledging the need to sustain competitiveness and to meet the increasing demands for skilled workforce in the S&T (Abdullah Ahmad Badawi, 2003), Malaysia was resolved to expedite the achievement of a 60:40 ratio of science to arts students at tertiary level (Eighth Malaysia Plan, 2001) (8MP, hereafter), foster lifelong learning through the utilization of ICT (8MP, 2001; 9MP, 2006), and provide greater access (up to 40%) to tertiary education for 17 to 23 year-old cohort. A special programme would be designed to increase enrolment in the postgraduate studies, especially in science and technology (9MP, 2006). To cater for the increase in the demands for S&T associate professionals and technicians, more courses at diploma levels would be offered (ibid). The emphasis on science and technical related studies at first degree and diploma levels in public and private tertiary institutions in Malaysia has seen a big leap in student enrolment from 229, 014 in the year 2000 to 291, 546 in 2005 (9MP, 2006). The government’s 60:40 policy of science to arts undergraduate intake has almost materialized when the 2005 enrolment in all public universities recorded at around 58% science to 41% arts undergraduates (Kam & Tham, 2004, cited in Alis, 2006; Utusan Malaysia, 2005a).

In addition, to prepare students into becoming English proficient scientists and technocrats, the government revised its language and education policy in 2002 by implementing English for Science and Technology (EST, hereafter) as an elective subject for form four and five students in upper secondary school (Kementerian

Pendidikan, 2002a; Rohani & Netty, 2004). Please refer to appendix A1 for government circular on the implementation of EST paper in all secondary schools. In the same year, another language policy change took effect by making English language the medium of instruction for the subjects of mathematics and science at all education levels, commencing with the first year of primary and secondary education, and later throughout all classes by the year 2008 (Abdullah, 2004; Ain Nadzimah, 2004; Alis, 2006; Chan & Tan, 2006; David, 2004; Gill, 2005, 2006; Hassan, 2005; Isahak, 2005; Kamal Shukri, 2002; Kementerian Pendidikan, 2002b; Mohd Noor, 2004; Shaharir, 2005). Please refer to appendix A2 for government circular on the announcement of this policy change.

There are three main assumptions following the government's initiatives in enhancing the nation's S&T capability and capacity mentioned above. First, early and sustained exposure to scientific English would improve the students' understanding of scientific concepts in English as they progress up the education hierarchy (Knowles, 2004). This would, at the same time, improve the students' proficiency in the target language (ibid). Second, success in science programmes at tertiary level is pertinent in supplying the country with S&T workforce and enhancing the nation's research and development endeavors. And finally, independent reading as entailed in lifelong learning initiative (Cornford, 2002; Desjardin, 2003) is vital in ensuring local S&T professionals are kept abreast with and able to read the primary source of the latest scientific breakthrough and discovery published in English in books, academic journals (Abdullah, 2004; Che Lah & Kaur, 2001; Knowles, 2004; Sidhu, 2006), and postings on the internet (Mohd Noor, 2004; Musa, 2003; Ungku Aziz, 2003).

It is evident from the underlying assumptions of the new language policy that the success of Malaysia's S&T initiatives will depend to a large extent on how efficient science undergraduates and S&T professionals in Malaysia are at reading strategically in order to learn from printed and online texts. Reading does not stop at the exit of a university graduation hall nor learning end upon mastery of current technology or scientific discovery. With the information technology revolution and rapid scientific development and progress world wide, knowledge doubles within six months and thus, anything learnt today will become obsolete in a very short time span (Halimah, 2004). Therefore, professionals like doctors, engineers, scientists, as well as teachers must always keep up with the changing practices in their respective professions and efficient reading is the fastest way to catch up with the scientific and technological race.

1.3 Reading difficulty of academic texts at tertiary level

While the government intensifies its efforts to increase the supply of highly skilled manpower in S&T to enhance Malaysia's international competitiveness, young Malaysian undergraduates are struggling to cope with reading English academic texts and scientific materials. A study by Lee (1994) indicated that 84.2% of Malay undergraduates found it very hard to read professional journals and textbooks while 65.8% said that reading chapters in the reference books was as difficult. In the same year, Saragunan and Nambiar found that 90% of the law students did not read beyond the lecture notes and the required references and regarded reading law texts as arduous and laborious work. Silverman (1996, p. 24, cited in Ramaiah, 1997) too found that undergraduates read lecture notes and hardly other things since they had difficulty reading English books. Jamaliah and Faridah's (2001) study revealed that out of 1117 respondents, 59.9% claimed that reading English academic texts was difficult and the difficulties involved not only in understanding the author's opinions and main ideas but also comprehending the vocabulary and sentences. Jamaliah and Faridah's respondents were Malay undergraduates in the University of Malaya and 41.8% of them were from the science and professional degree programmes.

Numerous studies conducted on undergraduates in Malaysian universities (Cooper, 1984; Goh, 2004; Jamaliah & Faridah, 2001; Lee, 1994; Lim, 1992; Nik Suriana, 2001; Ponniah,1993; Ramaiah, 1997; Ruhaizan, Mohd Jasmy, Norlena & Rosadah, 2001; Sargunan and Nambiar, 1994; Teoh, 1996; Yap, 1981) as well as one other study in a foreign university (Noor Fadhillah, 1999) revealed that Malaysian undergraduates continued to have serious problems in reading English academic texts at least in their first year at the university. Sargunan and Nambiar (1994) reported that undergraduates were lacking in reading strategies and reading perseverance, while Noor Fadillah's (1999) respondents claimed that reading skills they acquired in secondary schools as well as matriculation centres were insufficient to meet the demands of tertiary academic reading in an Australian university.

English language and content lecturers naturally attribute the difficulty in reading academic texts amongst undergraduates to inadequate English language proficiency as also asserted by other second language reading researchers (Carrell, 1988; Clarke, 1980; Chen & Donin, 1997; Harvey, 2005; Tan, 1995; Yorio, 1971, cited in Alderson & Urquhart, 1984) as well as lack of practice and preparation in reading authentic English academic texts prior to entering the university (Abdul Razak,1989 cited in Ramaiah, 1997; Carrell & Carson, 1997; Cooper, 1984; Noor Fadillah, 1999; Shih, 1992). Indeed, reading difficulty in content-area texts is most prominent when ESL students make the transition to English medium academic mainstream from secondary to tertiary level (Rosenthal, 1996, p. 116; Shih, 1992). This perception is supported by the findings of Imran Ho (2001) regarding English language proficiency of 3518 undergraduates entering Universiti Kebangsaan Malaysia in its 2001/2002 academic session based on the bands they obtained in the Malaysian University English language Test (MUET). From the six possible proficiency bands in MUET where band 6 indicates excellent command of the four language skills and band 1 indicates very poor English competence (Mohd Don, 2004), Imran found that for science undergraduates, the majority of Chinese and Indian students obtained bands 4 and 5 respectively and Malay students band 3.

Hence, to remedy the linguistic problems and to prepare ESL undergraduates for their content classes, most universities require their first year students to enroll in English for Academic Purposes (EAP, hereafter) courses. These courses are designed to enhance undergraduates' English language proficiency (e.g. content area vocabulary, sentence analyses), develop reading skills (e.g. determining main ideas, finding supporting details or arguments, and guessing unfamiliar words using contextual clues), and practice pre-reading strategies such as activating prior knowledge (Shih, 1992; Simpson, Stahl & Francis, 2004). Helpful as they are, these linguistic and skill building exercises are insufficient (Noor Fadillah, 1999; Shih, 1992; Simpson et al., 2004) in assisting 'unpractised' nonnative readers, as Cooper (1984) called the local Malaysian undergraduates, in overcoming multiple reading difficulties posed by conceptually and linguistically challenging texts, such as the scientific texts. What is apparently missing in these EAP classes is a systematic training on comprehension strategies (Shih, 1992), in particular cognitive and metacognitive strategies, which have repeatedly been found to make a significant difference in the comprehension of English academic texts (Auerbach, & Paxton, 1997; Nik Suriana, 2001; Ponniah, 1993; Ramaiah, 1997; Salataci & Akyel, 2002) and in fact could lead students to become active and critical readers (Simpson, et al., 2004).

Moreover, according to Khalijah (1997), learning science requires an in-depth understanding of scientific principles. This understanding entails cognitive processing which includes the employment of logical and rational thinking as well as decision making skills through inductive and deductive evaluations (ibid). Learning science in a second language such as English puts more demands on ESL students' cognitive processes. They are no longer just processing the abstract principles of the scientific knowledge but are also negotiating the language of the texts. Cognitive processing in an individual may have developed naturally but in many cases must be activated through vigorous training (Khalijah, 1997). Once students are able to think independently and are at the same time aware of their own thinking processes, they are able to monitor they own academic progresses (Koda, 2005).

The contention that cognitive and metacognitive strategies could play a significant role in reading comprehension of science academic texts among science undergraduates can be deduced from the findings of Jahara and Norazina's (2001) study. They looked into the academic performance of science undergraduates based on their Cumulative Grade Point Average (CGPA, hereafter). Since reading academic and scientific texts makes up a big fraction of undergraduate coursework in the faculty of science, it could safely be assumed that the CGPA obtained by these students is a reflection of their comprehension and understanding of the assigned reading materials for each course (Benson, 1991; Brown, 1988; Koda & Zehler, 2008; Levine, Farenz, & Reves, 2000; Mestre, 1981, cited in Graham, 1987). Jahara and Norazina (2001) found that the mean CGPA for Chinese students was between 3.16 and 3.20 for three consecutive years from 1999-2001 whereas for Indian and Malay students the mean CGPA was between 2.42 and 2.59. If the findings that Indian, Chinese, and Malay students entered the university with MUET bands 5, 4, and 3 respectively (Imran Ho, 2001) could be generalized to all science undergraduate population in Malaysia, it than indicates that English language proficiency alone cannot be responsible for the reading comprehension of science academic texts of the three groups of students. Thus, if English language proficiency could not explain science undergraduates' academic performance, what are other factors that could?

The significant difference in the mean CGPA of Chinese, Indian and Malay students may be attributed to a repertoire of other variables (Devitt, 1997) such as prior knowledge brought to the scientific reading materials by these science undergraduates (Chen & Donin, 1997; Spence, Yore & William, 1995; Tan, 1986; Yore, Craig & Maguire, 1993) , motivation to succeed (Guthrie, Alao & Rinehart, 1997; Huang, 2006), interest in the topics of the reading texts (Alexander & Kulikowich, 1994; Hidi, 2001; Schiefele & Krapp, 1996), and comprehension strategies (Anderson, 1991; Bernhardt, 2000; 2005; Carrell & Wise, 1998; Horiba, 1990; Koda, 1993; 2005; Spence *et al*., 1995). However, Frederiksen (1982, cited in Palmer, MacLeod, Hunt, & Davidson, 1985) attributes individual differences in reading comprehension to three classes of processes: processes in (a) analyzing the visual aspects of individual words and sentence, (b) intergrating information presented at different points in a text, and (c) relating information in a text to general world knowledge. These processes bear a resemblance to Hammadou's (1991) claim about the correlates of reading. According to Hammadou, reading is a complex interaction of three major variables; the reader's language proficiency, prior knowledge and metacognition. But how much difference could science prior knowledge attribute to the significant difference in the mean CGPA of Chinese, Indian and Malay undergraduates when the majority of first year undergraduates who underwent Malaysian primary and secondary education system would share almost common domain specific knowledge specified by the Curriculum Development Centre? Hence, besides English language proficiency and prior knowledge, the significant difference found between high and low achievers amongst first year university students may be attributed to the metacognitive awareness, monitoring and cognitive strategies they employ during reading (Anderson, 2008; Bonner & Holliday, 2006; Cuasay, 1992; Koch, 2001; Koda & Zehler, 2008; Otero, Campanario & Hopkins, 1992), in which the third variable, metacognition, plays a significant role (Flavell, 1977, cited from Pressley, 2006).

While general English language proficiency and prior knowledge are imperative in the success of reading comprehension (Bernhardt, 2000; 2005; Bernhardt & Kamil, 1995; Brantmeier, 2005; Carrell, 1991; Chen & Donin, 1997; Tan, 1986; 1995), strategies undertaken to process conceptually challenging texts are a necessity not to be overlooked (Baker & Brown, 1984; Coady, 1979; Koda, 2005; Paris, Wasik & Turner, 1991). Studies done to observe how accomplished readers read found that they constantly and deliberately choose specific actions (Bazerman, 1985; Pressley, 2006; Wyatt, Pressley, El-Dinary, Stein, Evans & Brown, 1993) or reading tactics to overcome comprehension difficulties and resolve reading confusions to ensure full understanding and correct interpretation of the text read (Anderson, 1991; Baker & Brown, 1984). These specific reading tactics are what researchers call comprehension or reading strategies (Block & Pressley; 2002; Carrell, 1989; Mokhtari & Sheorey, 2002, Singhal, 2001), cognitive and metacognitive strategies (Weinstein and Mayers,1986), strategic reading (Koda, 2005; Paris *et al.*, 1991), or problem-solving strategies (Ponniah, 1993).

Cognitive and metacognitive strategies are, in essence, actions taken by readers to make sense of what they read, steps employed to comprehend what they do not understand, and alternatives considered and executed to get around "knotty" texts (Koda, 2005). Since these cognitive actions or strategies are carried out in a deliberate manner as mentioned earlier, it suggests the presence of higher order thinking skill or metacognition that is monitoring, governing, and directing these cognitive strategies into actions during a reading process.

The findings from the many studies mentioned above may have shed a little light into the source of difficulty faced by Malaysian undergraduates in reading tertiary level academic texts in English. It can be concluded that being linguistically proficient and knowledgeable does not always guarantee a smooth reading process especially when readers are engaged in conceptually difficult materials. Every reader will encounter some kinds of comprehension failure especially as he or she “ascends the educational ladder” (Koda, 2005). However, readers who are armed with personal cognitive tools (Paris, Wasik, & Turner, 1991) such as cognitive and metacognitive strategies will make conscious effort to stride through the complexities of the text in order to get to the core message with correct interpretation. Thus, the need has arisen for a study that looks into cognitive and metacognitive strategies employed by undergraduates, science undergraduates in particular, when reading scientific texts. Information from such study will in turn be used to train students with reading difficulty in regulating their reading stategies through the use of personal cognitive tools (Koch, 2001) such as cognitive and metacognitive strategies. These efforts are more crucial than ever now with the reversal of the language policy in Malaysia as mentioned in section 1.2 above.

On the other hand, if Malaysian university students, in particular science majors, are oblivious to their own thinking capacity, unaware of the benefits of cognitive and metacognitive strategies in reading, and not proficient in the English language (Berita Harian, 2007), they will fail to extract valuable scientific information, facts, and details (Koch, 2001) which are extremely vital for the future progress and growth of the country. Thus, strategies which are effective for the use of science undergraduates must be explored, identified, and brought to fore to be shared by other less skilled science readers. Ultimately, explicit cognitive and metacognitive strategy training to read scientific texts could be designed and conducted to assist science undergraduates in reading academic texts in their content classes.

1.4 Problem statement

Comprehension strategies, in particular cognitive and metacognitive strategies, have been shown to be very significant in improving reading comprehension of narrative and non-scientific expository texts amongst second language learners (Barnett, 1989; Block, 1986; 1992; Crain Thorenson, Lippman & McClendon-Magnuson, 1997; Hosenfeld, 1977; Kern, 1989; Koda, 2005; Olshavsky, 1977; Salataci & Akyel, 2002; Saricoban, 2002; Singhal, 2001). However, there is still a lack of research that looks into how second language learners read scientific text written for native speakers and navigate through its scientific terminology and syntactic complexity (Halliday, 2006).

Similarly, Malaysian researchers investigating reading strategies in second language reading comprehension studies have always preferred non-scientific academic texts to scientific texts, such as Law (Ponniah, 1993; Saragunan & Nambiar, 1994), Accounting (Noor Fadillah, 1999), Business, Management and Public Administration (Ponniah, 1993), Library Science (Lee, 1994), Social Science (Goh, 2004; Mohd Shah, 2004), Humanities and Business (Nik Suriana, 2001), and fiction (Sheikh Ahmad & Mohd Ashraf, 2004). A few exceptions are qualitative studies by Soars (1995, cited in Nuretna, 2002), Teoh (1996) and Nuretna (2002) who used chemistry and biology texts in their studies on second language reading comprehension and strategies. Clearly, there is still too little research done on second language reading comprehension of scientific texts, especially amongst undergraduates in local context. Indeed, more research in this area is needed to determine the repertoire of strategies brought to and utilized by first year science undergraduates in their reading processes of scientific texts at tertiary level. Moreover, research evidence is needed to show whether second language learners employ similar or different cognitive and metacognitive strategies when reading scientific texts as compared to non-scientific texts.

While there has been much emphasis on the teaching of EST to upper secondary students and EAP and English for Specific Purposes (ESP) to undergraduates in various degree programmes, a review of the literature shows that the focus of research so far has been directed towards helping learners to understand scientific terminology and syntax to be able to read (Halliday,1988; Love,1991; Tarantino,1991) and write scientific reports in the scientific language of English (Braine,1989; Parkinson & Adendorff, 2004; Sionis, 1995; Swales, 1971; Weissberg, 1984). There has been hardly any study that looks specifically at the reading strategies taught in these courses to determine if they are in fact appropriate for reading academic texts in a specific domain area such as science. Malaysian researchers in their qualitative studies, on the other hand, found that the local science undergraduates made use of visual representations (Teoh, 1996) such as drawing mind maps (Nuretna, 2002) while reading scientific texts. This particular strategy, however, is not listed in many leading reading strategy inventories such as Block's reading strategies (1986), Pritchard's Taxonomy of Processing Strategies (1990), and MARSI (Mokhtari & Reichard, 2002). Therefore, it is pertinent to conduct a study that looks into and identify the strategies that effectively influence the reading comprehension of scientific texts rather than taking for granted that a list of strategies fits all types of reading texts.

Unlike general English texts, scientific texts written for native speakers and experts in the field are found to be very difficult to read not only by ESL readers but also by readers whose first language is English (Bell & Perfetti, 1994; Flick & Anderson, 1980; Halliday, 2004). The high usage of passivization (Conrad, 2001; Higgins, 1967), scientific terminology and nominal groups (Banks, 2004; Halliday, 2004; Hutchinson & Waters, 1987; Jaipal, 2001) contributes to the syntactic complexity and ambiguity (Halliday, 2004) of scientific texts. Reading these texts is extremely demanding, especially for first year science undergraduates who are learning abstract concepts of science at a more advanced level in their second language. Since reading comprehension determines undergraduates' academic performance at the university (Brown, 1988; Carrell, 1989; Cooper, 1984; Levine, Ferenz & Reves, 2000; Simpson & Nist, 2002), undergraduates must be taught to become active and strategic readers by utilizing cognitive and metacognitive strategies (Simpson, Stahl, & Francis, 2004). Thus, information gathered from the studies that explore what successful local ESL readers do while reading scientific texts can be shared and taught to other science readers in EST, EAP, ESP, and other content area courses.

Furthermore, the need to understand how local students cope with scientific texts written in English becomes even more critical with the educational policy shift[1] of 2002 as mentioned earlier (Please refer to Section 1.2) in this chapter. The change in the language of instruction for science subjects from Malay to English (Kementerian Pendidikan, 2002b) has left thousands of science undergraduates "trapped in transition" between the current Malaysian Education Policy and the language policy of the 1957 which, prior to the year 2003, stipulated the teaching of all subjects, except for English and pupils' own languages, to be in the national language (Asmah, 1982; 2003; Raja Mukhtaruddin, 1992; Sidhu, 2006). The main obstacles to academic success amongst the ESL science undergraduates affected by this new policy arise from having to cope with the complexity and abstraction of scientific English at the university and also the problem of translating and relearning scientific terminology used in the English language (Ahmad Saat, Badrul Hisham, & Syed Yusainee, 2001). Based on this important grounds, an in-depth study on how first year science undergraduates cope with the language transition especially when reading scientific texts in the English language is therefore timely and significant.

Finally, second language reading researchers (Bernhardt & Kamil, 1995; Brisbois, 1995; Carrell, 1991; Clarke, 1980; Kern, 1989; Koda, 2005; Tan, 1986; 1995) claim that L2 proficiency is the key to efficient L2 reading comprehension where L2 proficiency entails the knowledge of L2 vocabulary (27% of the variance in L2 reading comprehension) and syntax (3%) (Bernhardt & Kamil, 1995; Bossers, 1991; Brisbois, 1995; Carrell, 1991). Yet, at least two studies so far have shown that L2 proficiency does not always determine successful reading comprehension of domain-specific academic texts (Anderson, 1991) such as biology (Chen & Donin, 1994). For this reason and the reason given in Section 1.3 about the English language proficiency and CGPA of Malay, Chinese and Indian students in Malaysian public universities, the researcher would like to establish the roles played by L2 proficiency, prior knowledge, and metacognition in the reading comprehension of scientific texts at tertiary level. At the same time, the proposed research would like to identify the nature of the interactive compensatory strategies (Stanovich, 1980) utilized by these second language learners that seem to assist their understanding of scientific texts with lesser L2 proficiency.

Thus, this research is aimed at conducting an in-depth study on first year science undergraduates who learnt science subjects in Malay in their primary and secondary educations but are required to understand the scientific concepts in English at the university. The present study focuses on identifying the cognitive and metacognitive strategies the students employ in extracting meaning from the scientific texts. Besides, the study looks into the relationships among L2 proficiency, prior knowledge, metacognition, and cognitive and metacognitive strategies which contribute to the reading comprehension of three university level scientific texts by ESL learners.

1.5 Research objectives

Based on the discussions above, the objectives of the study are as follows:

Quantitative research objectives

1. To determine the relative contributions of metacognition, scientific prior knowledge and L2 proficiency on cognitive and metacognitive strategy choices when reading two scientific texts.

2. To determine the relative contributions of metacognition, scientific prior knowledge, and L2 proficiency to the success of reading comprehension of two scientific texts.

3. To determine the repertoire of cognitive and metacognitive strategies that are commonly employed by first year science undergraduates with high and low English language proficiency when reading two scientific texts.

4. To identify the cognitive and metacognitive strategies which are significant in enhancing the reading comprehension of scientific texts.

5. To determine which of the following independent variables (metacognition, scientific prior knowledge, L2 proficiency, cognitive and metacognitive strategies) most influences reading comprehension of the two scientific texts.

6. To identify the characteristics of good ESL readers of scientific texts.

Qualitative research objective

7. To find out how ESL readers with different levels of L2 proficiency negotiate the two scientific texts.

8. To find out the difficulties encountered by ESL readers while reading the two scientific texts and the approaches to overcome the obstacles.

1.6 Research questions

In line with the above objectives, this study seeks to answer the following quantitative and qualitative questions:

Quantitative research questions

1. Is there a significant relationship between **metacognition** and
   a) cognitive and metacognitive strategies utilized when reading the two scientific texts?
   b) reading comprehension scores of the two scientific texts ?

2. Is there a significant relationship between **scientific prior knowledge** and
   a) cognitive and metacognitive strategies utilized when reading the two scientific texts?
   b) reading comprehension scores of the two scientific texts?

3. Is there a significant relationship between **L2 proficiency** and
   a) cognitive and metacognitive strategies used to read the two scientific texts?
   b) reading comprehension scores of the two scientific texts?

4. a) What are the types of strategies commonly employed by first year ESL science undergraduates with high and low English proficiency when reading the two scientific texts?

b) Which specific strategies (cognitive and metacognitive strategies) significantly contribute to the reading comprehension scores of the two scientific texts?

5. Which variable (metacognition, scientific prior knowledge, L2 proficiency, or reading strategies) most influences the reading comprehension of the two scientific texts?

6. What are the characteristics of good ESL readers of scientific texts?

Qualitative research question

7. How do ESL readers with different levels of L2 proficiency negotiate the two scientific texts?

8. What are the difficulties they encountered while reading the two scientific texts and how did they overcome the problems?

1.7 Significance of the study

The findings of this study will have an impact on both theoretical and pedagogical aspects of reading in a second language. In terms of the theoretical significance, this study sets out to contribute to the present body of knowledge on cognitive and metacognitive strategies in reading scientific texts in the second language. The study may provide insights into the interactions of knowledge resources as hypothesized in the interactive compensatory reading model and thus helps establish the relationships among the key variables in L2 reading comprehension of scientific texts. In terms of the pedagogical significance, the study will contribute to at least four aspects of learning in Malaysia.

First, the study is significant to all secondary and matriculation students as well as undergraduates and post graduates students who are pursuing higher level education. The demand to be literate and proficient in English is getting higher and higher especially with the new types of literacy nowadays. Reading proficiency in particular cannot be divorced from the academic world and the pursuit of excellence in any given fields. Malaysian university students are required to read textbooks, journal and electronic articles as well as reference books which are mostly written in their second language, which is the English language (Abdullah, 2004; Imran Ho, 2001). Since education at tertiary level provides very limited science reading materials in the students' first language (Abdullah, 2004; Sidhu, 2006), there is an urgent need for these students to acquire skilled reader's strategies in reading academic English of scientific texts. Understanding what strategies to use, why and when during reading is vital for academic success in order to understand, decipher and remember new, abstract and complex scientific concepts.

Second, this study is significant for lifelong learning (Cornford, 2002; Desjardin, 2003; Ibrahim, 2005). The avalanche of academic reading materials in the market as well as in the internet today has compelled the world populace to adopt skilled reader's strategies and tactics for maximum reading comprehension and learning. Independent reading necessitates efficient and effective reading tactics. The demand for reading in English increases as undergraduates embark upon their chosen career paths as young professionals in the fields of science (Koch, 2001). As new knowledge is continuously being discovered as well as created and new information rapidly replaces the old ones, people ought to learn new technology and discoveries through reading. Thus, having learnt how to read strategically, these young professionals will become efficient independent and self regulated readers (Paris, Wasik & Turner, 1991; Koch, 2001).

Third, this study is significant to all reading teachers of any languages at all levels of education, be it primary, secondary or tertiary. Methodology such as think aloud protocol and verbal reports have provided a window for others to observe how skilled readers strategize and orchestrate the use of their comprehension strategies while reading. Information on these workable strategies can be documented and analyzed. Strategies shown to significantly contribute to comprehension can be shared and taught to other less or unskilled readers through explicit instruction and training. Data from a wide array of research on strategy instruction and training indicate that comprehension strategies can be learnt and when utilized during reading, comprehension improves (Block & Pressley, 2002; Goh, 2004; Nik Suriana, 2001). Most potent training is those on metacognitive awareness (Carrell, 1989; Koda, 2005). This is because, when readers are aware that they have comprehension problems and know that they can take action to offset the confusion, they will take the necessary cognitive steps to remedy the situation. Another important insight that this study may reveal is how readers process conceptually and linguistically complicated texts, such as scientific texts, which may require different set of comprehension strategies from processing general texts.

Fourth, this study is significant to curriculum designers and policy makers. There is an urgent need for a whole new subject called reading education at all levels of education starting from elementary years up to tertiary level. According to Block (1992), reading is such a silent and covert process that what goes on in the mind of the reader is not known until his/her understanding of the text is assessed during discussions of post reading comprehension exercises or marks s/he receives in a reading comprehension test. The biggest mistake ever committed by reading instructors is to assume that students comprehend a reading text just because they are reading (RAND study, 2002). Researchers of the study maintain that the ability to read the words in a text does not necessarily guarantee comprehension of the text.

The current practice in Malaysia is to assess the ability to read through the employment of post reading comprehension questions as well as comprehension tests. What is being overlooked is the appraisal of the cognitive processes and comprehension monitoring during the reading activity itself. What has been ignored in Malaysian reading classrooms is the syllabus on nurturing efficient reading processes and effective comprehension strategies which will eventually yield an end result of producing proficient adult reader. This proficient reader would in turn be able to read a variety of materials with ease and interest, for different purposes with comprehension regardless of how demanding or how intrinsically unmotivating the texts may be (RAND Study, 2002).

1.8 Definition of terms

1.8.1 Scientific text

Scientific texts refer to texts written about sciences and made use of scientific language, terminology, and concepts (Higgins, 1967; Halliday & Matthiessen, 2004).

1.8.2 L2 reading comprehension

Reading comprehension is defined as *the process of simultaneously extracting and constructing meaning through interaction and involvement with written language* (RAND Study, 2002, p. 11). While L2 indicates the process of reading and comprehending a text in the reader's second language.

1.8.3 L2 proficiency

L2 proficiency refers to the knowledge of vocabulary, syntax and grammar (Brisbois, 1995; Gascoigne, 2005; Koda, 2005) of a second language, which in this study refers to the English language.

1.8.4 Scientific prior knowledge

Prior knowledge is accumulated knowledge acquired and possessed by an individual through life experiences and stored in his/her long term memory (Anderson & Pearson, 1984). Scientific prior knowledge refers to the knowledge of science topics possessed by readers, who in this study refers to the first year ESL science undergraduates.

1.8.5 MUET

Malaysian University English Test is a test of English language proficiency for public university admissions (Mohd Don, 2004).

1.8.6 Metacognition

Metacognition refers to learner's understanding and control of his/her own thinking and learning (Flavell, 1985).

1.8.7 Comprehension strategies

Comprehension strategies are also known as reading strategies. They include cognitive, metacognitive, affective, and support strategies utilized by a reader during reading to assist in the comprehension and understanding of the text read. For the purpose of this study, only cognitive and metacognitve strategies are studied.

1.8.8 Lower level cognitive strategies

Lower-level cognitive strategies are also known as local strategies (Block, 1986), bottom up processing or lower-level processing (Koda, 2005). They are attempts to understand specific linguistic units (Block, 1986).

1.8.9 Higher level cognitive strategies

Higher level cognitive strategies are cognitive steps aimed at global comprehension of the text by synthesizing information in the text with the reader's prior knowledge, content knowledge, and linguistic knowledge to interpret reading texts and solve reading difficulties (Urquhart & Weir, 1998). These strategies include accessing prior knowledge, inferring, summarizing, analyzing and elaborating.

1.8.10 Metacognitive strategies

Metacognitive strategies are those strategies related to self-management or self-regulation while one is reading a written text, reflecting and thinking on what is being read and the extent of his/her understanding of the text (Koda, 2005; O'Malley & Chamot, 1994).

1.9 Chapter summary

This chapter has outlined the justifications to study comprehension strategies used by first year science undergraduates when reading scientific texts in English as their second language at tertiary level. The chapter begins by providing a background on the country's aspirations in generating more science and technology manpower which have led to some policy changes at all levels of education. This is then followed by an overview concerning the difficulties faced by Malaysian undergraduates when reading academic texts, references and professional journals in their second language, which is the English language. There are three reasons for conducting a study that looks into comprehension strategies used by ESL learners when reading scientific texts. The first reason is that there is a dearth of information on strategies utilized by ESL readers when reading scientific texts, whether in local or foreign literature. Second, there is an urgent need to understand how ESL readers read scientific texts so that significant findings regarding successful strategies can be documented, shared and taught to other ESL learners of science. Third, a study such as this could provide an in depth understanding on how Malaysian science undergraduates who experience the language policy shift cope with reading English scientific texts at a more advanced level. This chapter finally examines some of the benefits and significance of the study to ESL readers and teachers at all educational levels as well as the insights and understanding for a better strategy training in the future.

Notes:

[1]The Malaysian Education Policy of 1957 aimed at providing education to all Malaysians through a common language as a medium of instruction, which was the Malay language (Asmah, 1982). The phasing out of English from Malaysian administration, schools and education and the implementation of the Malay language as the sole official language of the nation and of educational instruction were prompted by the need to unite Malaysians who were then economically, ethnically and educationally divided (p. 16), a system imposed by the colonial rulers, the British. However, with the explosion of information technology, globalization of industries, and internationalization of education, English language has become the most dominant language in all types of interfaces and dealings both at local and international levels (Asmah 2003; Hafriza, 2006; Knowles, 2004) and have, thus, led to the growing demands for mastering the English language. In 2002, in its attempt to improve English proficiency amongst Malaysians, the government announced an education policy change, calling for English as the medium of instruction for all mathematics and science subjects (Baharuddin Zainal, 2006, p.6; Chan & Tan, 2006; David, 2004;Gill, 2005; 2006; Kementerian Pendidikan, 2002a; Mohd Noor, 2004) in stages in all schools commencing with the first year of primary and secondary education, and later throughout all classes by the year 2008.The teaching of science and mathematics in the Malay language, in all secondary schools throughout the nation was phased out by the year 2007 and in all primary schools by 2008.

CHAPTER TWO

THEORETICAL FRAMEWORK

2.1 Overview

This chapter covers the theoretical framework for the study. It begins with detailed discussions on the Reading Theory and the four reading models, primarily the Bottom-up Reading Model, Top-down Reading Model, Interactive Reading Model, and Stanovich's Interactive Compensatory Reading Model. This is then followed by the Schema Theory and Metacognition Theory. The final section of this chapter describes how these three key theories are used as a platform to guide the researcher in the study.

2.2 Key theories in reading comprehension processes

In order to understand the root of and motive for second language (L2, hereafter) readers' cognitive and metacognitive strategy choices in reading scientific texts, this study draws on theories closely associated with the reading comprehension processes namely the reading theory, schema theory, and metacognition theory.

2.3 The Reading Theory

Reading is a psycholinguistic process of making sense of the written language (Goodman, 1988; 2005). Readers as active recipients of the textual input (Narvaez, 2002; Pressley & Afflerbach, 1995; RAND Study, 2002) constantly undergo constructive thinking process to comprehend explicit and implicit meaning of the text (Pumfrey, 1977, p.2). Reading begins with written symbols encoded by the writer and ends with meaning constructed by the reader. Readers who are able to construct meaning close to the intended meaning by the writer are proficient readers who efficiently use "strategies for reducing uncertainty, always being selective about the use of the cues available, and drawing deeply on prior conceptual and linguistic competence" (Goodman, 1988, p. 12). A constructivist views reading comprehension as not only being influenced by the readers' linguistic knowledge but also by their reading purpose, schematic and prior knowledge, socio-cultural background as well as their ability to integrate and synthesize these stored knowledge with the text content (Kern & Schultz, 2005; RAND, 2002).

Three reading models developed in first language reading research but have significant impact and implications on L2 reading research (Bernhardt, 2005; Carrell, 1983b; Lee, 1986a) and instruction (Coady, 1979; Grabe, 1991) are bottom-up, top-down, and interactive reading models. These reading models discussed below offer insights on the direction of strategy shifts and choices utilized by readers when they interact with different texts of varying syntactic difficulty and topic familiarity.

2.3.1 Bottom-up Reading Model

The bottom-up reading model hypothesizes reading as an encoding process of text symbols from left to right, to words, phrases and finally sentences in discrete stages before intended meaning of the author is reached and interpreted in the reader's primary memory (Gough, 1972; Samuels & Kamil, 1984; Urquhart & Weir, 1998). In this left to right eye movement (Gough, 1972), readers are assumed to 'pick up' (p. 32) small chunks of data from the text before adding them to earlier chunks until the stings of words yield meaning (Barnett, 1989; Spiro & Myers, 1984). The proponents of bottom-up reading model assert that these lower level cognitive processes precede higher cognitive processes of interpreting meaning in reading comprehension. In other words, bottom-up reading model views reading as a one-way flow of information from the text (bottom) to the reader's mind (up).

As a data-driven process which is typically controlled by textual input and recognition of letters and words (Weaver & Resnick, 1979), bottom-up reading model emphasizes on fluent verbal coding skills such as automaticity and the speed of word recognition to decode printed text (LaBerge & Samuels, 1974). Problems with decoding skills will severely impede comprehension as the working memory and attentional resources are overloaded with the decoding tasks and thus exhaust the ability to process meaning (LaBerge & Samuels, 1974; Samuel & Kamil, 1984).

While this reading model is less favourable among second language reading researchers for pedagogical purposes (Bernhardt, 1986 cited in Barnett, 1989), it nevertheless provides a glimpse on the approaches to reading by less proficient second/foreign language readers. Studies by reading strategy researchers (Hosenfeld, 1977; Olshavsky, 1977) reveal that bottom up processing alone does not lead to successful comprehension if readers do not activate their prior knowledge and fail to integrate meanings amongst the sentences. In fact, proficiency in decoding may still be insufficient to ensure successful comprehension of the reading text (Spiro & Myers, 1984). Fleisher & Jenkins (1978) found that training children to fluently decode words that would appear in a story failed to improve their reading comprehension. This leads to a conclusion that reading comprehension requires the acquisition of processing skills beyond those involved in acquiring the written code (Spiro & Myers, 1984).

2.3.2 Top-down Reading Model

The popularity of textual decoding was, however, contested by the top-down processing model advanced by, among others, Kenneth Goodman (1967) and Frank Smith (1971) who posit that reading is a psycholinguistic process. Smith (ibid) argues that reading is not an analysis of letter by letter or word by word of the text as it is not only laborious but also fails to explain the behaviours of skilled readers who read efficiently and effectively (Goodman, 1988; Grabe, 1991). Goodman (1967) refers to reading as a psycholinguistic guessing game that begins with a prediction of meaning in the reader's head and is followed by selective reading of certain parts of the text to confirm or reject the prediction.

Top-down reading model puts major emphasis on higher level cognitive processes such as making inferences and generating hypotheses based on reader's prior knowledge (Goodman, 1967; Smith, 1971) and existing schemata. Each reader brings his or her own unique experience to the reading text and based on this prior knowledge, s/he makes hypotheses about the text content. The reading process is, thus, controlled by higher thinking skills while lower level skills are only utilized when the need arises (Weaver & Resnick, 1979). Unlike the bottom-up view which puts the reader in the periphery of meaning making process, the top-down model recognizes the central role played by the reader's familiarity of the content which promotes comprehension.

The psycholinguistic reading model has been widely cited and much favoured in the second language reading circles (Clarke & Silverstein, 1977; Coady, 1979; Grabe, 1991). The contentions put forward by this reading model help explain the phenomena in second/ foreign language reading especially amongst adult L2 readers. They are often proficient first language readers who bring a repertoire of world and content knowledge to their L2 reading (Koda, 2005). The ability of adult L2 readers to make predictions about a second language text based on their extensive general knowledge plays a big role in their L2 reading comprehension. The fact that activating one's prior knowledge can reduce dependency on textual input has practical pedagogical implications to second/ foreign language reading instruction. The principles advocated by the psycholinguistic model have led second and foreign language reading instructors to emphasize the higher level cognitive activities prior to reading such as in an effort to activate L2 reader's prior knowledge which could ultimately facilitate comprehension of the L2 text (Clarke & Silverstein, 1977; Coady, 1979).

2.3.3 Interactive Reading Model

Instead of viewing reading as a linear sequential process of either bottom-up or top-down processes, Rumelhart (1977) suggests that reading is an interaction of both bottom-up and top-down processes. Interactive reading model recognizes the concurrent interaction of both lower level processing skills which entail identification of letters, decoding of words and automatic recognition of words with that of higher-level cognitive reasoning such as making inferences and interpretations (Spiro & Myers, 1984). Rumelhart argues that reading involves simultaneous perceptual and cognitive processes. To demonstrate the effect of cognitive process which utilizes semantic knowledge (high level cognitive process) on word perception (low level cognitive process), Rumelhart provides empirical evidence regarding decisions in word guessing. Word guessing is more efficient when a pair of words are semantically related, as in bread-butter and nurse-doctor than if they are semantically unrelated like bread-doctor and nurse-butter. Likewise, the speed of word recognition is faster when more context is given before presenting the target word than if the word is presented in isolation.

According to Rumelhart, when a reader looks at the written print, words and spellings will be registered in the visual information store (VIS) where the feature extraction device will extract the key features of these words (bottom-up process) before the information is sent to a pattern synthesizer. At the pattern synthesizer, all the reader’s knowledge sources will come together to interpret what is being read (top-down processes). “Thus, all of the various sources of knowledge, both sensory and nonsensory, come together at one place and the reading process is the product of the simultaneous joint application of all the knowledge sources" (p. 588). Grabe (1991, p. 383) too asserts that "reading involves an array of lower-level rapid, automatic identification skills and an array of higher-level comprehension and interpretation skills".

Interactive reading model makes a lot of sense regarding the reading process especially in a second language where adult L2 readers are usually stymied with limitations in L2 phonological knowledge. The concept of interaction between the reader and the text in this reading model explains and acknowledges the utilization of L2 reader's prior knowledge as well as reading strategies acquired in L1 onto the L2 reading text. Thus, to sum up, in the psycholinguistic view of reading which emphasizes the interactive nature of a reading process, the L2 reading performance requires three key skills; decoding, reconstruction of meaning from text, and integration with prior knowledge.

2.3.4 Stanovich's Interactive Compensatory Reading Model

Based on the assumption that reader's multiple component skills can operate on compensatory manner, Stanovich suggests an "interactive-compensatory" model of individual differences where "a deficit in any knowledge source results in a heavier reliance on other knowledge sources, regardless of their level in the processing hierarchy" (Stanovich, 2002; p. 63).

Stanovich's interest in the phenomenon on individual differences in fluency reading was triggered by contradictory findings on word recognition and context effects by good and poor readers. According to top-down model, good readers will use contextual clues based on their prior knowledge to facilitate word recognition in text (Goodman, 1976; Smith, 1971). Poor readers will not be able to use contextual clues because they are assumed to not have that prior knowledge in the first place and thus would rely on visual information only, which is the source of reading difficulty amongst poor readers (Smith, 1971). Interactive model, on the other hand, assumes that all knowledge sources will interact with the visual input and thus, predicts that both poor and good readers will have a fair chance at recognizing the words in print.

To examine the above phenomenon, West and Stanovich (1978) had subjects named target words based on preceding complete and incomplete sentences which matched the target words, preceding complete and incomplete sentences which did not match the target words, and no–context condition except simply for the word "the". The results of the experiment among others revealed that poor readers were, in fact, more reliant on contextual factors then previously thought while good readers most often merely rely on direct visual input for automatic word recognition. The findings imply that poor readers are more dependent on contextual clues to guess at meaning of words, which means utilizing strong syntactic, semantic and prior knowledge to compensate for lexical or orthographic deficiencies. In contrast, good readers waste no time on predictions and hypotheses for automatic word recognition. The studies such as these suggest that it is the poor readers who hypothesize from context more than good readers.

The concept of interactive-compensatory model of reading process seems more satisfying in explaining the reading process in a second language (Bernhardt, 2005). This model suggests that certain knowledge sources can assist and undertake the role of other knowledge sources that are deficient, inadequate or nonexistent (ibid, p. 140). Bernhardt views knowledge sources as working "synchronically, interactively and synergistically". In other words, according to Bernhardt, second language reading process is a juggling process in cognition.

2.4 The Schema Theory

Schema theory has emerged as a theoretical framework to account for the role of prior experience and knowledge in the mind (Carrell & Eisterhold, 1983; Nassaji, 2002; 2007). This theory of knowledge is the key reference to explain cognitive processes such as problem solving, inferencing and remembering for many experimental research on learning, comprehension and memory (Nassaji, 2002). Schema theory focuses on the constructive nature of the reading process which demonstrates the role of conceptual and background knowledge in L1 and L2 reading comprehension (Carrell, 1984; Carrell & Wise, 1998; Crain-Thorenson, Lippman, & McClendon-Magnuson, 1997; Hammadou, 1991; Lee, 1986a; Pritchard, 1990; Roller & Matambo, 1992).

Initially proposed by Kants (1781, cited in Barnett, 1989) and later by Bartlett (1932), the concept of schema refers to the structure of an acquired knowledge gained through past experiences (Nassaji, 2002). Hence, *schemata* is a reader's existing knowledge structures or world concepts in a variety of domains already stored in the memory (Anderson & Pearson, 1984). These world concepts are what theorists call background knowledge which include linguistic and discourse schemata.

Based on the schema theory, comprehension and recall of the information read depend on how the textual data match the readers' background knowledge. The theory posits that the text in itself does not carry meaning but merely provides direction for the readers (or listeners) to reconstruct the meaning based on their prior knowledge (Rumelhart, 1980). Reading is therefore viewed as an interactive process between the readers' background knowledge and the text. The interpretations of the author's point of views, arguments and perspectives hinge on the readers' past experience, prior knowledge as well as cultural beliefs and prejudices (Bernhardt, 1984 cited in Barnett, 1989). Readers' background knowledge that matches the text content makes reading comprehension easier and retention of information better (Carrell, 1983; Nassaji, 2002). However, incompatibility between both knowledge sources would result in retention difficulty even though the words and sentences are linguistically familiar and comprehensible (Urquhart & Weir, 1998).

As a reader reads a text, a particular schema is triggered that enables him/her to fill in the information gap in the sentence with appropriate details from his/her schemata. For example, if the reader reads these sentences, "the policeman held up his hand and stopped the car" and "the superman held up his hand and stopped the car", (Carrell & Eisterhold, 1983) s/he would manage to activate two different schemata. The first sentence would lead the reader to infer that "no physical contact between the policemen and the car and the driver applied the car brake to stop" while the second sentence would elicit an inference of "there was a physical contact between the superman and the car and no car brake was applied to stop". The ability for a reader to make such inferences indicates that reading involves background knowledge, conceptual abilities and processing strategies as argued by Coady (1979, p. 7) and discussed on page 100.

The above utilization of a reader's schemata successfully elucidates the interaction of the bottom up and top down processes mentioned earlier. Top down literally means the reader uses his/her background knowledge stored in the mind (top) to the written print (down). Bottom up, on the other hand, means the reader works on the textual prints (bottom) in order to interpret the meaning up in his/her mind (Carrell, 1983a). Reading similar content over time would enable the bottom up reader to gradually form a schema of the new knowledge and eventually will process text of similar content from the top down. In most reading instances, both top down and bottom up processes occur concurrently, facilitating each other to resolve comprehension difficulties.

Researchers have so far differentiated between content and formal schemata. Content schemata are prior knowledge pertaining to the topic or content of a text which can either be discipline specific, culture specific, or even religion specific. Texts on medicine, law and economy (Tan, 1984), Asian Indian and American weddings (Steffensen, Joag-dev, & Anderson, 1979), Muslim and Catholic personages (Carrell, 1987), and American and Palauan funerals (Pritchard, 1990) were used to examine the effect of familiar/ unfamiliar topics on readers from inside and outside the discipline, culture, and religion. Readers from the same reading community who used relevant content schemata in processing such texts successfully made correct inferences and accurate elaborations while reading. In contrast, those from the outside who lacked the appropriate content schemata found reading laborious as they had to work their way up to comprehension from the data in the text.

Formal schemata are knowledge about rhetorical organization of a text. Formal schema for a story should contain a setting, a beginning, a development, and an ending (Carrell, 1987). Expository text, on the other hand, may have as many as five different structures such as cause and effect, problem and solution, comparison and contrast, argumentation, and description. Research found that having the appropriate content schemata alone may not be enough without formal schemata. For example, most readers may possess common background knowledge on a text such as *Washing Cloth* compared to a novel text like *Balloon Serenade* (Carrell, 1983; Roller & Matambo, 1992) and it was assumed that readers would recall the earlier text better than the latter. On the contrary, most readers recalled more details of the novel text. This is because the formal schemata of the *Balloon Serenade*, the *if-then* organization, was easier to follow compared to the loose and wandering organization of the *Washing Cloth* (Roller & Matambo, 1992).

2.5 The Metacognition Theory

Flavell (1978, 1979, 1985) refers to metacognition as the knowledge about the universality of human as cognitive processor and with this knowledge, one is able to manipulate or orchestrate his/her cognitive resources and strategies to meet the demand of his/her immediate cognitive task or goal. Flavell maintains that metacognition comprises of two key components; metacognitive knowledge and metacognitive experience (1985: p. 105; 1992: p.4). Baker and Brown (1984), on the other hand, conceptualize metacognition as the knowledge about cognition and the regulation of cognition.

2.5.1 Metacognitive knowledge

Metacognitive knowledge or knowledge about cognition refers to declarative (knowing that) and procedural (knowing how) knowledge about human cognition (Baker and Brown, 1984; Flavell, 1979). For example, a person may have a declarative knowledge that s/he cannot remember more than five items to shop but possess a procedural knowledge to overcome his/her poor memory by writing down a shopping list. This ability to reflect on one's cognitive abilities and processes helps to increase the effectiveness of the person's execution of his/her cognitive tasks and goals. Flavell divides metacognitive knowledge into three knowledge categories; metacognitive knowledge about persons, tasks and strategies.

Metacognitive knowledge about person includes any knowledge and beliefs about human cognition which branches out into three subcategories, within-person cognition, between person cognition and cognitive universals. Only metacognitive knowledge pertaining to within-person and cognitive universals are discussed here as both are relevant to this study on the use of cognitive and metacognitive strategies in reading scientific texts. Having within-person cognition means a matured person knows that s/he is better in one subject, for example History over Physics, or that s/he learns better by listening than by reading. A person who grew up reading narratives and fictions will have accumulated metacognitive knowledge about how to go about reading and understanding novels as opposed to reading informational texts (Flavell, 1979). The reader may have a declarative knowledge about what academic texts look like but may not possess enough procedural knowledge on how to go about reading and understanding them.

Cognitive universals refer to the metacognitive knowledge about human minds. Almost all adults know that human minds are remarkable but the short term memory is very limited. People are aware of their ability to recall information now and to forget later, to forget the information now but to recall it later, or to understand information correctly at times and to misunderstand other information at other times. These are the working of the minds that are common knowledge. Having this metacognitive knowledge about human cognitive, people tend to adopt certain strategies to enhance and direct their cognitive skills to maximize their cognitive endeavors (Flavell, 1979; 1985).

Two other categories under metacognitive knowledge are tasks and strategies. Task category concerns the information available for cognitive processing which could be in abundant or meager, familiar or unfamiliar, well or poorly organized, and redundant or densely packed (Flavell, 1979). Task also involves time limits to perform a certain activity. Too little information regarding an issue under strict time constraint may imply flawed judgments and decisions. Similarly, syntactically difficult text containing unfamiliar content may be very laborious to read and time-consuming to comprehend and remember. Having the metacognitive knowledge about the nature of information and variations of tasks to perform implies that a person would have to know how his/her cognitive endeavors should best be managed and orchestrated to achieve his/ her goals.

Strategy category is about the knowledge of cognitive and metacognitive strategies. It is about having the knowledge on strategies available to be employed in order to undertake certain cognitive activities. In short, cognitive strategy helps a person to achieve his/ her goal while metacognitive strategies provide the person with the information about the cognitive tasks in hand (Flavell, 1979). For example, when a reader feels that s/he has not understood a text, his/her cognitive strategy would be to reread the text and note down the main points. In contrast, if the reader wants to know how much s/he has understood a text, his/her metacognitive strategy would be to question himself/herself about the text content. By doing that, s/he evaluates and monitors his/her comprehension of the text.

2.5.2 Metacognitive experience

Besides metacognitive knowledge, another key component of metacognition is metacognitive experience (Flavell, 1979, 1985). Flavell defines metacognitive experience as the "feeling of knowing" that understanding or comprehension is not attained, that problem regarding comprehension has occurred, or the feeling of satisfaction with the solution to the problem. In other words, metacognitive experience is the feeling one has "deep" inside that he has understood everything or that he is not adequately prepared for a test, or that the feeling that he is stymied in his attempt to understand something he is reading.

This metacognitive experience may emerge in situations that require a lot of higher level deliberate thinking. This feeling of knowing checks and evaluates one's cognitive activity and it affects a person's cognitive goals or tasks by helping him/her to modify his/her strategy. Metacognitive experience also shapes metacogntive knowledge base by adding to it, deleting from it, or revising it. Baker and Brown (1984: p.354) call the same phenomenon as the *regulation of cognition*. It is a mechanism employed by active learners during an ongoing task to check the outcome of their moves, plan their next move, monitor the effectiveness of their attempted actions, revise and evaluate the strategies being utilized to ensure that the goal is achieved satisfactorily. Thus, it is believed that both metacognitive knowledge and metacognitive experience or self-regulatory cognitive mechanism interact with each other to influence a person's cognitive activities (Flavell, 1985).

2.6.1 Theoretical framework

The theoretical framework of this study is designed following three important underpinning theories in reading research, namely the four reading models in reading theory, the schema theory and the metacognition theory discussed earlier. Please refer to Figure 2.1.

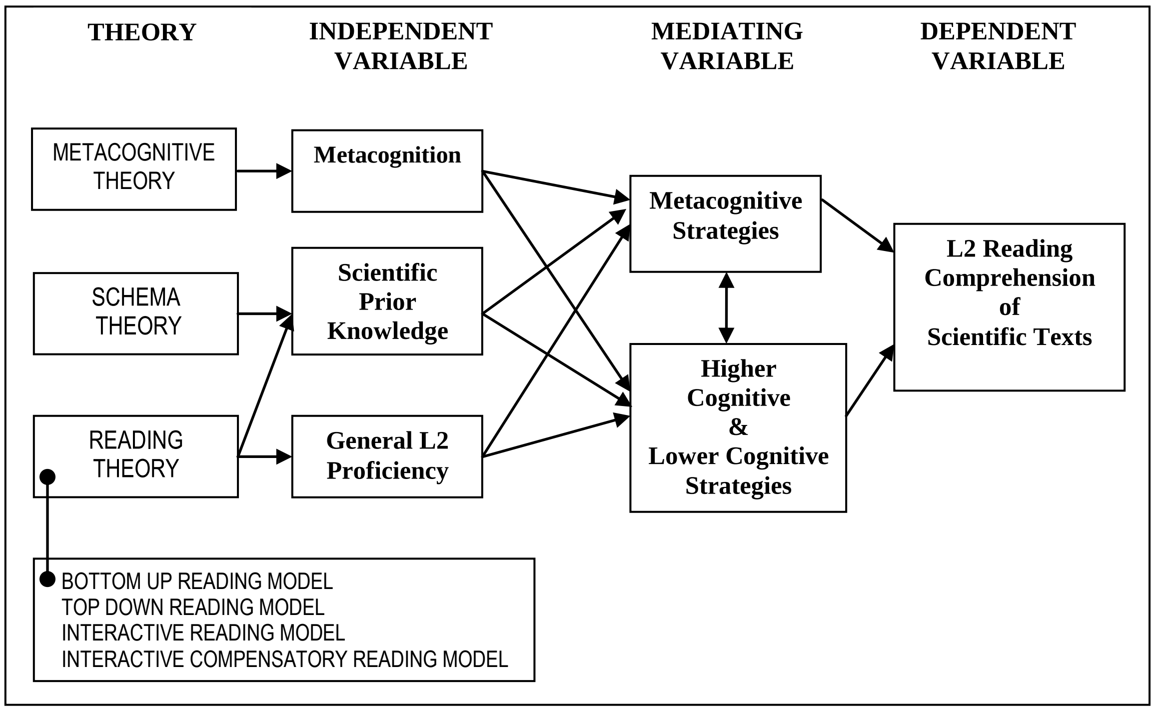

Figure 2.1 Theoretical framework of the study

Based on the three theories discussed earlier in section 2.4, L2 reading comprehension of scientific texts depends primarily on the ESL learner's general L2 proficiency, the scientific prior knowledge stored in his/ her memory, and the metacognitive knowledge and experience that s/he brings to the reading task. General L2 proficiency is required for a learner to decode the written prints (bottom up) in order to construct a representation of the text up in his/her mind. Based on the schema theory, the learner's comprehension of the scientific text is assisted by his/her pre existing schemata on the science topic (top down). The more compatible the learner's scientific prior knowledge is to the text content, the easier and better comprehension and retention of the information read. However, if the content of the scientific text does not match the learner's existing scientific prior knowledge, comprehension and retention of information would be difficult. According to the metacognition theory, matured (as opposed to children) learners are assumed to have a metacognitive knowledge about their ability in certain areas of learning and have accumulated metacognitive experience to go about maximizing their cognitive endeavors. If the content of the scientific text does not complement the learners' prior knowledge, top down processing may not be possible and this will require the readers to work from the bottom up to comprehend the scientific topic. On the other hand, if the content is familiar but the language of the text is difficult, the learners may employ top down processing using their scientific prior knowledge to compensate for their linguistic deficiency. However, reading is expected to be laborious if ESL readers possess insufficient L2 proficiency and lack scientific prior knowledge on the science topic.

Metacognitively aware ESL learners would seek for a strategy or a combination of strategies deemed effective in achieving their cognitive undertaking that is comprehending the scientific text. The shift in strategy choices between higher and lower cognitive strategies is anticipated to be in direct influence from ESL learner's L2 proficiency, scientific prior knowledge and level of metacognition. Thus, the reading theory based on the four reading models as well as the schema and metacognition theories are used as a platform to guide the researcher in examining ESL learners' change of reading strategies between higher and low cognitive strategies as well as the employment of metacognitive strategies while reading the two scientific texts which are used in the present study.

2.7 Chapter summary

This chapter has discussed three theories which are particularly pertinent in understanding strategy choices made by readers during reading comprehension processes. The four reading models provide the basis for the higher and lower cognitive strategy choices whereas metacognition theory provides a guideline in understanding reader's awareness and control of their thinking in choosing one strategy over the others. Schema theory, on the other hand, explains how prior knowledge possessed by readers could interact with the materials in the text during a reading process and lead the readers to use it as a higher level cognitive strategy to either compensate for language inadequacy or expand on the new idea found in the text for better comprehension.

CHAPTER THREE

THE REVIEW OF RELATED LITERATURE

3.1 Overview

This review is organized according to the subject matters most relevant to the study. This chapter will first discuss the challenges in reading English scientific texts by non native readers and the significant features of scientific language. Both provide a rationale for the study on the utilization of cognitive and metacognitive strategies while reading scientific texts. It is followed by the definitions of comprehension strategies in reading comprehension and empirical research on cognitive and metacognitive strategies utilized by second language (L2, hereafter) readers in reading non scientific and scientific academic texts. The contributions of three key variables, namely L2 proficiency, prior knowledge, and metacognitive awareness, to strategy usage and reading comprehension are discussed next before the review ends with a summary.

3.2 Scientific text

In the fields of science, English has long been recognized as the predominant medium of international discussions amongst the scientific communities for more than four centuries, ever since the first scientific record, the Philosophical

Transactions of the Royal Society of London (PTRS) was published in 1670 (Atkinson, 2001). It is estimated that more than half of the scientific literature produced worldwide are reported and published in the English language (Lott, 1971; Swales, 1987). This has resulted in extraordinary interest in reading and acquisition of English as a second language (Bernhardt, 2000; 2005; Koda, 2005) amongst non native English speakers and world nations. Hence, there has been increased demands for the mastery of scientific English as an important vehicle for scientific knowledge, information, and argumentations so as to enable the world nations to participate in, contribute to, and benefit from the scientific progress.

Corollary to this, ESL students embarking on a tertiary education and pursuing any degree programmes in science related fields are required to embrace a mind set of having to undertake a serious English language academic reading regime of scientific texts with comprehensibility regardless of the extent of content and linguistic difficulties (Love, 1991; RAND Study, 2002). Dense and lengthy chapters in textbooks (Koch, 2001; Simpson & Nist, 2002) as well as conceptually complex (Jaipal, 2001) and complicated prose of supplementary reading assignments (Shih, 1992) are norm and demand deliberate and complex reading processes (Li & Munby, 1996; Soonthornmanee, 2002) by the students in order for them to make sense of the scientific discourse.

Unfortunately, difficulty in understanding authentic scientific texts written for native speakers and experts in the fields of science appears to be a major obstacle confronted by ESL readers (Amer, 1994; Fang, 2006; Flick & Anderson, 1980; Flowerdew, 1993; Walsh, 1982). Scientific texts are often informationally dense, syntactically complex, and linguistically and conceptually domain-specific (Atkinson, 2001; Conrad, 2001; Halliday, 1993; 1998) which are perceived as very demanding reading texts even for native students (Flick & Anderson, 1980). The difficulty in comprehending scientific texts is naturally much more pronounced and taxing for ESL readers (ibid; Amer, 1994) whose stumbling block in comprehending L2 texts concerns the disparity between what they know and what native readers know about the language and the content (Eskey, 1986 cited in Li & Munby, 1996). Nevertheless, self-initiated independent reading of printed as well as online references and professional journal articles is pertinent and crucial to tertiary level academic success (Brown, 1988; Carrell, 1989; Cooper, 1984; Flowerdew & Peacock, 2001; Koch, 2001; Koda & Zehler, 2008; Simpson & Nist, 2002; Spector-Cohen & Wexler, 2001) and ought to become a second nature to these ESL science undergraduates as a regular reading routine.

Comprehension difficulties of scientific texts were initially assumed to be the consequence of low English language proficiency among the ESL readers (Chen & Donin, 1997). The argument is reasonable to a certain extent due to the nature of the English phonology, orthography and grammar which are cumulative composite of "general English" (Tarantino, 1991). However, Hutchinson and Waters (1987: p. 165) assert that the difficulty may also arise from the language of science embedded in scientific text consisting of higher frequency of specific grammatical forms and scientific vocabulary which is significantly different from those of the general English. Halliday (1993; 1998), Bloomsfield (1939, cited in Tarantino, 1991) and

Swales (1990) make important observations regarding scientific text in that comprehension of the text requires not only the knowledge of general English but also the language, rhetoric and terminology of science. Halliday (1988) further describes the English language of science as having typical features that classify it as scientific English which include nominalization of verbs and adjectives, extended nominal groups, causal and reasoning verbs, tentative or hedging language, impersonal language, passive constructions, and technical vocabulary.

In the language of science, verbs and adjectives are often turned into entities, which are nouns, for example, the verb *move* and adjective *deep* can be turned into nouns *motion* and *depth* (Halliday & Matthiessen, 2004). Thus, the word *motion* as an entity now (instead of a happening *moving)* is a phenomenon which can be ascribed certain properties such as a *perpetual motion*, *linear motion, rotary motion, periodic motion, parallel motion* and the like (ibid). This process of changing syntactic functions of words into nouns is called nominalization (Banks, 2005; Fang, 2006).

Jaipal (2001) notes that everyday or general English language is easier to comprehend because of the structure of the language. It consists of process clauses and one clause is made up of nominal group, verbal group, adjectives, adverbs or prepositions. Scientific language, in contrast, is often expressed in sophisticated grammatical pattern which consists of nominal groups and connected by a verbal group (Fang, 2006; Halliday & Matthiessen, 2004). The verbs or happenings *expose* and *deteriorate* are changed into entities or 'things'. For example:

Prolonged exposure *will result in* *rapid* *deterioration of the item.*
Nominal group verbal group epithet nominal group

The difference between the sentence in general language known as Doric and the scientific sentence, Attic, is that the first contains “a nexus of two clauses, forming a clause complex” (Halliday & Matthiessen, 2004, p. 103). The Attic, however, contains one clause and most of the words are rearranged into nominal groups. The Attic version of the sentence above is a care label attached on clothing. The question posed by Halliday was that why had the manufacturer not used a simple everyday sentence, the Doric. Halliday speculates that the Attic version of scientific language carries greater value and authority and gives the impression of wisdom and proven fact.

Nominalization is a special feature of scientific language (Lemke, 1990; Halliday & Martin, 1993; Unsworth, 2001). It enables scientific texts to be packed with information by having a large number of noun compounds in a single sentence. This makes scientific text dense with information (Conrad, 2001) and markedly long sentences (ibid; Fang, 2006). Long sentences are necessary to give a comprehensive account of a scientific concept. Multiple ideas are pulled together and packed into a single sentence to explain a difficult idea which in everyday language requires several clauses to convey similar idea.

Atkinson (2001) studied scientific discourses across history and found that scientific texts of the 1675 tended to be written in an ‘author-centered’ approach. However, towards the end of the nineteenth century research articles describing phenomena were predominantly written in the ‘object-centered’ approach where reference to the author was being avoided. By the twentieth century, research articles have become more ‘object-centered’ and ‘impersonal’. The reason for this is its underlying linguistic features which are mainly of passive constructions. Atkinson claims that the modern day scientific writing has become extremely passivized, especially when texts are accounts of experimental methods.

In addition, scientific text not only requires the readers to be linguistically competent in English but also to be informed and knowledgeable about certain scientific concepts reiterated in the text (Graesser, Leon, & Otero, 2002; Ozuru, Dempsey & McNamara, 2009). One example of a scientific concept is *cold fusion* (Tarantino, 1991). This concept, which is obvious to the people within a particular domain, does not require further elaboration for its definition in the scientific text. Nevertheless, for lay audience, the meaning is not very obvious. *Cold fusion* cannot be perceived like *cold milk*, which can be converted into *the milk is cold*. The phrase *the fusion is cold* is a grammatically perfect sentence yet meaningless and absurd. *Cold fusion* here also does not imply low temperature nor does it mean to combine, melt, or join. On the contrary, *cold fusion* means the transformation of one chemical substance into another which involves the release of radiation and great heat and energy (ibid). In addition to understanding specific terminology, readers must read all the words in a scientific text to understand all the information and not just read most of the words (Draper, 1997, cited in Koch, 2001). This is because each word carries precise meaning and crucial to the information in the text.

In short, the difficulty in the comprehension of a scientific text is primarily attributed to its complex syntactic structure, highly specialized terminology, specific rhetorical organizations, and the assumption that the readers of scientific text share similar knowledge of scientific concepts and subject matter as the author (Koch, 2001; Swales, 1971). According to Walsh (1982), besides the linguistic problem, the abundance of scientific concepts in a scientific text is yet another source of difficulty for ESL readers, especially first year undergraduates.

The contention that the complexity of scientific academic text as a major source of reading difficulty to ESL readers is well founded since each discipline of sciences adheres to specific writing convention which is familiar to and understood by the people, researchers, scientists and students in that particular field. This in itself makes reading texts of different disciplines difficult to readers who are outsiders to the field or just starting out in the particular domain. A physicist may be an expert in his field but reading biology or chemistry texts may prove problematic. A lawyer is an expert in reading complicated legal documents but may be at loss when reading medical journals and vice versa for a doctor reading legal documents. Nonetheless, one only needs to be a proficient and efficient reader in the language of his/her discipline in order to function, improve and become critical of the progress and development of his/her specific domain.

As complex and tricky as it may be, English language reading proficiency of academic text at tertiary level is crucial for academic excellence (Anderson, 1999;

Flowerdew & Peacock, 2001; Nel, Dreyer & Klopper, 2004; Spector-Cohen & Wexler, 2001). This notion is also endorsed by Carrell (1988) who claims that:

> …in second language teaching/ learning situations for academic purposes, especially in higher education…in programs that make extensive use of academic reading materials written in English, reading is paramount. Quite simply, without solid reading proficiency, second language readers cannot perform at levels they must in order to succeed…(p. 1).

Academic reading, as opposed to general reading, is extremely challenging since students are not only expected to understand the propositions in the text but also to remember, evaluate, and synthesize information and knowledge from other texts and sources (Simpson & Nist, 2002). Following that, learners have to provide critical stance on the issue in the form of written assignments or apply the knowledge gained from the reading to other settings (Li & Munby, 1996; Shih, 1992).

Reading scientific academic text is even more daunting, demanding and taxing to ESL students as interpretations of the texts must be correct, details remembered, and experimental procedures precisely complied with. Error in understanding and interpretation will have serious repercussions to the experimental procedures and the subsequent outcomes. Reading scientific texts also involves concentration, memory and critical thinking (Shih, 1992) as well as requiring specific cognitive tools which are personal and flexible, such as reading strategies (Simpson & Nist, 2002; Teoh, 1996).

3.3 Comprehension strategies and reading

In view of a myriad of significant discoveries and research findings in the fields of science and technology frequently reported in English, the need to acquire efficient personal cognitive tools in reading printed texts is imperative. It is estimated that 50 percent of what is learnt in school and university will become obsolete in five years time and the shelf life of current knowledge in many fast growing disciplines has been reduced to as low as 2.5 years (Halimah Awang, 2004). Current information and new knowledge are being disseminated world wide through publications in books, academic journals (Knowles, 2004; Sidhu, 2006) and postings in the internet (Musa, 2003; Ungku Aziz, 2003) to be read by the world populace. Halimah (2004) stresses that with this rapid development, more efforts must be geared towards nurturing students into becoming life long learners who are able to learn and acquire new knowledge and skills independently to meet the changing needs (p. 246).

Second language reading ability on demand presently is one which permits an L2 reader to comprehend L2 texts of at least his/her discipline efficiently (Desjardin, 2003; Koda, 2005), independently (Bernhardt, 2005; RAND Study, 2002), and critically (Koh, 2001; Freebody & Luke, 2003). Therefore, in addition to L2 reading proficiency (Kern, 1989; Qian, 2002; Qian & Schedl, 2004; Zareva, Schwanenflugel & Nikolova., 2005) and first language (L1, hereafter) reading ability (Bernhardt, 2000; 2005; Clarke, 1980; Schoonen, Hulstijn & Bossers, 1998; Vivaldo-Lima, 1997), both of which contribute about 50% of the variance to L2 reading comprehension (Bernhardt, 2000; 2005; Bernhardt & Kamil,1995; Bossers,1991; Brisbois; 1995; Carrell, 1991), reading researchers in the first and second language strongly advocate for the employment of comprehension strategies during reading to improve comprehension.

Comprehension strategies are valuable personal cognitive tools (Brown & Baker, 1984; Koda, 2005) in assisting readers not only to make sense of the written text during the course of a reading process but also monitor their own comprehension to enhance understanding of the text content. Through self-monitoring and evaluation, readers are able to plan for 'fix-up' strategies to cope with comprehension difficulties or failures (Singhal, 2001; Stanovich, 2000).

According to Barr (2001), research on strategy instruction in reading comprehension has taken root since the 1960s and 1970s and has continued well into the 90s. The strong interest to facilitate reading comprehension amongst learners has resulted in many empirical studies that examined how readers read in addition to interventional studies that encouraged learners to be conscious of their own reading processes. Among such studies include those that trained learners to use think aloud during reading (Anderson, 1991; Auerbach, & Paxton, 1997; Crain-Thorenson, Lippman, McClendon-Magnuson, 1997; Cotteral, 1990; Goh, 2004; Ponniah, 1993) and metacognitive strategies (Block, 1992; Carrell, 1989; Nik Suriana, 2001) during reading processes. Barr admits that experimental research on strategy instruction has not been very popular lately because the focus of reading strategy research has shifted considerably into studying special populations which include bilingual learners. On the rise are also studies on content-specific strategy programmes in areas of science and mathematics.

3.4 Types of comprehension strategies in reading

According to Goodman (1988), reading is as much about decoding the language of the text as it is about the involvement of the writer's and reader's thoughts. As the reader decodes the language, s/he will simultaneously begin to construct the intended meaning of the writer by integrating the information with his/her prior knowledge and thus forming a model based on the text content (van Dijk & Kintsch, 1983). The process of reconstructing meaning is a complex yet extremely dynamic cognitive activities (Pressley & Afflerbach, 1995). As the reader's eyes fall onto the printed words, several knowledge sources like lexical knowledge, syntactic knowledge, semantic knowledge (Stanovich, 1980) as well as prior knowledge (Carrel & Eistherhold, 1983, Nassaji, 2002) will act concurrently on the information provided by the text.

While reading is in progress, readers may wish to optimize the integration of meaning between the data in the text and the information they possess. Alternatively, there may be a breakdown in the information provided by one or more knowledge sources mentioned above and thus comprehension of the text is at stake. In these circumstances, the readers may take certain deliberate actions known as comprehension strategies to maximize understanding or resolve comprehension difficulty (Urquhart & Weir, 1998). These actions are cognitive strategies employed by readers to process input from texts in either L1 or L2 (ibid).

Paris, Wasik & Turner (1991, p. 610) consider cognitive strategies as a repertoire of tactics that readers employ to comprehend a text and these tactics are deliberate and calculated cognitive actions (Anderson, 1991) that help regulate reading behaviours and comprehension. Other researchers view strategies during reading as taking certain purposeful steps to help readers optimize the reading process so that the goal of maximum comprehension is achieved (Baker & Boonkit, 2004; Koda, 2005 Pritchard, 1990; Urquhart & Weir, 1998; Young, 1993).

Brantmeire (2002) maintains that these cognitive strategies are also specific "attacks" that readers opt for when faced with a challenging text and more so when encountering comprehension difficulty while progressing through it. Unlike reading skills which imply what a reader *can* do (Koda, 2005; italic original) during a reading process like decoding skill, automatic word recognition skill, and even summarizing and paraphrasing skill, comprehension strategies entail what a reader plans to do or *intends* to do (ibid; italic original) when s/he encounters different types of texts or faces reading difficulties.

Readers' strategy selection and change are thus influenced by the fact that the process of reconstructing meanings of texts varies from one type of discourse to another (Dhieb-Henia, 2003) due to the complexity of the language structure (Cohen, Glasman, Rosenbaun-Cohen, Ferrara & Fine, 1988), unknown or domain-specific vocabulary, new and challenging concepts or even unfamiliarity of ideas.

Thus, to maximize the extraction of meaning a reader normally employs comprehension strategies or a combination of strategies consistently during a reading process. Familiarity with the language and content of text may lead to the employment of higher-level cognitive strategies which focus on conceptual processing of the text. Alternatively, the same reader may opt for lower-level strategies and focus her or his attention on language based processing when confronted with more linguistically or conceptually challenging texts. The shifts in focus and strategy use while reading reflect the reader's current language competence especially her or his decoding and word recognition skills. Hence, reader's selection of employing lower or higher level cognitive strategies is primarily the result of her or his conscious decision during reading (Koda, 2005) based on the types of texts on hand.

A review of the literature on foreign and second language reading strategy research indicates that comprehension strategies are grouped into different categories. Block (1986) categorizes reading strategies into two groups which are general and local strategies while others label similar strategies as global and local strategies (Barnett, 1988; Block, 1992; Brantmeier, 2002; Carrell, 1989; Young & Oxford, 1997). Local strategies are more focused on attempts to understand specific linguistic units such as solving vocabulary problems and questioning meaning of a clause or sentence (Block, 1986). General and global strategies include steps taken to conceptualize the meaning of the content and actions employed to monitor comprehension of the text (ibid).

Pritchard (1990), on the other hand, labels comprehension strategy categories according to the function of the strategies such as supervising strategies (monitoring comprehension), support strategies (using references and previewing), and paraphrase strategies (establishing intrasential ties). Anderson (1991) classifies comprehension strategies into five groups namely supervising, supporting, paraphrasing, establishing text coherence, and test taking strategies. In essence, the first three categories in Anderson's Processing Strategies (1991) list were modeled on and modified from Pritchard's (1990) inventory of reading processing strategies, thus they represent similar strategies.

More recent and widely drawn on strategy groupings by reading strategy researchers are those categories identified by Chamot and O'Malley (1994) which are cognitive strategies, metacognitive strategies, and social/ affective strategies. Cognitive strategies are steps taken to comprehend materials such as inferencing, guessing meaning from context, summarizing, rereading, and relating new information to prior knowledge or content schemata. Metacognitive strategies are steps related to self-management or self-regulation of those cognitive strategies while reading which include planning and monitoring strategies. Social and affective strategies are actions taken by interacting with other people to assist in learning and solve comprehension problems.

3.5 Cognitive strategies and reading

Cognitive strategies are further divided into two categories, higher-level and lower-level strategies. Higher-level cognitive strategies are primarily guided by the readers' content and formal schemata or their acquired knowledge about the topic and organization of the text on hand. These higher-level cognitive strategies also known as top down processing are attempts that focus on synthesizing information from various sources in order to conceptualize the text content. They consist of actions such as relating new information to familiar concepts and prior knowledge, making predictions and inferences based on both new and previous information, inferring, guessing meaning from context, hypothesizing, and elaborating (Block & Pressley, 2002; Paris, Wasik, & Turner, 1991; Pressley, 2006).

In contrast, lower-level cognitive strategies are actions directed towards breaking the linguistic codes such as decoding and recognizing words, syntactic structures and parts of speech, and translating words and phrases (Block, 1986). These lower-level cognitive strategies can normally be performed by skilled readers automatically with minimal cognitive effort, thus freeing the working memory for other higher-level processing that leads to comprehension (Phakiti, 2004). However, automated lower-level processing can be achieved through extensive practice or when reading familiar topics.

In sum, higher and lower cognitive strategies are conscious brain activities utilized explicitly to accomplish particular reading tasks so that the goal of reading is accomplished (Chamot & O'Malley, 1994; Paris et al., 1991). Hence, during the course of constructing and deriving at meaning intended by the writer, skilled readers very deftly coordinate the use of several cognitive strategies to draw stored data from multiple knowledge resources in their long term memory to assist them in the synthesis of information for the purpose of making sense of the text (Paris et al., 1991: p.611).

3.5.1 Cognitive Strategies in L2 Reading Research

Hosenfeld (1977; cited in Hosenfeld, 1984) views cognitive strategies as a kind of problem solving tactics utilized by L2 readers when confronted with problems in trying to understand foreign language texts. The participants of her study were forty ninth grade students who were native speakers of English and were learning French, Spanish and German as a second language. They were grouped into successful (high scorers) and unsuccessful readers (low scorers) based on a reading proficiency test for native speakers. To determine the strategies used by the successful and unsuccessful readers, the participants were asked to verbally report their thinking processes or whatever that came to mind in their L1 as they read a French text.

Hosenfeld's list of strategies reportedly utilized by successful readers reveal that they tended to use more higher-level cognitive strategies such as keeping the meaning of passage in mind, reading in broad phrases, skipping inessential words, guessing the meaning of unknown words from context, reading the text title and making inferences from it, using prior knowledge of the world, examining illustrations, and having a positive self concept. To resolve reading problems, these successful readers employed some lower-level cognitive strategies such as identifying grammatical category of words, demonstrating sensitivity to a different word order in the foreign language, using orthographic information (e.g.

capitalization), referring to the side gloss, recognizing cognates, and looking up words. In contrast, unsuccessful readers were more inclined to use lower-level cognitive strategies such as reading word by word or in short phrases, rarely skipping words, and turning to the glossary for the meaning of new words. They also tended to lose the meaning of sentences as soon as they decoded them and had a poor self concept as a reader.

Even though Hosenfeld's study managed to expose the hidden cognitive processes of successful and unsuccessful readers, the study did not go a step further in determining the contribution of the successful strategies to the overall comprehension of text content. The data, thus, fell short in providing evidence for the correlation between successful strategies and reading comprehension of the text content.

Block (1986) examined the correlation between employment of strategies and reading comprehension. Her participants were native speakers of English, Chinese, and Spanish who were in remedial reading classes. Comprehension of text was measured through retelling of the text and multiple-choice questions. Block found that there were two categories of strategies, local and general strategies. Local strategies were language dependent and attempts to understand specific linguistic unit such as paraphrasing, rereading, questioning the meaning of words, clauses and sentences, and solving vocabulary problems. General strategies were comprehension gathering and comprehension monitoring strategies. Comprehension gathering strategies were questioning information in the text, integrating information, interpreting text, recognizing text structure, anticipating content, and using general knowledge and associations. Comprehension monitoring strategies were commenting on behaviour or process, monitoring comprehension, reacting to the text, and correcting behaviour. Block discovered that readers who obtained high scores in the retelling of the text and multiple choice questions often used higher-level cognitive strategies such as referring to their prior knowledge, integrating information in the text, and delineating main ideas from details. In contrast, low comprehension scorers rarely employed such strategies. Block also found that language background of the reader did not predict the type of strategies used in reading English texts.

Sariq (1987) examined the relationship between strategies and reading comprehension in both L1 and L2. The study was also aimed at investigating the transfer of L1 cognitive strategies to L2 reading process. Participants of the study were ten female native speakers of Hebrew aged 17 to 18 years old who were learning English as a foreign language. They were from low, intermediate and high English proficiency levels. They read academic texts in Hebrew and English and were asked to self report their thinking processes while reading.

Sariq managed to identify four types of reading moves or strategies to facilitate text processing from the data which were (a) clarification and simplification moves, (b) technical-aid moves, (c) coherence-detecting moves, and (d) monitoring moves. Clarification and simplification moves were strategies to simplify syntax, decode meanings of words or groups of words in context using synonyms or circumlocutions, simplify ideas by analyzing propositions, and paraphrase. According to Sariq, these moves are language dependent. This essentially means that this category is of lower-level cognitive processes in nature (Chamot & O'Malley, 1994). Technical aid strategies involved skimming, scanning, skipping, marking and writing key elements in the text, summarizing, and using glossary. Coherence-detection moves included strategies like identifying macroframe of the text, using prior content schemata, identifying key information as well as people in the text and their views or actions, and relying on textual schemata to predict about text. In sum, both technical aid and coherence-detection strategies resemble higher- level cognitive strategies as prescribed by Chamot and O'Malley (1994).

The final category identified by Sariq is the monitoring moves which involve strategies to promote comprehension like conscious changing of plan and carrying out tasks, changing reading speed, recognizing misunderstanding and conflicting interpretations, correcting mistakes, self-evaluating, and slowing down. As the name implies, monitory moves are akin to metacognitive strategies. Sariq found that the last three categories of moves which were in essence top down and global strategies (higher-level cognitive and metacognitive strategies) led to both successful and unsuccessful reading comprehension. This finding seemed to contradict earlier studies which found that global or higher cognitive strategies resulted in successful comprehension (Block, 1986), while clarification and simplification moves (lower-level cognitive strategies) were strategies that contributed the least to successful comprehension (p. 113).

Another study that examined strategy and reading comprehension in L2 context was conducted by Kern (1989) who looked into reading strategies used by 53 university students learning French. The participants were divided into two groups, the experimental and control groups, in which the earlier received explicit instruction on reading strategy in addition to the normal course content. Among the strategies taught were analysis of cognates, prefixes, suffixes and orthographic clues, analysis of sentence cohesion and signaling cues, inferencing, hypothesizing, anticipating, questioning and locating main ideas, skimming, and scanning. Pre and post reading tasks required students to first identify difficult words from a list of eighteen words to gauge the amount of word inferences that took place during reading. Then participants were asked to read a French text, one sentence at a time and were told to comment on their thinking process. To assess participants' comprehension of the text, they were asked to retell everything they could remember about the text and state the main ideas. Word inference skill was calculated as the percentage of words checked as unfamiliar at the beginning of the test but the meaning became clear during the reading process.

Kern found that there was a statistically significant main effect difference between the experimental and control participants' comprehension gain score. The findings indicated that strategy instruction did have a positive effect on reader's comprehension of test passages. Closer inspection of the strategies taught to the experimental group revealed that Kern had focused on training higher-level cognitive strategies to the participants. This training led the participants, especially the low and intermediate ability readers, to learn to liberate their limited cognitive resources from laborious lower-level processing and thus make more room for higher level cognitive processing such as inferencing and synthesizing information.

For the studies mentioned above, it could be concluded that higher-level cognitive strategies greatly influence reading comprehension of L2 narrative and expository texts. However, there is one conflicting data in that higher-level cognitive strategies which, according to Sariq (1987), were the contributors to success as well as failure in reading comprehension among her participants.

3.5.2 Cognitive Strategies in Reading Scientific Texts

While comprehension strategies utilized by readers in reading L2 texts have been widely researched, the strategies employed by readers in reading authentic scientific texts in their L2 have not been thoroughly studied and understood. Where there were studies on the reading of scientific texts, the focus has always been on either the proficiency level or the prior knowledge of the readers or both (Chen & Donin, 1997; Tan, 1984), which influence the readers' reading comprehension. Therefore, due to the dearth in studies on strategies used by L2 readers reading scientific texts, studies that looked at how native speakers read scientific texts were also used as references to provide a framework for the types of cognitive and metacognitive strategies normally associated with science education.

Tan (1984) studied the roles played by prior knowledge and L2 proficiency in readers reading academic texts in specific domain areas, with one of the texts being scientific medical passage. She found out that having high knowledge base was clearly more advantageous to comprehension of the text than low knowledge base. Tan concluded with a prediction that a low L2 proficiency reader with high prior knowledge would be able to perform better than a proficient L2 reader who lacked in prior knowledge of the content. However, proficiency was the best predictor in reading comprehension of scientific texts for L2 readers engaged in unfamiliar texts. The employment of comprehension strategies could clearly be inferred from this study but strategies were not the focus of Tan's research.

In another study, Chen and Donin (1997) who examined graduate science and engineering ESL students reading scientific texts admitted to the fact that participants with insufficient L2 linguistic knowledge to process the text content at lower level seemed to employ higher level cognitive strategies like using contextual clues to make inferences about the propositions in the text. However, the types of strategies used by the science participants were not the focus of the research and thus the conclusion made was primarily based on comparisons of the two variables under investigations which were prior knowledge and L2 proficiency.

In a different study investigating the interrelationship of knowledge, interest and recall, Alexander, Jetton and Kulikowich (1995) had premedical and graduate educational psychology native English speaking students read highly specialized scientific texts in the areas of human immunology/ human biology and physics. The researchers found that high knowledge base was closely associated to high interest in the topic of the text and this was reflected in the high scores on the free-recall measure, and vice verse for the low knowledge base group. Since all participants were native speakers of English reading English scientific texts, English proficiency was not the issue in point. However, despite the fact that much of the lower-level processing was automated, it did not facilitate ease of processing and the employment of efficient higher-level cognitive strategies in the absence of scientific prior knowledge.

DiGisi and Yore's (1992) review of literature on science reading strategies among native English speaking students found that there were at least five effective instructional strategies that could help secondary school and university students read scientific texts. The five strategies include organization of information, attending to misconceptions, concept mapping, knowledge of text structure, and conceptual questions at the end of reading. However, knowledge about using such strategies effectively requires metacognitive awareness in the individual science reader.

Brill, Falk and Yarden (2004) further added a few more strategies to the list by DiGisi and Yore (1992). They conducted a study on two high school students who were native English speakers reading simplified research article on biology. The two students used a variety of strategies when reading science text such as connecting information in the text to prior knowledge, using illustration, reading repeatedly, making predictions, using added explanation, ignoring technical terms, as well as asking expert. They also utilized some metacogntive strategies such as declaring miscomprehension and acknowledging the complexity of the text.

In local studies, Soars (1995; cited in Nuretna, 2002) examined the strategies employed by four 16 years old ESL science students and compared them to those of their peers in the arts stream. Soars' data indicated that in comparison to arts students, the science students made use of more higher level strategies such as anticipating content, questioning information in the text based on prior knowledge, recognizing structures, integrating information, interpreting the text, and using general knowledge and associations. They were also found to employ more metacognitive strategies like commenting on behaviour or process, monitoring comprehension, correcting behaviour, and reacting to text. Arts students, on the other hand, tended to question meaning of clauses and words, which were lower level cognitive strategies.

In addition, Nuretna (2002) conducted a qualitative study to investigate the comprehension strategies of two ESL science undergraduates while reading two types of scientific texts; textbook and professional journal. The two participants were at upper intermediate and intermediate English proficiency levels and final year students majoring in microbiology. Using Block's (1986) list of general and local strategies to analyze her research findings, the researcher found that these science undergraduates most frequently used paraphrasing and translating strategies which were lower-level cognitive strategies to process the scientific texts. They were also found to utilize a number of higher-level cognitive strategies such as using general knowledge and association, questioning the information in the text, and anticipating content.

There were two interesting findings in Nuretna's study. The first was that these two science students did not use four higher-level strategies usually associated with successful strategies in reading texts of non scientific domains (Block, 1986; 1992; Crain-Thorenson, Lippman, & McClendon-Magnuson, 1997) which are interpreting the text, integrating old and new information, commenting on behaviour and process, and correcting behaviour. The second finding worthy of note is the frequent use of drawing mind maps to represent the information in the text. This strategy is apparently missing in many reading strategy inventories of general L2 texts but is acknowledged in science education (Amer, 1994; Cook, 2006; Derbentseva, Safayeni & Cañas , 2007; Lowe, 1989).

Nevertheless, since this was a qualitative study, the extent of the contributions of the strategies utilized by the two ESL science undergraduates on reading comprehension of the two texts is not known. With too little information on the reading process of ESL science students reading scientific texts, speculations on how they would actually fare in a reading comprehension measure are not very easy to form.

3.6 Metacognition and reading

Another crucial component of comprehension strategies is metacognitive strategies which are under the direct influence of metacognition. According to Weil (2004, p. 194), "metacognition is the process of thinking about thinking that improves performance in thinking and life". Flavell (1976: p. 232, cited from McCormick, 2003) refers to metacognition as "one's knowledge concerning one's own cognitive processes and products or anything related to them". Flavell added that metacognition includes "the active monitoring and consequent regulation and orchestration of the processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete goal or objective”. Brown, Armbruster and Baker (1986, cited in Carrell, Pharis & Liberto, 1989) claim that metacognition is crucial in reading while Otto (1985) notes that when readers have developed their metacognition, they usually know the cognitive processes involved and factors that influence efficient processing in reading. In contrast, poor readers are often a sign of underdeveloped metacognition. These readers may be able to perform certain cognitive processes with explicit guidance from the teachers but lack awareness of what reading is all about (p.575). Schraw and Dennison (1994) maintain that metacognition enables learners to better manage their own cognitive skills and to identify weaknesses so that these shortcomings can be remedied through the employment of better suited cognitive skills.

Two aspects of metacognition put forth by theorists are knowledge about cognition and control or regulation over cognition (Flavell, 1978 cited in Baker & Brown, 1984; Paris & Winograd, 1990, cited in McCormick, 2003). Knowledge about cognition often referred to as awareness (Baker & Brown, 1984) or metacognitive awareness (Schraw & Dennison, 1994) is the knowledge readers have about their abilities that affect their cognitive processes and reading behaviours. What this means is that if readers are aware of their reading ability and know what they must do to efficiently understand a text, then there is a good possibility that they will take the necessary steps to meet the demand of the reading task (Baker & Brown, 1984; Carrell, 1989; Koda, 2005). On the other hand, control over cognition or comprehension monitoring is the process of planning, evaluation and regulation of those cognitive skills and strategies. Successful readers monitor their understanding of texts by planning strategies to achieve a designated goal, evaluating the success of the strategy and comprehension, monitoring the progress in reaching the goal of reading, and modifying or revising the strategies for maximum comprehension (Baker & Brown, 1984; Winograd & Johnston, 1982).

3.7 Metacognitive strategies and reading

Metacognitive strategies during reading are those supervisory activities that manage and regulate the earlier mentioned cognitive processes during reading (Baker & Brown, 1984; Chamot & O'Malley, 1994; Koda, 2005; O'Malley & Chamot, 1990) which may consist of the acts of previewing or over viewing tasks, solving problems, planning the next move (Baker & Brown, 1984), looking at pictures before reading as well as checking, monitoring, testing and evaluating reader's comprehension and understanding of text (Li & Munby, 1996; McCormic, 2003; Phakiti, 2004)

Besides metacognitive awareness and monitoring, Baker and Brown (1984) have included another aspect under metacognition strategies which is compensatory strategies. Simply put by Koda (2005), if the readers are metacognitively capable, they would know the limitation of their cognitive processes. Knowing that comprehension failures have occurred, metacognitively able readers would compensate their shortcomings to get around the comprehension problems (p. 206). They may keep the confusion in their working memory as a pending question to be clarified later after reading more into the text or they may wish to reread or read ahead in the text. The readers may also decide to consult a dictionary or seek assistance from other more experienced readers (Baker & Brown, 1984: p. 357; Singhal, 2001).

Metacognitive strategies, by Singhal's definition (2001), are those behaviours undertaken by a reader to plan, arrange and monitor the comprehension of his/her reading. She further argues that in the context of reading, a number of affective strategies which are self encouraging behaviours to reduce anxiety and encourage learning as well as facilitate comprehension come under metacognitive strategies. The use of metacognitive strategies has been linked to successful reading comprehension performance and achievement (Tang & Moore, 1992; Zicheng, 1992). There is evidence that indicates students who employ metacognitive strategies are more able to control, plan and monitor their reading comprehension.

All these cognitive processes and metacognitive tactics undertaken by a reader may vary depending on different reader and text variables as well as the context of the reading activity. In other words, reading is not just a one way cognitive processes but it involves multiple interactions that require changing of reading behaviours and shifting of comprehension strategies to reach the end goal of comprehension, or otherwise abandonment of the reading task. A case in point is when readers are reported to use good strategies but still fail to understand the text and in contrast, those reported to use 'ineffective' strategies manage to understand with success (Kern & Schultz, 2005). Thus, the effectiveness of the strategy depends very closely on the reader's purpose, L2 proficiency, L1 reading ability as well as the features of the text being read (p. 386). A well designed study to explore how readers read their university textbook, in particular a science text, would provide important information not just on what strategies they opt for and are comfortable with but also when they use a particular strategy and how they use them.

3.7.1 Metacogntive Awareness and Strategies in L2 Reading Research

Cassanave (1988) argues that metacognitive awareness is the basis for comprehension monitoring since, as pointed out by Baker and Brown (1984), "knowing that" which is a declarative knowledge precedes "knowing how", a procedural knowledge. This essentially means that a reader has to know (be aware of) about the effectiveness of strategies and the effects on reading before s/he can make accurate strategy choices and execute (control) them during the actual reading process.

To investigate the metacognitive awareness of second language readers and its relationship to their reading comprehension in first language (L1, hereafter)) and second language (L2, hereafter), Carrell (1989) studied two groups, each of which consisted of 45 native speakers of Spanish and 75 native speakers of English. The first group was at intermediate and advance levels of English proficiency and the latter was at first, second and third year levels of Spanish classes. Participants were asked to read two texts on the general topic of "language" in each language and later answered ten multiple-choice questions on each as a measure of comprehension. Subsequently, metacognitive questionnaire consisting of 36 statements about silent reading strategies in English and Spanish was administered to assess readers' awareness of their own metacognition.

Carrell's findings indicate that there is in fact a positive correlation between metacognitive awareness and reading comprehension. For the Spanish group reading English as a second language at a higher proficiency level, some "global" or higher-level cognitive strategies were positively correlated with reading comprehension. And those at lower proficiency levels, it was the "local" or lower-level cognitive strategies that were positively correlated with reading comprehension. The same findings were true for the English group who read Spanish as a second language. At lower proficiency, they tended to use "bottom up" or lower-level cognitive strategies and these strategies correlated to their reading comprehension. Thus, there was awareness on the part of the readers which compelled them to opt for strategies that best suited their current competency and linguistic proficiency.

In another study, Sheorey and Mokhtari (2001) examined the metacognitive awareness of native and non-native readers of English in reading academic texts. Participants were 150 native English speaking US and 152 ESL college students. The instrument to assess participants' metacogitive awareness of their own reading strategies was the *Survey of Reading Strategies (SORS)* which was designed to gauge strategies utilized by native and non native speakers of English from high school to university level. The result revealed that the reported usage of cognitive and metacognitive strategies was found to be higher among high-reading-ability native and non native English speakers compared to their lower-reading-ability counterparts. Even though this study did not correlate this finding to the readers' reading comprehension, it could safely be concluded that successful readers are more metacognitively aware of their reading processes than less successful readers.

Similar study on examining metacognitive awareness of L1 and L2 readers reading academic texts was conducted by Mokhtari and Reichard (2004). The participants were 141 US students and 209 multilingual Moroccan students in American and Moroccan universities respectively. Assessment of the readers' metacognitive awareness was done using *Metacognitive Awareness of Reading Strategy Inventory (MARSI).* The findings reveal similar patterns of strategy awareness despite being schooled in different socio-cultural environments. Both groups of students were found to exhibit a moderate to high strategy awareness level with the inclination for problem solving strategies, followed by support strategies and global strategies. As most of the students in both groups rated themselves as having "good" and "excellent" reading ability in English, this study again endorsed the notion that metacognitively aware readers are better readers as they do have the knowledge pertaining to their own cognitive resources, skills and strategies (Baker & Brown, 1984; Schraw & Dennison, 1994).

Li and Munby (1992) carried out a qualitative study to find out the metacognitive strategies of L2 readers in reading academic texts. Participants were two Chinese graduate students from social science programmes. Both participants obtained a score of more than 600 in the TOEFL. Unstructured interviews, think aloud sessions, and self report journals were the means used to collect data. Li and Munby found that the participants used a number of metacognitive strategies. First, the strategy to check understanding of the content in the text book is to translate the *meaning* (emphasis added) of the sentence into Chinese (L1). With regards to translation strategy used by L2 readers, Kern (2000) claims that:

> Familiar words can be stored in working memory faster and more effectively…they can be more effectively synthesized into meaningful propositions. Translation may thus allow the reader to establish a kind of mental scratch pad or semantic buffer, where phrase-level and text-level meanings can be represented and assembled in native language form, in order to optimize processing efficiency (p.120).

The fact that the participants translated when reading academic texts (and did not translate when reading 'for fun') indicates that metacognitive strategy of monitoring and checking understanding was at work. Checking of understanding as a metacognitive strategy to determine if their reading goals have been achieved was also realized in the form self questioning. Questioning oneself was usually done when the participants encountered with unfamiliar words and concept or even when they did not get the point the author was trying to convey. To solve the problem of unfamiliar words and concepts, the participants were found capable of using contextual clues and prediction.

Another metacognitive strategy was identifying the root of their comprehension difficulty. The participants realized that the content of the text was difficult to understand due to their lack of prior knowledge on Canadian history.

Thus, gathering extratextual information through additional reading was the action that the two graduates took to solve their reading problem. In general, Li and Munby's study revealed a repertoire of cognitive strategies employed by the two graduate students in reading academic materials. Metacognitive strategies only emerged when readers encountered reading difficulties (Block, 1992). In the case of the study above, the participants' metacognitive strategies usage became apparent when they came across unfamiliar words and concepts, and had no prior knowledge with which to synthesize the information gathered in the text.

Nik Suriana (2001) examined social science undergraduates use of metacognitive strategies in reading English for Academic Purposes (EAP) materials. She found that the more proficient readers employed three types of metacognitive strategies which were planning, monitoring, and evaluating understanding. On the other hand, the less proficient readers usually stopped short at planning and monitoring.

In short, previous researchers are consistent in their findings that there is a significant correlation between metacognitive awareness of one's reading ability and reading comprehension scores (Carell, 1989) and perceived reading abilities (Mokhtari & Reichard, 2004; Sheorey & Mokhtari, 2001) in both native and non native speakers of English. In addition, metacognitive strategies are the manifestation of that awareness which are employed by good readers when comprehension is at stake.

3.7.2 Metacognitive awareness & strategies in science education research

Metacognition in science education has long been recognized as it is a construct that provides insights into the awareness and executive control of knowledge and reading strategies (Anderson & Nashon, 2006; DiGisi & Yore, 1992; Koch, 2001; Spence, Yore & William, 1995; Thomas, 2006; Yore, Craig & Maguire, 1993). For scientific texts such as Physics, each word must be read and understood without skipping (Koch, 2001). This is because scientific texts do not carry unnecessary information. In contrast, all words have their precise meanings. Koch's (2001) study found that science reading comprehension ability of adult L1 students in reading Physics text improved significantly more than control group after a metacognitive treatment. Metacognitive treatment in this study involved practicing self-awareness aimed at monitoring one's own reading comprehension level and identifying the source of own mistakes.

Anderson and Nashon (2006) studied L1 students' metacognition and how it influenced their knowledge construction processes while learning physics concepts embedded in the rides at an amusement park. To discover the students' learning processes and strategies, the researchers first obtained students' self-report metacognitive profiles and reviewing audio and video recordings of student discussions at the park as well as in-class discussions, post-visit interviews, and post-activity interview. Unlike Schraw and Dennison (1994), these researchers divided metacognition into six dimensions; awareness, control, evaluation, planning, monitoring, and self-efficacy. Anderson and Nashon found that students with high self-efficacy tended to push their perception of knowledge to other members even when the constructs were incorrect. However, a strong possession of awareness, monitoring and evaluation of one's thinking is very important to ensure the knowledge and understanding constructed are valid and correct. The one key factor that made a difference in generating correct understanding of Physics concept in this study was found to be a strong sense of awareness. According to Anderson and Nashon, metacognitive awareness is crucial in alerting the individual of dissonance in understanding a concept.

Spence, Yore and William (1995) investigated the relationship between metacognition and science reading comprehension of ninth-grade native English speaking students. The students were explicitly instructed in metacognitive reading strategies for more than 22 weeks. Analyses of the metacognitive awareness, metacognitive self-management, and comprehension results indicated a significant correlation between metacognitive awareness and science reading comprehension. Positive correlation was found between metacognitive self-management and science reading comprehension success.

Bonner and Holliday (2006), on the other hand, studied to uncover college students' note taking strategies while listening to lectures and reading science texts for a genetic course. The researchers were comparing the note-taking theory of students in the study to Van Meter, Yokoi and Pressley's (1994) "college students" theory of note-taking. According to Zimmerman and Martinez-pons (1988, cited in Bonner & Holliday, 2006) note-taking can predict with high degree of precision a student's academic achievement. The efficiency of note taking strategies is determined by the ability of the students to connect their prior knowledge to the lecture content and science text. Bonner and Holliday examined and analyzed the notes taken by 32 students enrolled in the genetic course and interviewed 23 of them for five times over the semester. All of them were native speakers of English. This study revealed that note taking is greatly influenced by prior knowledge as found by Van Meter et al. (1994). Two other factors that influence effective note taking are realistic goal setting and a repertoire of strategies to modify current inefficient strategies. However, the key finding in this study indicates that metacognitive awareness which was indirectly developed through "metacognitive conversation" during the researcher-participant interviews has helped the students to reflect inward, watch themselves utilizing certain strategies, and decide which strategies worked and vice versa.

Burdick (1991) investigated the direct instruction of two metacognitive strategies, in particular critical self-questioning and interpretive self-testing, in reading expository science texts. Both were comprehension monitoring strategies. Subjects were 180 ninth-grade English speaking students in Idaho, United States. The findings of this study indicated that training students to self-question does not improve the final reading comprehension performance. Burdick further concluded that both strategies did not supersede rereading and thus did not deserve a recommendation for instructional strategy.

Most L2 reading research on metacognitive strategies have been looking into reading in the social science discipline and of other general texts. Due to the dearth in the research on metacognitive strategies of science students reading scientific texts in their second language, studies that utilized scientific texts, academic texts, and challenging texts are referred to so as to provide a framework for the type of metacognitive strategies employed by the L2 readers under difficult conditions.

Dhieb-Henia (2003) investigated the effectiveness of metacognitive strategy training on the reading processes of L2 students when reading research articles in their specific domain area, which was biology. Her participants consisted of two groups of 34 and 27 undergraduate biology students in two different science institutions, A (experimental) and B (control). Participants were native speakers of Arabic, second language speakers of French and English was the third or foreign language to them. Metacognitive strategy training was conducted for 30 hours in ten weeks. Texts were chosen from journal articles in Biology. The two groups took a pre test before the training and a post test 12 weeks later. The tests consisted of three journal articles of four to ten pages in length and the tasks involved skimming, scanning, and careful reading. The amount of time to complete the tasks was calculated. Twelve students in institution A participated in a retrospective session after both tests. The retrospection focused on three areas, recognition of genre of research articles, identification of different parts of the articles, and the effect of the course on strategy use.

The analyses on the strategies used before and after the training revealed that the experimental group tended to utilize top down strategies (higher-level cognitive strategies) and guessed at meaning of words based on contextual and textual clues, as opposed to their initial strategies which were mainly bottom up (lower-level cognitive strategies). The training on metacognitive strategies provided the participants with the declarative knowledge about strategies options and procedural knowledge on what strategies to use, when and how. The participants' employment of the metacognitive strategies learnt was reflected in the significant increase of their mean comprehension scores after the training.

Research findings consistently show that metacognitive awareness is the key to enchanced reading comprehension as students were able to evaluate their own ability, recognize their strengths and weaknesses, and choose the most appropriate strategies to augment reading success as well as to remedy reading difficulties.

3.6.3 Comprehension monitoring in L2 reading and science education research

According to Smith and Dauer (1984), comprehension monitoring is the self-regulating of the cognitive activities which includes monitoring the effectiveness of particular strategies, self-testing, revising, and evaluating strategies. Winograd and Johnston (1982) summarize comprehension monitoring as a subjective feeling experienced by readers which informs them that they have understood or have failed to understand a text. In Block's (1992) words, comprehension monitoring requires "the ability to stand back and observe oneself" (p.320). Yang (2002) defines comprehension monitoring as general "competence", “control” or “status” that resides in one’s mind. Thus according to Yang, if a reader lacks in comprehension monitoring competency, it is not possible for him/her to employ a particular metacognitive strategy.

Reading in content area is generally more laborious compared to reading recreationally (Smith & Dauer, 1984). One reason could be that the latter type of reading matches the reader’s schemata, linguistically less demanding, or of narrative in nature. Thus, the cognitive process becomes fully automatic and routine (Winograd & Johnston, 1982). However, content area texts are usually packed with facts and details, syntactically more challenging, and a lot of the time contain new and unfamiliar concepts. Thus, reading can be laborious which requires reader’s undivided attention (ibid). For this type of reading, comprehension monitoring is crucial to L2 readers especially if they have very little prior knowledge on the topic and limited language proficiency (Block, 1992; Yang, 2002). L2 readers specifically need comprehension monitoring competency to assist in their choice of strategies, examine the success of certain strategies in overcoming their reading difficulties, and repair gaps in the understanding of the text. Smith and Dauer (1984) assert that comprehension monitoring should be taught to readers so that they could independently regulate their own comprehension.

Block (1992) examined the comprehension monitoring process used by native and non native English speaking first year university students as they read expository texts in English. There were 25 participants of whom 16 were proficient readers (eight L1 and eight L2) and nine were non proficient readers (three L1 and six L2). The passage was from an introductory psychology textbook, *Talking to Babies.* In this study, comprehension monitoring became apparent only when comprehension breakdown occurred. The problems encountered in the reading that interrupted with the participants' flow of comprehension were (1) finding the appropriate pronoun referents (e.g. these, it, this) and (2) defining unknown words (e.g. Urdu, toddler, take shape).

Block found that when participants encountered with these 'problems', proficient and less proficient readers undertook different means to control the monitoring process. There were three parts to the monitoring process: evaluation of comprehension, action, and checking of action. When the participants evaluated their comprehension, they recognized that they had problem in understanding the sentence. Before solving the problem they first identified the source of the problem. To take action, they planned a strategy and then acted on it. Finally, they checked if the strategy managed to help clarify the initial reading problem and revised earlier guesses or hypotheses.

Comprehension monitoring amongst L1 proficient readers reading challenging scientific text was examined by Smith (1985). The participants were nine mature and experienced master's and doctorate students and were required to read the same physics article entitled *Particles with Naked Beauty* from *Scientific American* magazine. To investigate comprehension and comprehension monitoring, Smith collected data from (1) participants' introspective accounts that described the participants were drawing conceptual maps, constructing glossaries and taking experience of comprehension and criteria for judging comprehension, (2) maps and summaries that reflected comprehension of the readers as they put the text aside for the last time, and (3) pre and post reading statements on the content of the text. Since the text was ten pages long, participants were given three weeks to read and complete the ensuing reading tasks.

Smith found that as the readers encountered reading difficulties, similar to Block's and Li and Munby's participants, they identified the source of the problem and took actions by employing support strategies like reading resource books on the related topics, encyclopedias, and even dictionary. They also employed comprehension testing strategy to review and establish what they had understood so far. This finding reveals that experienced readers make conscious effort in determining and ensuring comprehension. Cognitive strategies utilized by the detailed notes which were reviewed and revised were among the frequently reported strategies in Smith's study. Other strategies included writing summaries, posing and checking hypotheses, and making conscious use of textual features. These findings indicate that more proficient readers tend to have a strong hold of their comprehension monitoring by evaluating comprehension progress, solving difficulties, and checking their solutions compared to less proficient readers.

3.7 L2 proficiency and comprehension strategies in L2 reading research

Throughout much of the second language reading literature, the studies on comprehension strategies continue to proliferate. One of the reasons for the strong interest in exploring comprehension strategies in reading processes, according to Pressley (2006), is that comprehension strategy which takes time and effort to develop in readers, if at all, can be taught to even young readers and thus improve their strategy use during reading though strategy training. Ensuing direct explanation, guided practice on a small repertoire of comprehension strategies over a period of time as modeled by reading instructors (ibid; Shih, 1992) frequently produce huge gains of reading achievements at the end of the training session by weak readers (Kitajima, 1997; Salataci & Akyel, 2002) despite initial problems with reading fluency (Pressley, 2006; p. 210).

A plethora of research has been devoted to examine comprehension strategies utilized by second language readers in processing L2 texts and to date have accumulated extensive data and information on a wide range of contextual factors which influence second language readers' strategies choice. Many theories have suggested that the most significant variable that influences reader's strategy choice would be linguistic proficiency. L2 readers' inadequate proficiency in grammar and vocabulary may force them to fall back on lower level processing strategies such as decoding and word recognition which can inhibit global comprehension of text content.

Empirically supported findings have shown that reader's L2 proficiency (Bernhardt & Kamil, 1995; Block, 1986; Carrell, 1991; Koda, 2005; Tan, 1986) is the key to efficient L2 reading where L2 proficiency entails the knowledge of vocabulary and syntax. L2 proficiency is central to L2 reading comprehension so much so that limited L2 proficiency will ‘short circuit’ (Clarke, 1980) or inhibit a reader’s good L1 reading strategies from being transferred to and utilized in the L2 reading task. This will consequently cause him/her to employ poor reading strategies which would mainly be processing the text at word level (Horiba, 1990). Studies by Bernhardt & Kamil (1995), Bossers (1991), Brantmeier (2005), Brisbois (1995), Carrell (1991), and Koda (2005) confirmed this notion with the findings that L2 proficiency contributes 30%-38% of the variance in L2 reading comprehension.

Many reading researchers found that proficient readers who possess high level linguistic knowledge of the text read utilize a repertoire of higher level cognitive strategies while reading, especially those to assist in building propositional model of the text (Block, 1992; Crain-Thorenson, Lippman, & McClendon-Magnuson 1997; Mohd Shah, 2004; Perfetti, 1985; Sariq, 1987). High level cognitive strategies like activating and accessing prior and schematic knowledge, questioning, clarifying, summarizing, inferring, predicting, recognizing text structure, keeping meaning of passage in mind while reading, and connecting related information across sentences and paragraphs (Barnett, 1988; Block, 1992; Crain-Thorenson et al., 1997; Hosenfeld, 1977; Perfetti, 1985; Young and Oxford, 1997) are known as ‘good’ or ‘successful’ strategies and are reportedly utilized by skilled readers. These high level cognitive strategies demand maximum working memory capacity and require the readers to have already attained high linguistic proficiency in the L2 to the point of automaticity.

However, there exist contradictory findings regarding the contribution of L2 proficiency in L2 reading comprehension as well as strategy choices opted by less proficient L2 readers. First, for reading passages and accompanying comprehension questions designed to assess readers' reading ability in the second language, L2 proficiency of readers is the key factor that best predicts the success of reading comprehension. This is because testing materials designed to assess reading ability will require the readers to possess a certain level of L2 proficiency to score highly in the reading comprehension measure. As cited by Fitzgerald (1995) from the studies of Ammon (1987) and Garcia (1991), unknown vocabulary in questions and answer choices on tests was the main linguistic factor that negatively affected the reading test performance of L2 readers. Purpura (1997) found that grammar ability strongly predicts reading ability in ESL due to perhaps all standardize tests compel test takers to decode text at lexical and syntactical levels more than at inferential level (p. 304).

On the other hand, those studies that investigated the extent of readers' comprehension of the text content might have used comprehension measures that were free of questions that specifically designed to test L2 grammatical and vocabulary knowledge of the readers, and instead focused on gauging the extent of comprehension of the text content.

Second, the notion that assumes lower L2 proficiency would result in lower-level processing and thus inhibit the utilization of higher level strategies (Clarke, 1980; Horiba, 1990) has not been supported by a number of studies in examining L2 reading comprehension in specific domain areas. Instead, less proficient readers may exert greater compensatory strategies (Chen & Donin, 1997; Stanovich, 1980), especially their prior knowledge in their specialized area to make up for their inadequate linguistic knowledge. This would occur on the condition that the readers are equipped with relevant conceptual knowledge to rely on in compensation for their insufficient linguistic proficiency.

Anderson (1991) examined individual differences in strategy use while taking a standardized reading comprehension test and during academic reading tasks of specialized areas. His participants were 28 students enrolled at a university level intensive English as a second language programme in the United States. Based on the placement test conducted by the intensive English programme, the students were categorized into three English proficiency levels; nine were beginning level students, ten at intermediate level and nine more at advanced level. Two types of reading materials and comprehension assessments were used. The standardized reading comprehension test was taken from the *Descriptive Test of Language Skills-Reading Comprehension Test (DTLS)* which was designed to assess readers' L2 reading ability. Reading passages for academic reading tasks were taken from *Textbook Reading Profile (TRP)* which were typical of academic reading materials in participants' specific content areas. The comprehension questions were designed to have readers synthesize the text content.

To assess reading comprehension skills, the first form of the *DTLS* was randomly assigned to the participants on the first day under test taking conditions. The standardized test consisted of fifteen reading passages followed by two to four multiple choice questions. The test measured reading skills such as understanding main ideas, understanding direct statements, or drawing inferences. Participants' reading comprehension skills and strategies use while reading the second form of the DTLS and two passages from the *TRP* were assessed by having them verbalized their thoughts in a think aloud procedure in either their L1 (Spanish) or L2 (English). The TRP passages contained an average of 643 to 1057 words each and both passages consisted of 24 multiple choice questions.

Interesting results emerged from the simple regression which indicated that the level of L2 proficiency accounted for the variance in the total test score was 39% and was reduced to only 16% on academic reading measure. More surprisingly, higher level of L2 proficiency did not guarantee a better comprehension of the academic reading task as shown in Anderson's study. The results obtained by Anderson were reanalyzed by the current researcher using descriptive statistics. It was found that those whom Anderson found to be using more strategies and scored higher in the reading test (DTLS) were participants of higher-level of L2 proficiency. Participants possessing lower L2 proficiency tended to use less number of strategies and also scored less on the comprehension measure. On the other hand, similar result was not found in the textbook academic reading task (TRP). Almost all participants from all proficiency levels tended to reduce the number of strategies used, some to almost 50% less, when reading academic texts and under no time constraints. Participant 26 (intermediate proficiency level) utilized only 23 strategies and managed to score 54 marks on the TRP whereas participant 11 (advanced level) who utilized 122 strategies scored 60 marks, better by only 6 marks. These two participants were placed in the high ranking group based on their scores on the TRP.

As argued by Anderson, the DTLS was a test on English language reading ability and therefore it could safely be assumed that the test was designed not only to assess the comprehension of the content of the passages but also the English linguistic knowledge of the participants. Unlike the DTLS, the TRP strictly measured the comprehension of the content of the texts read and thus lacked in purposeful assessment of participants' English language vocabulary and grammar knowledge. This might also be the reason why participant 17 (beginning level) who utilized 24 strategies managed to score 46 marks in the TRP and thus successfully put himself in the high ranking group. At the same time, participant 27 (advanced level) who utilized 21 strategies scored only 33 marks and that placed him in the low ranking group.

Closer inspection of the strategies utilized by participant labeled as possessing lower L2 proficiency (participant 19) when reading the textbook reading passage (TRP) revealed that his level of L2 proficiency did not inhibit the employment of higher-level cognitive strategies. He was found utilizing strategies such as i) relating text content to personal experience, ii) predicting about meaning of words, iii) using prior knowledge, and iv) extrapolating from information in the text. In contrast, participant 20 (higher L2 proficiency) failed to use strategies i, ii, and iii, and consequently might have caused him to drop from the high ranking group as determined in the DTLS reading measure to low ranking group in the TRP reading measure. Thus, the contention that higher L2 proficiency strongly predicts better comprehension of L2 academic reading texts or that influences the utilization of higher level cognitive strategies is not supported in this study by Anderson.

Hayashi (1999) examined reading strategies and extensive reading of 100 EFL Japanese sophomores who were taking an English course. TOEFL institutional test was used as pre and posttest to measure their reading ability and they were put in the beginning and intermediate groups. Participants were required to read a textbook containing many newspaper articles about current issues. They were also encouraged to read about 100 pages from English books per month as out-of-class assignment and required to write a summary and comments on the reading. Besides, participants were asked to write the amount of time spent on reading as well as difficulties or gratification they experienced from the extensive reading. After five months, participants were given a questionnaire on the perceived strategy use when reading English textbooks. Hayashi divided the cognitive strategies utilized by the participants into three categories; data-driven strategies, conceptually-driven strategies, and socio-cultural strategies.

At the start of the study, participants of higher proficiency level were found to be using more number of higher level strategies (conceptually-driven) compared to those of lower proficiency level. On the other hand, the lower proficiency group tended to rely more on lower-level strategies (data-driven). Interestingly enough, after a strategy training programme and eight months of reading extensively, low proficiency participants tended to utilize more higher-level strategies than their more proficient counterpart. There was also a marked decrease on the over reliance on lower-level strategies amongst the same group of participants. However, since Hayashi was using TOEFL to assess reading comprehension of her participants, and the design of TOEFL was to assess L2 proficiency and reading ability, Hayashi found that in both pre and post tests, participants of higher L2 proficiency managed to get better scores than those of lower L2 proficiency. This study supports Anderson's findings regarding L2 proficiency and strategies use. In addition, the result of this study provides support for the contention that the design of reading comprehension assessment used will reflect what it was intended to do but may not reflect the true comprehension of the text content by L2 readers.

Mohd Shah (2004) examined the reading strategies used by form four ESL students in Malaysian schools. The participants were 32 Malay students with 18 being good and 14 average ESL learners. The study aimed at finding out if there was significant difference between good and average ESL learners in employing supervising, support and paraphrasing strategies while reading. In this study, the participants were required to read a piece of reading material for at least three times before they had to retell the content of the text in either Malay or English. There was no indication regarding the nature of the reading material utilized in the study. The best guess would be a passage from English textbook designed for ESL learners. However, the retelling procedure to assess the extent of participants' comprehension of the text content might have managed to avoid the 'testing of L2 knowledge' pattern. Participants then had to respond to questionnaires concerning their reading/ comprehension strategies. The researcher made use of Pritchard's (1990) Inventory of Reading Processing Strategies to collect the data.

The data from the above study indicated that there were significant differences between good and average learners with respect to their use of supervising strategies. Good learners were found to employ supervising strategies such as formulating questions as they read, referring to lexical items as well as to previous paragraph, and emotionally involved in the content of the text while reading. On the other hand, average learners were found to be using less of the above mentioned strategies. It was also found that good learners skipped unknown words and skimmed reading materials for a general understanding while average learners did less of the above but expressed the need to use the dictionary. Good language learners seldom translated words or used cognates between L1 and L2 to comprehend but often paraphrased and extrapolated from information presented in the text. Meanwhile, average learners seemed to do the opposite during reading. The researcher found that good learners made use of many good reading strategies and due to that, they performed better in the English language.

The findings in this study confirm the notion that L2 proficiency determines L2 reading comprehension and employment of good reading strategies. In contrast, inadequate L2 proficiency will compel the readers to use text-bound (Carrell, 1991) strategies. As in Anderson's (1991) and Hayashi's (1999) studies, Mohd Shah found that L2 proficient readers tended to utilize reading strategies more frequently than the less L2 proficient readers. Hence, the contention that L2 proficiency does not necessarily ensure full comprehension of the text content is not supported based on the findings in this study. Unfortunately, this study neither gave a full description of the reading materials used in the research that could have contributed to the result as such nor provided the reading comprehension scores of the participants that could be correlated to the extent of effectiveness of the strategies employed.

Chen and Donin (1997) investigated the effects of L2 proficiency and prior knowledge on lower level (lexical and syntactical) and higher level (semantic and conceptual) processing of biology texts. Participants were 36 Chinese (Mandarin) graduate science students. Eighteen were biology students and the other 18 were engineering students. Both groups of students were proficient readers of Chinese. The fact that they were proficient readers in L1 leads the present researcher to assume (because it was not explicitly stated in the article) that they possessed efficient comprehension strategies in L1. The biology and engineering groups were further divided into more L2 proficient and less L2 proficient groups.

Three biology passages were used as reading texts, each with two paragraphs; the first was a general description of the use of a bio-technique and the second was a step-by-step description of the particular bio-technique on the topics of monoclonal antibody, karyotype and radioactive tracer. All biology graduate participants were expected to have some general knowledge on these topics. On the other hand, the engineering students were not expected to be familiar on these topics, thus were presumed to have limitation in the utilization of higher-level cognitive strategies such as using prior knowledge, predicting and making hypotheses. Online recall was used as reading comprehension measure.

The findings of the study revealed that those participants with less proficiency in L2 but more prior knowledge on the topics managed to recall higher percentage of the text content compared to those with more proficiency but less prior knowledge. This was because participants who were confronted with insufficient linguistic knowledge to process the text content were seemed to be able to use contextual clues to make inferences about the propositions in the text. Therefore, they were able to recall on average 43.6% of the text proposition in English and 48.6% in Chinese. In contrast, the more L2 proficient engineering participants but were lacking in prior knowledge were not able to make use of their linguistic knowledge to perform more higher-level processing. As a result, their recall stood at 31.3% in English and 28.3% in Chinese. This shows that higher L2 proficiency affects the ease of processing at lexical and syntactical levels but does not facilitate semantic and conceptual processing which is of higher-level processing. With relevant knowledge in the content area, less proficient readers are capable of undertaking higher level cognitive strategies to compensate for their insufficient L2 linguistic knowledge. Coady suggests (1979) similar notion when he asserts that:

> The subject of reading materials should be of high interest and relate well to the background of the reader, since strong semantic input can help compensate when syntactic control is weak. The interest and prior knowledge will enable the students to comprehend at a

> reasonable rate and keep him involved in the material in spite of its syntactic difficulty (p. 12).

The above study also confirms Stanovich's (1980, 2000) interactive-compensatory reading model which postulates that a reading process at any level can compensate for deficiencies at any other level. Hypothetically, if there is deficiency at the linguistic level, a reader may impose his/ her higher-order knowledge to compensate for the deficit, vice verse for the skilled reader who lacked knowledge about the text topic. In this case, L2 proficient readers did shift to lower-level cognitive strategies when they were engaged in texts of unfamiliar concepts and faced with lexical difficulties. Most lower-level cognitive strategies found to be utilized by readers are using context to determine meaning of unknown words (Auerbach & Paxton, 1997; Barnett, 1988; Block, 1992; Hosenfeld, 1977), skipping unimportant words (Hosenfeld, 1977; Mohd Shah, 2004), using syntactical clues (Block, 1992) and rereading sentences or phrases (Block, 1992; Guthrie & Toboada, 2004; Mohd Shah, 2004) to support or fix comprehension failures of the printed text.

In contrast to this notion is the Linguistic Threshold Hypothesis which maintains that until the readers have surpassed the linguistic threshold level, they will have limited resources for higher-level processing as their attention capacity and resources will be focused on lower level processes, thus making them text bound (Anderson, 1991; Carrell, 1988; Cummins, 1981; Schoonen, Hulstijn, & Bossers, 1998) and their reading laborious. Participants 17 and 19 with beginning level English proficiency in Anderson's (1991) study and those with less L2 proficiency in Chen and Donin's (1997) study who managed to apply high level processing even with limited proficiency seemed to contradict the hypothesis.

With the inconsistencies found in a number of studies regarding the types of strategies used by high and low L2 proficiency learners, it is therefore imperative to get an in-depth understanding regarding how readers reading specialized texts in their own domain area select and utilize cognitive strategies and the reasons for the choices made. This is because, academic reading of scientific texts at the university level is cognitively very demanding and the level of comprehensibility and abstraction may vary greatly from the non-scientific texts.

3.9 Prior knowledge and comprehension strategies in L2 reading research

According to Pressley (2006), strategic readers are very active readers who begin cognitive processes before the actual reading begins to after the reading ends (p. 6). What is evident in strategic readers is the continuous responses verbalized by the readers while relating prior knowledge they possessed to the content of the text they were reading during the meaning construction process. Pressley and Afflerbach (1995) refer to strategic reading as continuously attempting to construct the meaning of the text by responding to the topic being discussed in the text to their prior knowledge. This means to say that over three decades of research has led comprehension strategies advocates to adopt a view that strategic reading first requirement is prior knowledge and how successful the reading endeavor is depends to a large extent on how much the readers manage to relate the information in the text to their prior knowledge.

Tertiary level L2 readers are assumed to have accumulated a wide range of prior knowledge in a variety of areas learnt in their L1. Urquhart and Weir (1998, p. 63) argue that in order to predict ESL reader's performance on a particular reading task, his prior knowledge must be taken into consideration. In addition, Koda (2005, p. 141) asserts that mature L2 readers already literate in their L1 usually rely heavily on their prior knowledge. Their reliance on previously acquired conceptual knowledge especially in highly specialized texts may lead to the utilization of top down processing to compensate for inadequate linguistic sophistication (ibid).

Coady (1979) has suggested a model of ESL reader, as shown in Figure 3.1, in which his/her prior knowledge interacts with his/her conceptual abilities and process strategies to result in the comprehension of the text content.

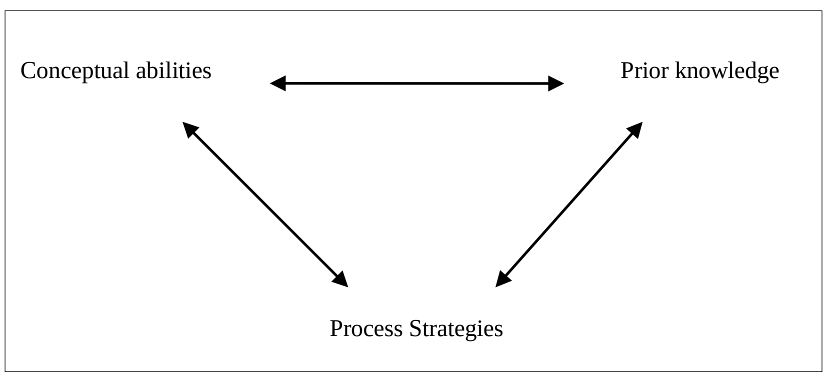

Figure 3.1 Model of an ESL reader (Coady, 1979; p. 7)

Coady's conceptual abilities mean general intellectual capacity (Carrell, 1983b). Coady states that the failure to achieve the required competence for university level education amongst adult foreign students may be attributed to their lack of intellectual capacity and not due to the lack of English proficiency. Nor

Azni's (2000) study that examined the interaction among English language proficiency, cognitive-academic proficiency (measured by SPM aggregate score) and university achievement (measured by CGPA) may shed some light on Coady's notion of conceptual abilities mentioned above. In Nor Azni's study, cognitive-academic proficiency is equivalent to general intelligence (p. 46) or general intellectual capacity as used by Carrell (1983b) and Coady (1979). It was found that participants' cognitive-academic proficiency or intellectual capacity was the variable that most significantly correlated to their CGPA and accounted for more than 12 percent of the variance in the CGPA.

According to Coady, besides conceptual abilities, prior knowledge is an important variable in reading as greater prior knowledge of certain subject matter could make up for the lack of linguistic control. The prior knowledge allows the reader to comprehend the text at a 'reasonable rate' and keeps him/her engaged in the materials despite the linguistic difficulty.

Finally, there are process strategies which interact with conceptual abilities and prior knowledge. As mentioned earlier in this chapter, process strategies are those general language processing skills (e.g., grapheme-morpheme correspondences, syntactic information-deep and surface, and lexical and contextual meaning) and cognitive strategies. Proficiency in the language of the text does not necessarily ensure the success in comprehending the text. As Coady (1979) has suggested, prior knowledge on the topic of the text in combination with effective comprehension strategies can have a strong impact on reading comprehension. This may be especially valuable when the L2 readers read highly specialized texts that demand considerable content area knowledge such as scientific texts.

McKee (2002) looked into the problems faced by nursing students pertaining to biological science subject area. As biological science was an important subject in providing scientific underpinning for nursing practice, the researcher examined the source of the difficulty. Her findings revealed that there was significant correlation between students' prior knowledge in the form of level of achievement in school biology to the performance in biological science examinations in the first year of nursing school. This study drove home the point that familiarity with the language, scientific concepts and scientific way of thinking assist in the acquisition of new knowledge in the specific domain area.

3.10 Chapter summary

This chapter discusses past studies on the use of comprehension strategies by readers, with special emphasis on L2 readers, in reading general, academic and scientific texts. It begins by highlighting the unique features of scientific language before emphasizing the critical contribution of comprehension strategies on reading comprehension of a reading passage. The types of comprehension strategies that the study examines are defined and described in detail. As this study specifically looks into cognitive and metacognitive strategies, past empirical research conducted by cognitive psychologists, reading experts, and ESL researchers are reviewed at length. It is noted that from the review of the related literature, most past studies have examined only comprehension strategies by skilled/ unskilled, proficient/less proficient, and successful/unsuccessful readers, be it in L1 or L2 reading. In addition, past studies have focused on the reading of general texts and academic texts in the social sciences. Therefore, studies that examine the employments of cognitive and metacognitive strategies in reading scientific texts have yet to be carried out. The chapter ends with a discussion on the dynamic interactions among ESL student's conceptual abilities, prior knowledge and process strategies.

CHAPTER FOUR

RESEARCH DESIGN AND METHODOLOGY

4.1 Overview

The purposes of this study are to identify the repertoire of cognitive and metacognitive strategies utilized by first year ESL undergraduates while reading scientific texts and to compare the strategies of good and poor readers of this cohort. In addition, the study explores the role of general second language (L2) proficiency, science prior knowledge, and metacognitive awareness on respondents' strategy use and reading comprehension of scientific texts.

This study followed the quantitative as well as qualitative approaches of data collection and analyses. A number of instruments were employed to assess the interacting variables in the reading process which ultimately affected the respondents' reading comprehension of scientific texts in English. This chapter describes the research design that was used in seeking answers to the research questions. Discussion in this chapter focuses on the following items: research design, research sample, independent and dependent variables, instrumentations which include reliability and validity, pilot studies, and data analysis procedures.

4.2 Research design

This study employed a mixed method research design. According to Creswell (2003), a mixed method approach is based on pragmatic grounds in establishing knowledge claims. It draws substantially from both quantitative and qualitative assumptions to provide the best understanding to the research problems. Data collection in a mixed method approach involves both numeric (eg. from instruments) and text information (e.g. think aloud and interviews protocols). A number of social science researchers (Neuman, 2006; Sekaran, 2003; Sullivan, 2001) believe that triangulation of research methods such as this is likely to produce a stronger confidence in the goodness of the data.

There are three general strategies to follow in a mixed method approach; sequential, concurrent, and transformative procedures (Creswell, 2003; Neuman, 2006). In sequential procedures, the findings from one method are expanded with the findings from another method to provide an in-depth understanding to the research problem. Concurrent procedures, on the other hand, combine data from both approaches concurrently to provide a comprehensive analysis of the research problem. Finally, in transformative procedures, the findings from one approach provide the conceptual framework for the subsequent processes in the study. The subsequent processes involve data collection method that follows either sequential or concurrent procedures (Creswell, 2003: p. 16).

A concurrent triangulation mixed method approach was finally adopted in which data was collected through quantitative survey as well as qualitative techniques. There were three reasons why the concurrent triangulation mix method was chosen as the research design. First, a large number of samples was required if the findings on the types of reading strategies used to read scientific texts by ESL science undergraduates in Malaysia were to be generalized to the wider populations of similar characteristics (Babbie, 1990; 2001; 2005). Second, it was also important to get the emic perspectives of the respondents while reading the scientific texts through qualitative data collection techniques like think aloud procedures and retrospective interviews. Third, by mixing both data collection techniques, this study stood to gain the strengths and advantages of both approaches (Neuman, 2006; Sekaran, 2003; Sullivan, 2001).

4.3 Research sample

4.3.1 Sampling criteria

The most important criterion was that the respondents were first year undergraduates. There were three reasons why first year undergraduates were chosen for this study. First, they were the cohort that was, at the time of the study, struggling to adjust to the transition of learning science in English, after being exposed to learning it in the Malay language in the national school. Second, they provided a window on how first year undergraduates adapt their reading style to accommodate independent reading of scientific texts at tertiary level as opposed to guided learning practised in schools and matriculation centres. And finally, they were the perfect target group to observe if reading skills learnt in public schools and matriculation centres were as effective for ‘post secondary school needs’ or independent academic reading at the tertiary level as they were aspired to be (Pusat Perkembangan Kurikulum, 2003, p. 1).

The next criterion was that the respondents were science majors (biology) in public institutions of higher learning with the ages ranging from 19 to 23 years old. Younger respondents in this study had completed two semesters of matriculation studies in science and foundational science course whereas older students had had two years of pre university studies (Lower and Upper Sixth Form) before sitting for the Malaysian Higher School Certificate (*Sijil Tinggi Persekolahan Malaysia or* STPM, hereafter). Both groups of respondents had had one to two years of exposure in learning and reading science in English before commencing their undergraduate studies and therefore possessed science prior knowledge, in particular biology. In sum, respondents of this study consisted of first year students enrolled in biology-related degree programmes.

To ensure that respondents shared almost common science/ biology prior knowledge, they had to be local Malaysian students who had undergone secondary and post secondary educations in Malaysia. This was because the curriculum in all public schools and post secondary education centres were designed under direct supervision of the Ministry of Education of Malaysia. Hence, the science syllabus at each level was the same throughout the country. In fact, the science syllabus in the Malaysian education system is almost the same at each education level as compared to the syllabus in the U.K, Canada and the U.S. (Wan Mohd Zahid, 2001).

4.3.2 Research population

There were no less than 19 public universities in Malaysia at the time of the study and 13 of them offered biology related degree programmes to some 5000 first year students nationwide. With a large number of first year science/biology undergraduates, researchers (Babbie, 2005; Burns, 2000; Cohen & Manion, 1980; Creswell, 2003; Neuman, 2003) suggested cluster sampling since simple random sampling would pose administrative problems and inconveniences. By cluster sampling, it is suggested that researchers randomly select a specific number of institutions and test all of the students in those institutions (Cohen & Manion, 1980; p: 99) or draw samples of students from each (Babbie,2005; Best & Kahn, 2003; Neuman, 2006). Stage sampling is an extension of cluster sampling where it involves selecting samples in stages. Thus, after selecting a specific number of institutions, researchers employing stage sampling may select a number of classes at random and later a number of students in the selected classes at random too (ibid).

4.3.3 Research sample for quantitative survey

Four public universities selected in the cluster sampling technique were University of Malaya, Universiti Kebangsaan Malaysia, Universiti Sains Malaysia, and Universiti Malaysia Terengganu. For easy reference, these universities were labelled University P, Q, R, and S. Following that, stage sampling procedure was conducted by selecting three first year biology classes in each university at random and all the students in each class were chosen to participate in the study. Selecting everyone in each of the chosen class would help to increase the probability of sampling both high and low academic achievers as well as good and poor ESL readers of scientific texts. Some lecturers of the biology courses permitted the researcher to conduct the survey during the second half of their class time while a few handed over the whole 3-hour tutorial time for the survey. There were other lecturers who requested that students participated in the survey during their free time and this situation resulted in a very low turn over of respondents. Table 4.1 shows the distribution of respondents in the four universities.

Table 4.1

Respondent Turn Over Based on Institution, Age, Gender and Degree Programme

Institution	Age	Gender		Total	Degree programme
		M	F		
University P	19-22	17	37	54	Genetic Biodiversity Microbiology Biological Science Bioinformatics Biohealth Chemistry
University Q	19-22	27	94	121	Biology Biotechnology Microbiology Zoology Bioscience Chemistry
University R	19-22	17	67	84	Biology Applied Biology
University S	19-23	21	92	113	Biological Science Biodiversity

A total of 372 first year undergraduates for the university admission of July 2007/2008 from four universities participated in the study. The survey was conducted between March and May 2008 when the respondents were in the second semester of their first year undergraduate studies. The sample size for this study was considered large enough (Best and Kahn, 2003; Burns, 2000; Sekaran, 2003; Sullivan, 2001) for a 95% confidence level and ±5% precision. To conduct inferential analysis, Best and Kahn (2003) and Burns (2000) argued for a large sample size so that the means of the samples will be normally distributed and thus reflect the means of the population. The standard deviation of the sample means is in fact the expected sampling error known as standard error of mean. Best and Kahn (p. 389) maintain that as the sample size increases, the standard error of the mean decreases, which means the larger the sample the more representative of the population it becomes (Burns, p. 97). In addition, to conduct multiple regression, Israel (2003) suggests a sample size of about 200-500 for a more rigorous state impact evaluations.

4.3.4 Research sample for qualitative study

Purposive sampling (Fraenkel & Wallen, 2008) was chosen to select respondents to participate in the qualitative data collection technique. The selection was based on certain criteria of the students in order to obtain the relevant data needed for the study (ibid; Wiersma, 2000; 2009). For example, a review of L2 reading strategy research shows that L2 proficiency, prior knowledge and academic achievement are significant variables in L2 strategy use and reading comprehension.

In addition, the research population of the study consists of students from the three major ethnic groups, namely Malay, Chinese and Indians. Thus, a profile of respondents from two biology classes of one university containing all the criteria was obtained and ten respondents were chosen for the study as shown in Table 4.2.

Table 4.2

Profile of the Ten Selected Respondents for the Qualitative Study

Name	L2 proficiency (MUET[1])	PK	GPA	Gender	Race
Wan	High	High	Low	M	Malay
Lolita*	High	High	Low	F	Indian
Di	High	High	Low	F	Chinese
Devi*	High	Low	Low	F	Indian
Rheka*	High	Low	High	F	Indian
Zeti	Low	High	High	F	Malay
Tan*	Low	High	High	M	Chinese
Az	Low	Low	High	F	Malay
Bee*	Low	Low	High	F	Chinese
Riz	Low	Low	Low	M	Malay

[1]MUET: Malaysian University English Test
PK- Prior knowledge based on biology grade obtained in Semester one
GPA – Grade Point Average obtained in Semester one

All ten respondents agreed to participate in the study and were briefed on the procedures which involved three sessions of think aloud training and two sessions of actual data collection. However, as the study progressed, five respondents (marked with asterisks in Table 4.2) pulled out one at the time. The five remaining respondents completed all sessions involved in the study.

4.4 Research instruments

This section first discusses the selections of scientific texts used in this study, the instruments to assess metacognitive awareness, scientific prior knowledge, L2 proficiency, cognitive and metacognitive strategies, and finally the reading comprehension measures. The research instruments prepared and used for this study were according to the research construct as shown in Figure 4.1.

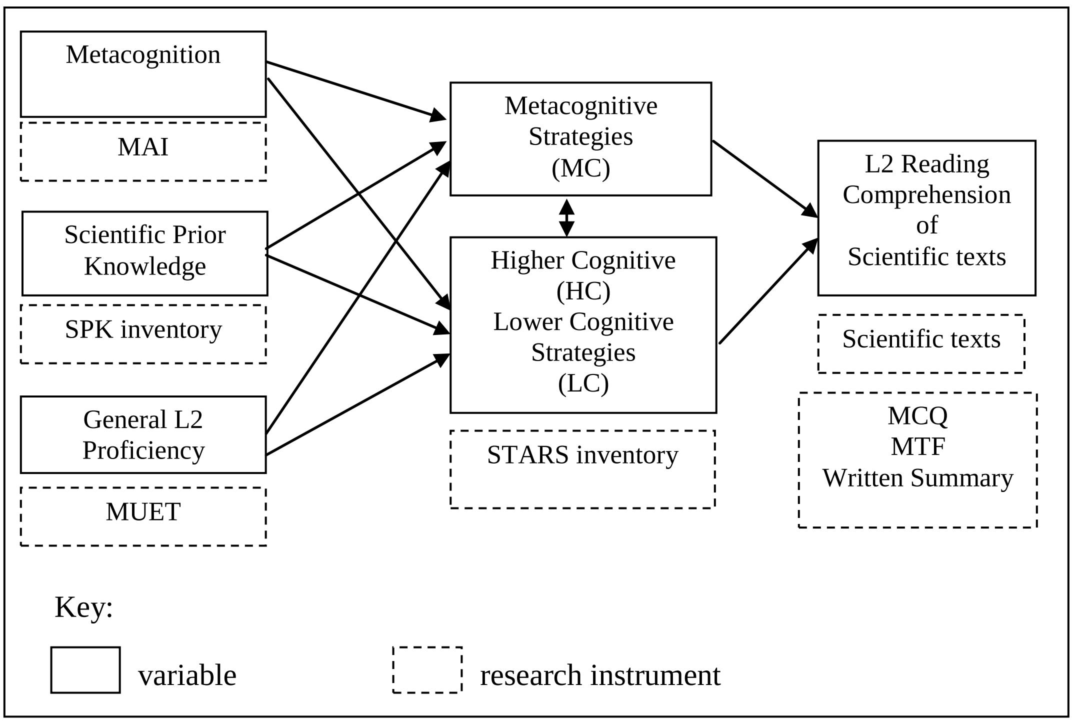

Figure 4.1 Variables and research instruments in the research construct of L2 reading comprehension of scientific text

4.4.1 Selections of scientific texts

To gauge and compare respondents' reading strategies of scientific texts, it is imperative to have them read the scientific texts first before administering the strategy questionnaire. This is because, having just read a scientific text for comprehension and understanding will enable them to readily reflect and contemplate on the strategies that they have just employed.

Two scientific texts in the English language used in this study were taken from university-level biology textbooks. Biology was chosen over chemistry or physics for three reasons. First, biology literature is full of figures in terms of both images and line drawings (Futrelle, 2004). Fifty percent of typical biology papers are high in figural content (ibid). Second, unlike Chemistry and Physics which contain a lot of equations and numbers, biology texts are highly descriptive and consist of verbal and figural contents. This type of dynamics within a single scientific text was deemed relevant to this study which intended to examine the strategies employed by ESL readers as they tried to comprehend scientific readings that blend together verbal texts and visual diagrams. Third, the field of biology has always been the choice for texts by reading researchers in the study of reading comprehension in domain-specific knowledge. Examples of biology topics used for reading research of scientific texts are parasitology (Tan, 1986), human biology (Alexander, Jetton & Kulikowich, 1995), heart disease (Tobias, 1995), and general biology (Chen & Donin, 1997), to name a few.

4.4.1.1 Criteria for text selection

Scientific texts for this study were chosen based on two important criteria which were (a) scientific language (less difficult/difficult) and (b) topic familiarity (somewhat familiar/less familiar). Familiarity refers to prior knowledge possessed by the first year science undergraduates on the topic discussed in each text. In addition, the selection took into account the Flesch readability index (Alderson, 2000; Goh, 2004; Krekeler, 2006) of each text that was computed on a *Microsoft Window XP Professional* computer. (Please refer to table 4.5 for a list of seven scientific texts chosen for selection). The Flesch Reading Ease and Flesch-Kincaid readability indexes could also be manually computed using the following formulas (Flesch, 1948; University of Memphis, 1999):

<u>Flesch Reading Ease</u>

$20.6.835 – (1.015 \text{ x } ASL^{a}) – (84.6 \text{ x } ASW^{b})$

<u>Flesch-Kincaid Grade Level</u>

$(0.39 \text{ x } ASL) + (11.8 \text{ x } ASW) – 15.59$

Notes:
[a]ASL = average sentence length (the number of words divided by the number of sentences)

[b]ASW = average number of syllables per word (the number of syllables divided by the number of words)

The Flesch Reading Ease formula is a number from 0 to 100 and the increase in the Flesch Reading Ease score indicates the easier the texts. Meanwhile, the Flesch-Kinciad Grade Level formula converts the Reading Ease Score to a U.S grade-school. Table 4.3 displays the correlation between the Flesch Reading Ease index to the U.S.educational level to the types of reading materials in the market. Table 4.4 below describes the reading ease based on the Flesch Reading Ease and Flesch-Kincaid Grade Level.

Table 4.3

Flesch Reading Ease, U.S. Educational Level and Reading Materials

Flesch Reading Ease	U.S Educational Level	Types of Reading Materials
91-100	5th Grade	Comics
81-90	6th Grade	Consumer Ads *Sweet Valley Teens* Series
71-80	7th Grade	*Chicken Soup For Teen Soul* Series
66-70	8th Grade	*Nancy Drew* Series
61-66	9th Grade	Sports Illustrated *Reader's Digest*
51-60	High School	*Time Magazine*
31-50	College	*New York Times*
0-30	College Graduate	Auto Insurance
<0	Law School Graduate	IRS Code

Source: Readability Formula, http://csep.psyc.memphis.edu/cohmetrix/ readability research.htm

Table 4.4

Flesch Reading Ease, Flesch-Kincaid Grade Level and Easy-Difficult Reading Scale

Flesch Reading Ease	Flesch-Kincaid Grade Level	Easy-Difficult Reading Scale
90-100	4	Very Easy
80-90	5	Easy
70-80	6	Fairly Easy
60-70	7-8	Standard
50-60	9-10	Fairy Difficult
30-50	11-14	Difficult
0-30	15-17	Very Difficult

Source: Goh (2004)

Table 4.5 displays the details of seven scientific texts initially selected, of which content lecturers helped to choose three texts for the pilot study.

Table 4.5

Seven Scientific Texts For Selection

Text	Topic	Diagram	No of words	Passive Const	Readability Index	
					Flesch Reading Ease	Flesch-Kincaid (1948)
Text A	DNA Replication	a) line diagram of double helix b) diagram with visual sequences	603	18%	38.5	12
Text B	Auxins and Elongation of Cells	a) photograph of plants b) line graph c) diagram with visual sequences	592	20%	41.5	12
Text C	The Limbic System of the Brain	a) static diagram of human brain	475	14%	30.3	12
Text D	Prokaryotic Cells	a) iconic diagram b) table c) photograph of bacteria	548	11%	33.1	12
Text E	Innate Biological Clock and Photoperiod of Plants	a) bar chart b) diagram with visual sequences	685	33%	44.4	12
Text F	Biomaterials for Organ Regeneration	a) iconic diagram b) photograph with visual sequence	535	50%	13.6	12
Text G	Hormones and Signal Transduction	a) 3 iconic diagrams	744	30%	25.7	12

Five of the texts (texts A – E) were taken from an introductory to biology textbook (Campbell, Mitchell, & Reece, 2000), one text (text F) was from a molecular biology textbook (Ishaug, Thomson, Mikos, & Langer, 1995), and the last one (text G) was taken from a biology reference book (Boyer, 2006), an International Student edition. All texts were accompanied by visual diagrams which served to clarify the texts; line graph, bar chart, table, iconic diagram or pictorial drawing (Hegarty, Carpenter, & Just, 1991), static diagram, diagram with visual sequences, and photograph.

All texts had a readability index of 12 on the Flesch Kincaid Index which indicated that the language structure was at college level. However, the Flesch Reading Ease Index revealed that the difficulty level of the seven texts varied to a great extent from 'difficult' to 'very difficult'. Hence, texts A, B, D and E fell under 'difficult' reading materials and texts C, F and G under 'very difficult'. Besides the readability indexes, another important criteria was the amount of passive constructions in each text. Passive construction is one of the typical features of scientific language that gives a scientific text its impersonal tone and syntactic complexity (Halliday, 2004). Texts A, B, C and D contained 20% or less passive constructions while texts E, F and G had 30% and above. The length of the texts which ranged from 475-744 words was deemed appropriate as academic reading materials for first year undergraduates. In comparison, other previous studies used academic texts in the range of 643-1057 words (Anderson, 1991), 500 words (Crain-Thorenson, Lippman, & McClendon-Magnuson, 1997), and between 713-870 words (Alexander, Jetton, & Kulikowich, 1995). Thus, this factor made text C a little shorter in comparison to those normally used in academic reading research.

4.4.1.2 Reliability and validity of scientific texts as research instruments

The reliability and validity of the scientific texts as research instruments lie in the texts as well as the appropriateness of their usage as reading materials for academic purposes by first year ESL science undergraduates. To ensure that scientific texts for the study were reliable, the seven texts were selected and taken verbatim from biology textbooks used for biology courses at tertiary level.

With respect to the issue of validating the scientific texts for this study, the expert judgement of two senior lecturers of biological sciences at the University Malaysia Terengganu was obtained (Best and Kahn, 2003, p.381). Their advice and recommendations were seeked as to which three texts should be used for the pilot study and ultimately for the main study (appendix B1). Together with the seven selections of scientific texts (labelled A, B, C, D, E, F, and G), the content experts were also given two sets of questionnaire to be filled. The first set of questionnaire assessed the content lecturer's academic qualifications, teaching experiences, and the language of instruction in their biology classroom. The second questionnaire was the *Assessment of Scientific Texts for the Reading of First Year Science (Biology) Undergraduates* (appendix B2). The assistance from the content lecturers was needed in three forms. First, they had to assess the difficulty level of the scientific language used in the texts (terminology and sentence structure). Second, they had to identify the texts which discuss topics that target respondents had already had prior knowledge or lack of it. Finally, they were invited to give constructive comments regarding any parts of the texts and suggestions to improve them. They were also invited to suggest the three best scientific texts to be used in this study.

The content experts rejected Text A (*DNA Replication*) and Text D (*Prokaryotic Cells*) as the contents of both texts had been extensively exposed to first year undergraduates prior to their enrolment to the university. Text B (*Auxins and Elongation of Cells*) was recommended as a more suitable text to be used in the study due to a good mix of old and new information discussed in the text. Text B was chosen as the first text (less difficult/ familiar) for the study. Text C (*The Limbic System of the Brain)* was eliminated for being a little shorter than the academic texts normally used in reading research as well as containing many scientific terminology which would be difficult for the respondents to process. Text E (*Innate Biological Clock and Photoperiod of Plants)* was also excluded from the study because the topic plant had already been chosen for the first text (Text B). The content experts identified Text F (*Biomaterials for Organ Generations*) as most appropriate for a second text (difficult/ less familiar). The reason was that the topic was different from the first text and the content was somewhat unfamiliar to the respondents. In addition, there was a description of a biochemical process of biomaterial degradation and tissue regeneration. This made Texts B and F shared a similar text organization.

For the third text, the content lecturers recommended Text G (*Hormones and Signal Transduction*). The topic was placed under ‘Special Topic’ in a biology reference book (Boyer, 2006) and deemed a very new biology topic for first year undergraduates, at the time of the study. This text was recommended because the topic on human biology was assumed to be an interesting reading to the respondents and a description of a biochemical process of hormones made it similar in text organization as texts B and F. Based on the feed back from the content experts, the researcher chose the following three texts to be used for the first pilot study:

a) Text B: *Auxins and Elongation of Cells*
(592 words; Flesch Reading Ease- 41.5; Passive construction – 20%).

b) Text F: *Biomaterials for Organ Regeneration*
(535 words; Flesch Reading Ease- 13.6; Passive construction – 50%).

c) Text G: *Hormones and Signal Transduction*
(744 words; Flesch Reading Ease- 25.7; Passive construction – 30%).

4.4.1.3 Piloting three selected scientific texts

The first pilot study was conducted with three focus groups comprising of ten first year science undergraduates from four different universities. The objective of the first pilot study was to gauge the difficulty level and topic familiarity of the three texts as perceived by the target sample. The findings of this study revealed that Text F (*Biomaterials for Organ Regeneration*) proved to be the most difficult text to read and comprehend. Therefore, the presentation sequence of the three scientific texts for the second pilot study was reordered as follows:

1) *Auxins and Elongation of Cells*: relabelled as Text A (appendix C1).
2) *Hormones and Signal Transduction*: relabelled as Text B (appendix C2).
3) *Biomaterials for Organ Regeneration*: relabelled as Text C (appendix C3).

For the second pilot study, all instruments for the main study were administered. When the study was conducted on one single day, it took the respondents nearly four hours to complete all the instruments, including reading the three scientific texts. The respondents were found very tired at the end of the survey. However, when the study was broken up into three different days for the three different texts, attendance for the second and third day was very poor. To solve the problem of mental fatigue and poor attendance, it was decided that only two scientific texts were used for the main study. Since text C (*Biomaterials for Organ Regeneration*) was found very difficult by most respondents in the two pilot studies, it was dropped from further use for the main study. Baker and Brown (1984) maintained that efficient learning entails active monitoring of one's own cognitive processes in a continuing effort to solve reading problems. Hence, it is crucial to choose texts of 'intermediate difficulty' because if the reading task is too easy, readers may not bother to strategize, yet if it is too difficult, they may give up (ibid). The two texts deemed of 'intermediate difficulty' level and appropriate for the target respondents were texts A and B above. In addition, to ensure good attendance during the main study, paid volunteers (Crain-Thorenson, Lippman, & McClendon-Magnuson., 1997; Davis & Bistodeau, 1993; Rupp, Ferne, & Choi, 2006) were engaged among the first year science undergraduates to participate in the study.

In sum, text A was syntactically less difficult than text B and the ratio of old to new information was 50:50 for first year biology majors. Text B was syntactically more difficult, less familiar and the old to new information ratio was 30:70. This ratio was determined based on the feedbacks received from three biology lecturers and 20 first year respondents who participated in the three pilot studies.

4.4.1 Reading comprehension assessments

Reading comprehension of each scientific text was measured using three different types of tests, (a) a written summary, (b) multiple choice questions, and (c) multiple true and false statements. Multiple choice questions (MCQ, hereafter) measured recall of facts and information while multiple true and false statements (MTF, hereafter) measured understanding of the scientific concepts. A written summary helped to distinguish good from poor readers as they had to write down the biochemical process described in each text as they had understood it. Discussion regarding the types of L2 reading comprehension assessment available and the choices made is presented in section 4.4.2.1.

Prior to answering the reading comprehension (RC, hereafter) questions, respondents were reminded to read each text for comprehension and were not allowed to refer to the text when answering the RC questions. The first RC assessment presented to the respondents after each reading activity was a written summary (appendix D1). They were required to write a short essay on the biochemical process mentioned in the text that they had just read. For text A, they had to write a biochemical process of *cell elongation* and for text B, the biochemical process of *signal transduction*. Respondents were allowed to write the composition in the national language, which is Malay, in their L1 if Malay was not their mother tongue, or in English or a mixture of all the two or three languages. Chang (2006) and Lee (1986b) claimed that the use of respondents' native language for recall or summary protocol could best reflect their true understanding of the L2 passage. Besides, summarizing requires the utilization of higher level skills of analyzing, evaluating, and synthesizing to comprehend the text (Riley & Lee, 1996). The full marks for each written summary were 30.

The second RC assessment consisted of two parts. The first part was on MCQ and the second part was on MTF statements. While respondents were required to circle only one correct or best answer in the four options given in the MCQ, all statements in each set of MTF must be identified. After reading the stem question or statement, respondents had to evaluate four to seven related statements that followed and identify each as true or false by circling the corresponding initial letter, T for True and F for False provided on the right-hand margin of the inventory (appendix D2).

RC for text A was made up of six MCQ and 30 MTF statements which gave a total of 36 marks. RC for text B was comprised of five MCQ and 28 MTF statements. The total marks for RC for text A (RCA, hereafter) were 66 and RC for text B (RCB, hereafter) were 63. Respondents' L2 reading comprehension for all data analysis procedures in this study was based on the total marks they obtained for RCA and RCB which were inclusive of scores for written summary, MCQ and MTF.

4.4.2.1 Rationale for choosing types of reading comprehension tests

Reading comprehension of L2 texts is commonly measured using a number of instruments such as multiple choice questions (Anderson, 1991; Bernhardt & Kamil, 1995; Carrell, 1989; Carrell, 1991; Javier, 1997; Lee & Schallert, 1997; Phakiti, 2003; Schoonen et al., 1998), verbal retellings (Block, 1986; Anderson, 1991), free written recall protocol (Barnett, 1989; Bernhardt, 1991; Brantmeier, 2005; Brisbois, 1995; Horiba, 1990; 1996; Kitajima, 1997; Taylor, 1985; Chang, 2006), written summary protocol (Riley & Lee, 1996), cloze text (Koda, 1993; Tan, 1984), short-answers questions (Koda, 1993), as well as True and False test items (Brantmeier, 2005).

For this study, cloze text was not considered for reading comprehension assessments of the two scientific texts because cloze text runs against the main objective of the study which was to determine the repertoire of strategies employed by science undergraduates while reading scientific texts. Furthermore, if cloze text were used, respondents would not only be employing reading strategies but also test-taking strategies (Anderson, 1991; Bernhardt, 1991). Finally, if the full passage of the scientific text were revealed to the respondents prior to the comprehension assessment in the form of a cloze text, the assessment would turn into a test of memory.

Thus, the assessment of reading comprehension must be valid, provide quantifiable data for large-scale comparison and contrast, and cater to the productive ability of L2 readers (Bernhardt, 1991) reading English scientific texts. For these reasons, different types of RC assessments such as multiple choice questions, free written recall protocol, written summary protocol, and true and false test formats were considered. Ultimately, the researcher had chosen written summary protocol, multiple choice questions, and multiple true and false test type (as opposed to simple true and false test type) as assessment measures of reading comprehension of scientific texts in this study.

4.4.2.2 Free recall protocol versus written summary protocol

Free written recall protocol is regarded as a 'purer' measure of comprehension (Bernhardt, 1991), yet it resembles a test of memory more than a test of comprehension (Bugel & Buunk, 1996; Chang, 2006). For Chinese students where rote learning is the norm and highly valued in Chinese education system, this type of test fails to discriminate between students who manage to memorize the text from those who actually comprehend the content (Sharp, 2004). Furthermore, free recall test focuses on details of text over main ideas and total number of units recalled as a measure of comprehension (Riley & Lee, 1996). However, recalling more details does not reflect what the students understood from the text but what he remembered. It also does not discriminate between recalled of gist of text from randomized details (ibid).

Written summary protocol to measure reading comprehension, on the other hand, meets the requirement of information processing theory of learning. It encourages students to attend to the thesis of the text as the major focus (Riley & Lee, 1996; Taylor, 1985), organize in a personal way and relate to the prior knowledge they already possess (Alderson & Hamp-Lyons, 1996). To do this, students need to go for global reading by delineating the main ideas of the texts and separate them from irrelevant details. Summarizing is also important at tertiary level as it requires students to utilize their higher level skills of analyzing, evaluating, and synthesizing to comprehend the text (Oded & Walters, 2001; Ponniah, 1993; Riley & Lee, 1996; Shih, 1992). Oded and Walters (2001) found that by writing summary of main points, learners were compelled to do extra processing of the text and thus would comprehend the text better. However, they believe that summary writing should be utilized as a learning instrument rather than a testing one.

A counter argument for using written summary protocol as a testing instrument was the issue of memory requirement similar to the free written recall protocol. A study by Chang (2006), although the researcher did not investigate written summary protocol, is relevant to be discussed as a case in point for the question of memory in a reading comprehension measure. Chang compared readers' performances on two types of reading comprehension measures, immediate written recall and translation in order to examine the effect of memory on readers' recall. The study showed that "the translation task yielded significantly more evidence of comprehension than did the immediate recall task" (p. 537). The respondents in this study demonstrated a high understanding of the two texts read as revealed by the translation task but this comprehension was not reflected in the score on their immediate recall protocols (ibid). This indicates that memory constraint hinders the exact recall of the text and what is not written in the recall protocol cannot be equated as lack of comprehension. Thus, the use of reading comprehension instruments such as free written recall protocol or written summary protocol which rely on memory requirement may not be able to accurately measure respondents' actual reading comprehension.

Nevertheless, the arguments for written summary protocol clearly outweighed those against it. A written summary as a test of comprehension can also be regarded as the floodgate that could help distinguish between good and poor ESL readers of the two scientific texts. Besides, the issue of memory versus comprehension raised by Chang (2006) and Sharp (2004) could be eliminated if respondents were allowed to use their native language for the summary protocol which, according to Lee (1986) and Chang (2006) could best reflect their true understanding of the L2 passage. For the reasons mentioned earlier, written summary protocol was adopted as a measure for RC in this study. To compensate for its shortcomings, if any, a second instrument was prepared which consisted of MCQ and MTF statements.

4.4.2.3 MC questions and MTF statements

Multiple choice questions (MCQ, hereafter) test is among the most convenient and popular method to be utilized in assessing readers' understanding of the text read. It is especially suitable in studies where the number of respondents is large. MCQ test type exhibits high reliability in terms of Cronbach's alpha coefficients. Frisbie (1973) found that MCQ was overwhelmingly more reliable than True-False statements. Dudley (2006) compared two test types, MCQ and multiple true and false (MTF, hereafter) by assessing learners' L2 vocabulary and reading comprehension and obtained very close results. He utilized two sets of questionnaire where each contained both MCQ and MTF tests to assess learners' English proficiency. For the first set of questionnaire, Cronbach's alphas were recorded at .90 for vocabulary test and .89 for reading comprehension for MCQ and alphas .92 and .89 for MTF. For the second set, Cronbach's alphas were recorded at .90 for vocabulary and .85 for reading comprehension tests for MCQ and alphas .93 and .90 for MTF.

Yet, items to be included in MCQ are very limited for scientific texts of 592 and 744 words in length. In addition, ten questions in MCQ with four options could only yield 10 marks (Dudley, 2006). They are also difficult to construct (Bernhardt, 1991) especially when it tries to assess scientific comprehension where prior knowledge and interrelatedness of the questions would come into questions.

MTF format is similar to MCQ with a difference. Instead of selecting only one best answer from several options provided as in MCQ, test takers in MTF must respond to each alternative by indicating if it is true or false in relation to the stem given (Dudley, 2006; Frisbie & Sweeney, 1982; Frisbie & Druva, 1986). MTF format allows for any number of alternatives and true and false response patterns (Kreiter & Frisbie, 1989).

The merits of MTF are numerous and well documented in the literature. Compared to MCQ, MTF format is able to yield more responses in a given time period (Hill & Woods, 1974). Ten questions on the MTF format can produce at least 40 responses (40 marks) which increase the validity and reliability of the test

(Frisbie & Sweeney, 1982; Kreiter & Frisbie, 1989). In a study to compare MTF and MCQ test formats, Hill and Woods (1974) found that in a given amount of time, the ratio of responses on MTF to MCQ is 2.32 to 1.00. Frisbie and Sweeney (1982) found a ratio of 3.44 to 1.00, while Kreiter and Frisbie (1989) obtained a ratio of 2.60 to 1.00. These findings clearly show that respondents can answer considerably more MTF items than MCQ items in the same given period.

In addition, the MTF format which elicits four responses or more per item enables inferences to be made about the test taker's knowledge and understanding about the content (Kreiter & Frisbie, 1989). MTF format requires equal thought and deliberation for each of the alternatives given. Therefore, test-taking strategies will be greatly reduced in MTF format (Kreiter & Frisbie, 1989) and thus reveal the extent of individual's understanding and knowledge of the content.

MTF tests have been repeatedly found to be equally or more reliable than MCQ tests. Most studies conducted to compare MTF and MCQ employed two sets of tests for each of the format. Frisbie and Sweeney (1973) found that the alpha reliabilities for MTF to be .81 and .84 to .65 and .71 for MCQ. Hill and Woods (1974) obtained internal reliability coefficients of .69 for MTF and .68 for MCQ test items. Similarly, Kreiter and Frisbie (1989) recorded MTF reliability alphas of .73 and .70 and MCQ alphas of .55 and .56. In conclusion, MTF test is an ideal test to assess reading comprehension of scientific texts. Not only it can be used to measure the recall of facts and information (Lackey, 2002), which is the lowest level in Bloom's taxonomy of test items, MTF can also be constructed to test higher order thinking skills (Legg, 1991) such as interpretive and problem solving skills. Therefore, the employment of MTF in this study was to assess not only respondent's recall of facts and information, but also reveal their full or partial knowledge (Albanese & Sabers, 1988) and understanding of the texts. In sum, besides written summary protocol, both MCQ and MTF test types were employed in this study to ensure that reading comprehension assessments were valid and highly reliable.

4.4.3 Metacognitive Awareness Inventory (MAI)

Metacognition is a measure of learners' ability to reflect, understand and control their learning (Koda, 2005; Flavell, 1979; Schraw & Dennison, 1994). Metacognitive awareness of first year ESL science undergraduates was assessed using Metacognitive Awareness Inventory (MAI, hereafter) developed by Schraw & Dennison (1994) (appendix E). MAI was chosen over other instruments because it taps into two-component model of metacognition, metacogntive knowledge and metacognitive regulation (Brown, 1987; Flavell, 1979; Schraw & Dennison, 1994). In addition, previous research (Baker & Brown, 1984; Schraw & Dennison, 1994) has found that metacognitively aware learners are also strategic learners who usually learn better than metacognitively unaware learners.

The first component of MAI is knowledge of cognition and it assesses what the learners know about their cognitive processes (declarative knowledge), the strategies and procedures that work best for them (procedural knowledge), and the conditions under which the cognitive strategies can effectively work (conditional knowledge). The second component is on regulation of cognition which focuses on the actual activities of planning that learners engage in to facilitate learning such as planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation. There are 52 items in the inventory with 17 items assessing knowledge about cognition and 35 items assessing regulation of cognition.

The first subscale under Knowledge of Cognition (Kcog) is declarative knowledge (DK) which refers to the factual knowledge that the learners may have about their own abilities and about important learning characteristics that eventually affect cognitive processes (McCormic, 2003). According to Schraw and Dennison, declarative knowledge is knowing *about*, knowing *what* and knowing *that.* Eight items under the subscale declarative knowledge in MAI are 5, 10, 12, 16, 17, 20, 32, and 46. The second is procedural knowledge (PK) which is the knowledge of *how* to execute the declarative knowledge such as learning strategies. Four items to assess procedural knowledge are 3, 14, 27, and 33. The third is conditional knowledge (CK) or the knowledge about *when* and *why* to use strategies and it is assessed through items 15, 18, 26, 29, and 35.

The component regulation of cognition (Rcog), on the other hand, assesses learners' control of learning in terms of planning, implementing strategies, monitoring, fixing comprehension errors, and evaluating learning progress. Planning (PC) focuses on learners' ability to plan strategies, set goal, and allocate resources before learning or reading. The seven items under this subscale are 4, 6, 8, 22, 23, 42, and 45. Information management strategies (OIC) sequence the processing of incoming information such as organizing, elaborating and summarizing. Ten items assessing this subscale are 9, 13, 30, 31, 37, 39, 41, 43, 47, and 48. Comprehension monitoring (MC) is the skill to assess the extent of one's learning, comprehension, or strategy use. Seven items measuring learners' comprehension monitoring skills are 1, 2, 11, 21, 28, 34, and 49. The final two subscales are debugging strategies (DSC-5 items), and evaluation (EC- 6 items). Debugging strategies are those used to correct comprehension or performance errors whereas evaluation analyzes performance and strategy effectiveness after a task. Items numbered 25, 40, 44, 51, and 52 measure DSC and 7, 19, 24, 36, 38, and 50 measure EC subscale.

MAI makes use of a 7- point Likert scale where 1 indicates "*Not true at all about* myself" and 7 indicates '*very true about* myself'. The average administration time of the inventory took about 15 minutes (Schraw & Dennison, 1994). Saemah (2004) did a back translation (Neuman, 2006) from English to Malay to English again of the original MAI. The researcher of the present study engaged two Malay language experts to proofread the Malay version of the MAI. Hence, the Malay version with the English translation of the inventory was administered to the respondents of this study.

4.4.4 *Scientific Prior Knowledge Inventory (SPKI)*

There were 80 true and false statements on the Scientific Prior Knowledge Inventory (SPKI, hereafter), with 50 false and 30 true statements (appendix F). Analysis of true-false item and test development rules (Frisbie & Becker, 1991, p. 71; Popham, 1981 cited in Frisbie & Becker) indicate that there should be more false than true statements in a single test. Please refer to section 4.4.4.1 for the discussion on the rationale for using the True and False test type.

The inventory was divided into two major parts based on the two scientific topics; *Auxins and Elongation of Cells* (text A), and *Hormones and Signal Transduction* (text B). There were 40 (15 true, 25 false) statements for the first topic, *auxin*. The first part of SPKI assessed respondents' knowledge on (a) plant hormones in general (1-4), (b) characteristics of auxins (5-25), the biochemical process of cell elongation (26-35), and scientific terminology found in text A (36-40). The second part of the inventory consisted of 40 (15 true, 25 false) statements which measured respondents' prior knowledge on (a) scientific terminology found in text B (41-49), (b) human hormones (50-56), (c) characteristics of human hormone (57-68), and (d) biochemical processes of signal transduction (69-80).

Respondents read each of the statements in the inventory and identified those which were true and false by circling the corresponding initial letter, (T for True and F for False) provided on the right-hand margin of the inventory. For statements identified as false, they were required to write down the correct answer in the blank space provided. This precaution was taken to reduce the inclination to guess. Respondents were also informed that the correct spelling for their answers was not compulsory as marks would not be deducted for spelling mistakes. Guessing answers was not encouraged, since correct or lucky guesses would not truly measure the actual prior knowledge possessed by the respondents. Thus, the choice DK (Don't Know) was provided as an alternative to True (T) and False (F) if respondents did not know or were unsure the answer.

4.4.4.1 Rationale for using True-False statements for SPKI

True and False (T/F, hereafter) test was chosen to assess respondents' prior knowledge of science for three reasons. First, T/F test permits testing over a large amount of information (Frisbie, 1973; Lackey, 2002; Mochida & Harrington, 2008) in a given time with a ratio of 1.5 to 1 when compared to multiple choice questions (Frisbie & Becker, 1991; Frisbie & Sweeney, 1983). Tan (1984) made used of both MCQ and T/F statements to gauge respondents' prior knowledge with each type carried 20 marks. Second, it is an ideal measure of scientific prior knowledge as this type of knowledge contains a lot of scientific terminology and biochemical processes which would be difficult to assess using other types of tests such as ranking (Hammadou, 1991) and simple notations (Crain-Thorenson, Lippman, & McClendon-Magnuson, 1997). Unlike other studies which compared prior knowledge of respondents from different academic disciplines (Alexander, Jetton, & Kulikowich., 1995; Alderson & Urquhart, 1988; Chen & Donin, 1997; Pritchard, 1991; Ozuru, Dempsey, & McNamara, 2009), this study looked into knowledge possessed by respondents who came from the very same field for relatively equivalent amount of time. Thus, a measure for scientific prior knowledge in this study must be very sensitive to very small difference in prior knowledge among the respondents. Third, T/F test is easy to construct as noted by Alderson (2000) that the ease of construction makes this test type a popular choice of testing.

Nevertheless, T/F testing is claimed to encourage 50% guessing of the right answer without actually understanding the text (Alderson, 2000; Hill & Woods, 1974; Venter, 2006; Wang, 1997) since there are only two options (True or False) to choose from. However, this percentage can be reduced to 33.3% by adding another option “Not Given”. Razi (2005) argues that the third option tends to test the ability of inferring meaning rather than comprehension.

Another alternative is to include the option “DK” for “Don’t Know”. Respondents can answer the test in one of the three ways; by choosing the correct response (T), by choosing the incorrect response (F), or by choosing the option “don’t know” (DK). The scale for reading comprehension of the text would be constructed by counting the number of correct responses given by each respondent. Thus, incorrect responses and “DK” for don’t know are assumed to indicate the same thing, which is lack of understanding or knowledge (Mondak and Davis, 2001). Caprini and Keeter (1993) claim that by encouraging DKs, the researcher is able to increase the reliability of knowledge scales. This is because, if those who answered DKs were instead to guess, reliability of the knowledge scale would decrease. Another benefit of “DK” is that it increases validity since correct answers do not stem from lucky guesses.

The potential of T/F test with the option “DK” for “Don’t Know” to assess knowledge was enormous and thus was chosen as a measure to assess respondent’s scientific prior knowledge for this study. Guessing in T/F test type to assess scientific prior knowledge would rapidly “diminish” as the test length increases

(Frisbie & Becker, 1991; Hopkins & Stanley, 1981, cited in Wang, 1997). Nunnally (1972; cited in Venter, 2006) recommended increasing the T/F items to more than 60 to eliminate error due to guessing. In addition, with a table of critical value of passing scores for True-False and MCQ tests constructed by Wang (1995; 1997), one can safely set a level of passing score higher than that which can be achieved through blind guessing.

4.4.5 Malaysian University English Language Test (MUET)

Respondents' general L2 proficiency in this study was measured using the result obtained by each respondent in the Malaysian University English Language Test (MUET, hereafter). MUET is a university entrance-level English test to be taken by all Malaysian students who wish to pursue a college degree in all public universities in Malaysia (Goh, 2004; Mohd Don, 2004). MUET is administered by Malaysian Examination Council and is developed to help universities evaluate students' reading, writing, listening and speaking proficiency in the English language. The full possible marks in MUET are 300. MUET reliably measures students' reading proficiency by virtue of its strong emphasis on reading comprehension and vocabulary, with 135 out of 300 marks are allocated on reading task alone while 45 marks each are for listening and speaking and 75 marks are for the writing task (Mohd Don, 2004).

There are six possible bands in MUET where band 6 (260-300 marks) shows excellent command of the four language skills or highly proficient user and band 1 (below 100 marks) indicates very poor proficiency or very limited user of the

English language. Obtaining the higher bands predicts the ease in the learners' ability to cope with the academic reading and writing tasks at the university while lower bands such as bands 1 and 2 indicate learners' need for remedial English classes to improve their English language proficiency. MUET is usually taken by students aged 19 years old and above. Candidates sitting for MUET are those planning to pursue a tertiary education in local universities upon completion of two years of pre university or two semesters of matriculation studies.

4.4.6 Scientific Texts Academic Reading Strategies Inventory (STARS Inventory)

The main focus of this study was to understand and identify respondents' cognitive and metacognitive strategies which mediated between independent variables (metacognitive awareness, scientific prior knowledge and L2 proficieny) and reading comprehension of scientific texts. These three independent variables were predicted to influence the types of strategies chosen by the readers while reading so that maximum comprehension was achieved (Koda, 2005; Carrell, 1989; Schraw & Dennison, 1994; Baker & Brown, 1984; Chen & Donin, 1997; Hammadou, 1991).

Reading strategies were assessed using an 80-item Scientific Text Academic Reading Strategy (STARS, hereafter) inventory. STARS inventory measures two types of reading strategies, namely, metacognitive strategies (28 items) and higher and lower cognitive strategies (52 items) (appendix G).

4.4.6.1 Items assessing metacognitive strategies

There are four categories under metacognitive strategies (MC, hereafter); MC planning (7 items), MC monitoring (9 items), MC evaluation (5 items), and MC debugging (7 items). Table 4.6 lists the item numbers for each type of MC strategies.

Table 4.6

Subscales and Item Numbers Assessing Metacognitive Strategies

	Item number in STARS Inventory
MC Planning	1, 14, 28, 44, 55, 62, 67
MC Monitoring	3, 13, 16, 25, 26, 41, 52, 68, 69
MC Evaluation	12, 31, 53, 58, 71
MC Debugging	27, 43, 54, 63, 66, 74, 76

Planning strategies are those focusing on the general or macro analysis of the text such as setting the purpose for reading, previewing the content of text, and predicting about the content. Monitoring strategies are steps employed to check comprehension progress such as adjusting reading speed and going back and forth in the text to find relationships among the ideas. Evaluating strategies are steps taken to assess the extend of one's performance in comprehending the ideas such as stopping from time to time to reflect and checking if guesses and predictions made during the reading were correct. Finally, debugging strategies are those aimed at correcting performance errors and solving local or text related comprehension problems when reading becomes difficult.

4.4.6.2 Items assessing higher and lower cognitive strategies

There are 28 statements to reflect a reader's higher cognitive (HC, hereafter) strategies and 22 items to assess lower cognitive (LC, hereafter) strategies. Table 4.7 lists the item numbers for each type of HC and LC strategies.

Table 4.7

Subscales and Item Numbers Assessing HC and LC strategies

Higher Cognitive (HC) Strategies	Item number in STARS Inventory	Lower Cognitive (LC) Strategies	Item number in STARS Inventory
Visualizing	10, 24, 42, 61, 79	Decoding words	15, 29, 45, 65, 70
Analyzing visual diagrams in text	4, 11, 39, 48	Translating	8, 20, 33
Analyzing text	23, 38	Questioning meaning of words	2, 75
Inferring language	6, 32	Paraphrasing	5, 72
Inferring content	7, 19, 21, 34, 36, 49	Memorizing and taking notes	30, 46, 57, 73, 77, 80
Accessing Prior knowledge	9, 22, 37, 51	Reading for local understanding	56, 59, 60, 64
Summarizing	18, 35, 78		
Questioning content	17, 40		

HC strategies include visualizing (5 items), analyzing visual diagram in text (4), analyzing text (2 items), inferencing linguistic items (2 items), inferencing content (6), accessing prior knowledge (4 items), summarizing (3 items), and questioning ideas/content (2 items). In contrast, lower cognitive (LC, hereafter) strategies are attempts made to understand specific linguistic units. There are 22 items under this category; decoding words (5 items), translating words, phrases or sentences (3 items), questioning meaning of words or phrases (2 items), paraphrasing sentences (2 items), memorizing and taking notes (6 items), and reading for local understanding which focuses on understanding each word/phrase in a sentence (4 items).

The inventory uses seven point Likert scale ranging from 1 (*not true at all about how I read just now*) to 7 (*very true about how I read just now)* and is presented in two languages, Malay and English. The average administration time took about 20 minutes.

4.5 Research instruments for qualitative data

4.5.1 Overview of qualitative data collection technique

Qualitiative research is about understanding people and their behaviours (Babbie, 2005). To obtain an in-depth understanding of an ESL reader's active use of cognitive and metacognitive strategies while reading scientific texts, the researcher had to get inside the reader's mind and understand her/his decisions and choices while s/he was reading. The extent of qualitative study for the purpose of this study was thus limited to the qualitative data collection techniques which were think aloud procedures and semi structured retrospective interviews.

Think aloud method provides information on the complex cognitive activities of the ESL readers as they verbally report their own mental processes and the actual strategies they are opting for at the exact time of reading (Afflerbach, 2000; Bereiter & Bird, 1985; Crain-Thorenson et al., 1997; Ericsson & Simon, 1980; Goh, 2004; Goh & Fatimah, 2006; Kern, 2000; Koda, 2005; Matsumoto, 1993; Mokhtari & Reichard, 2002; Olshavsky, 1977). This method is capable of tapping on those strategies utilized unconsciously during reading by readers and compensate for the shortcomings of survey type assessments (Anderson, 1991; Block, 1986; 1992; Crain-Thorenson et al., 1997; Kern, 1989; Oxford & Young, 1997). Thus, data from the concurrent think aloud method can be used to triangulate data findings on respondents' perceived reading strategies collected from the reading strategy inventory, such as the STARS inventory. Even though this method of data collection provides the researcher with readers' motivation and affect (Afflerbach, 2000), these characteristics were not the focus of the study but would be mentioned in passing whenever they were called for.

It is important to note that think aloud procedures or verbal reports depend on the ability of respondents to verbalize their thoughts in the language that they are most comfortable with (Afflerbach, 2000). Afflerbach adds that the gender differences and relationship between the respondents and researcher are significant influences on readers' verbalization and subsequently the data gathered.

Another method of data collection for the qualitative study is retrospective interview. The objective of the interview is to get more insights about the online verbal reports provided by the respondents (Bernhardt, 1991; Davis & Bistodeau, 1993). The interview focuses on identifying respondent's covert strategies which remain hidden even during think aloud procedures and determining reasons and conditions for utilizing certain strategies. However, the threats of retrospective data are present in two forms, long-term memory data and data biasness due to close interaction with the researcher. (Ericsson & Simon, 1980; Haastrup, 1987; Taylor & Dionne, 2000). These threats challenge the reliability of retrospective interview data and thus should be minimized. As precautionary steps, retrospective data to be gathered are on respondents' (i) covert strategies if any, (ii) reasons and conditions for strategy choices used during the reading tasks, (iii) judgement on topic familiarity, language difficulty and scientific terminology of the texts (appendix H). In addition, data from retrospective interview act as support data which can be used to clarify and interpret think aloud protocols (Davis & Bistodeau, 1993).

4.5.1.1 Think aloud training session

Ten respondents participated in the think aloud training sessions. The training sessions took place in a counselling laboratory where there was a round table and five chairs surrounding it. Three to four respondents were present in each training session and each group received three sessions of think aloud training prior to the actual think aloud procedure. In the first training session, the researcher explained the objectives of the study and procedure of the think aloud method. They were also told the length of time each training session and each think aloud procedure (TAP, hereafter) of the actual study would take. To motivate the respondents, they were told that they would be rewarded with some token of appreciation. Besides, they were given the opportunity to choose the date and time of the training session and think aloud procedure for the main study by placing a tick on a pre prepared schedule. Contact numbers were exchanged between respondents and the researcher so that rescheduling and difficulties in attending either the training sessions or the TAP would be handled efficiently.

When all respondents had agreed on the procedure and schedule of the TAP training and the main study, the training began with the researcher explaining the steps in the TAP (Please see appendix I for the TAP training script). Among the instructions given during the training were for the respondents to read the text aloud, to stop at the end of the sentence marked with a red dot, and to verbalize their thoughts aloud. Respondents were encouraged to think aloud in a language that they were most comfortable with and they could also code switch. It was observed that Malay respondents preferred to use Malay, Malaysian Chinese learners used either Malay or English or a mixture of both while Malaysian Indians preferred to think aloud in English. The researcher demonstrated how to think aloud for the first two paragraphs (Crain-Thorenson et al., 1997) of Practice Text 1 entitled *Innate Biological Clocks and Photoperiod of Plants* (appendix I2) and modelled some comments accordingly. The researcher modelled how to think aloud and read the first 4 sentences of the first paragraph in the practice text. During the modelling, the researcher purposely included *visualizing, questioning, repetition, translation, skipping words, expression of confusion, acknowledgement of comprehension,* and *predicting.* This was to ensure that respondents were exposed to a variety of comments. Respondents were then requested to try the third and fourth paragraphs on their own. They were also informed to verbalize their comments whenever they felt they needed to or upon reaching the red dot. Practice texts 2 and 3 were used for the next two training sessions.

4.5.1.2 Think aloud procedure & semi structured retrospective interview

A total of five respondents completed the actual TAP 1 for text A and TAP 2 for text B for the main study. Data were collected using digital voice recorder as well as a video recorder. The TAP procedures were conducted in an air-conditioned counselling laboratory. The respondents read each of the scientific texts aloud and verbally reported their mental activity and strategies they utilized during the reading task. Their reading and verbal reporting were recorded using a digital recorder. Their facial expressions, gestures, and other body movements were captured on a video recorder. When the respondents were satisfied with the reading and their comprehension of the text, the researcher took about five minutes to administer a buffer task. This was done to avoid memorized facts and details of the text from interferring with the assessment of the respondents' true comprehension and understanding of the content (Alexander, Jetton, & Kulikowich, 1995; Linderholm & van den Broek, 2002; Pritchard, 1990; Sharp, 2004).

Semi-structured retrospective interview was carried out after the TAP procedure to enquire from the respondents about their verbal reports in their protocols (Bernhardt, 1991; Davis & Bistodeau, 1993). Prepared questions as well as probing questions were posed to each respondent. These questions focused on respondents' choice of strategies, focus of attention during reading, differences in processing text and visual diagrams, obstacles encountered, and ways to overcome reading problems when reading academic scientific texts. Besides, respondents were asked to clarify any comments they made during the TAP session which were not readily obvious to the researcher. Queries also concerned the use of certain strategies over others (Kern, 2000; 2005; Koda, 2005). The data from the interviews were used to clarify and interpret the Think Aloud Protocol (Davis & Bistodeau, 1993). The think aloud and interview protocols were later transcribed, coded and analyzed.

4.6 Research procedures and administration of tests

Data were collected from respondents studying in Universiti Malaysia Terengganu, University of Malaya, Universiti Kebangsaan Malaysia, and Universiti Sains Malaysia over the course of three months from March to May 2008. The schedule for quantitative and qualitative data collection were pre arranged a month ahead of time to ensure a systematic, efficient and productive data collection. Letters of permission were sent to the Dean of the Faculty of Science of each university (appendix J). Face to face meetings were made between the researcher and every Head of Biology Departments and their respective Biology lecturers. Depending on the Faculty of Science in each university, meetings between the researcher and the respondents were either made by the researcher or by the lecturers themselves. Meetings fixed by the researcher were usually on weekends or in respondents' free time while those made by the lecturers were during tutorials or laboratory hours. The deans and heads of Biology department requested that the study be conducted in only one session even though they were informed that the study would take about two an half to three hours to complete.

4.6.1 Quantitative data collection

In this phase of data collection, a classroom or lecture hall which could accommodate 40 to 50 respondents was chosen as the venue of the study. Thirty minutes before the start of the study, the researcher and her assistant would place a folder containing all the instruments and three blank A4 papers (if respondents wished to scribble notes) on each table. Also placed on the table were a small white envelope containing stationery (pencil, eraser, sharperner, plus a token of appreciation worth RM10), a bottle of mineral water, and a packet of snacks (biscuits and chocolates). As respondents came to the classroom for the survey research, they were requested to sit where there were a folder and other items on the table. Most respondents did not come together and start the survey at the same time. Thus, to ensure that the researcher did not waste respondents' time by waiting for the classroom or lecture hall to be filled by other respondents, the researcher and her assistant would explain the details of the procedure to each respondent individually. The explanation to each respondent is summarized below.

They were told that:

1. the folder contained 11 instruments (SPKI, MAI, demographic information, Text A, STARS inventory for Text A, Written Summary A,

MCQ and MTF for text A, Text B, STARS inventory for Text B, Written Summary B, MCQ and MTF for text B).

2. they should complete each instrument in the order given and once they had finished, they could not go back to the previously completed instrument.

3. they should read the text to understand as they would read any important texts for their biology and academic courses at the university.

4. they were encouraged to take as much time as they needed to understand the text and they were allowed to use the blank A4 paper for whatever use during the reading process.

5. they would be answering comprehension questions on the text after that and could not refer to the text or the used A4 paper while answering the reading comprehension questions.

6. they should not discuss the text or other instruments with friends during the study.

7. they could eat and drink the refreshment provided at any time during the study and request for more (water and chocolates) if they wanted to.

8. they should stop to rest and stretch after answering the MCQ and MTF on text A and come back in 10 minutes to complete the remaining instruments.

9. they were provided with stationery together with a RM10 note for their use.

10. they were reminded to relax throughout the whole duration of the survey and not to copy others as marks they obtained in the study would not affect their final grade for the biology or other academic courses.

4.6.2 Rationale for the Order of Research Instruments

As noted in point number one above, the research instruments were purposely ordered in a pre determined sequence and this was done for several reasons. First, SPKI or scientific prior knowledge inventory was placed at the very beginning and was far separated from text A, the first reading text. The long interval between SPKI and the first scientific text was aimed at reducing the effect of memory after reading the True/False statements in SPKI on the reading text A. The distance placed between these two instruments was also hoped to eliminate respondents' inclination to go back and change their responses in SPKI after noticing the correct answer from the text.

Second, STARS inventory A was placed in between Text A and written summary A. This means that respondents had to answer STARS inventory right after reading a scientific text. The purpose was to ensure that the retrospective report on strategies used while reading the text was done when the reading process undertaken was still fresh in the respondent's mind. Another reason for administering STARS inventory before reading comprehension assessment was to act as a buffer task (Linderholm & van den Broek, 2002; Pritchard, 1990), a distraction task (Sharp, 2004), or an intervening task (Alexander, Jetton, & Kulikowich, 1995). Pritchard and Sharp required their respondents to complete a questionnaire about their reading attitude and extracurricular activities while Alexander et al. had the respondents solve a mathematical problem. The objective was primarily to control for any effects of short-term memory.

Third, the two parts of reading comprehension assessment of texts A and B were written in two separate research instruments. In addition, written summary came before MCQ and MTF. This sequence was done as such to ensure that the information in the form of statements in MCQ and MTF would not influence respondent's answers on the written summary. Furthermore, respondents were reminded not to go back and work on any of the research instruments once they had started on the next instrument.

Fourth, even though texts A and B were on *Elongation of Cells* and *Hormones and Signal Transduction* respectively as described in section 4.4.1.3 in this chapter, the order was reversed for 50% of the respondents. This means that from the total of 372 respondents who participated in this study, 186 read *Elongation of Cells* as text A and *Hormones and Signal Transduction* as text B. The other half or 186 more respondents read *Hormones and Signal Transduction* as text A and *Elongation of Cells* as text B. The placement of texts A and B was switched to avoid the reading effect of always being the first text (received more attention as the respondents were still fresh) or always being the second text (when the respondents were already tired and experience mental fatigue). Thus, both texts had equal chance of being the first and the second texts read by respondents in this study.

4.6.3 Qualitative Data Collection

The qualitative data collection focused on respondents' reading processes and thinking aloud of the two scientific texts which was then followed by a semi structured retrospective interview. This phase was carried out on two different days with an interval of at least one week between the first and the second TAP session. Each TAP and retrospective interview session lasted for about three hours.

The researcher met each respondent individually for the TAP session according to an agreed schedule. In each session, the respondent would meet the researcher outside the counselling laboratory. The laboratory was equipped with a table and two chairs, air conditioner, and video camera. As it was for the quantitative study, each respondent for the qualitative study was provided with stationery and also refreshment to be taken at anytime during the study.

Small talk between the researcher and respondent opened the TAP session to ensure that the respondent was relax and comfortable. The sequence of the research instruments was relatively similar to the quantitative study with two exceptions. Each qualitative respondent was given the Scientific Prior Knowledge inventory to be answered first followed by a short reading text (appendix P1) for the respondents to practice think aloud for ten minutes. After that, s/he was given the actual scientific text to read for comprehension as well as to be read aloud. Following that, the instrument demographic questionnaire was administered and it acted as a buffer between reading the first scientific text (A) and answering the reading comprehension questions (written summary and MCQ-MTF) of text A. Once the respondent had completed the reading comprehension assessment, the researcher began the retrospective interview. When the respondent came for the second think aloud session on a different day, s/he was given the second practice text (appendix P2) to practise think aloud for ten minutes. After the respondent had read the second scientific text, s/he was given the instrument MAI which acted as the buffer between reading the second text (B) and answering the reading comprehension questions on text B. Retrospective interview began as soon as the respondent had completed the comprehension assessment and was ready. Please see appendix P3 for texts A and B used for the TAP sessions. For both think aloud sessions, STARS inventory was not administered as the TAP itself would be providing the researcher with the data on reading strategy use. The actual TAP and interview sessions were digitally taped and video recorded. The researcher did not sit directly in front of each respondent during the TAP session for fear that this act would intimidate and cause anxiety to him/ her to express himself/ herself (Crain-Thorenson et al, 1997).

4.7 Pilot study

The aim of the pilot study was to determine the clarity and measure the reliability of the research instruments prepared by the researcher to study ESL students' cognitive and metacognitive strategies while reading two scientific texts. In addition, the pilot study was essentially a trial run to determine the amount of time taken by the respondents to complete the whole research procedure. Ambiguities in the inventories discovered by the respondents during the pilot study and the reliability index obtained during data analyses were used as the basis for further improvements.

4.7.1 Quantitative study

The sample population was first year undergraduates enrolled in Bachelor of Science degree programmes in Marine Science and Marine Biology in Universiti Malaysia Terengganu, Kuala Terengganu. Data were collected on the second week of the July semester 2007. Contact with the respondents was made through the lecturers teaching both groups of undergraduates. The form entitled *Kajian Pencapaian Akademik Pelajar Sains Sesi 2007/2008* to survey the academic achievement of science undergraduate for the enrolment of 2007/2008 was distributed to be filled by the respondents. Upon completion, fifty respondents were selected to participate in the pilot study based on three criteria; (1) English language proficiency as indicated by the band obtained in the Malaysian University English Language Test (high and low proficiency), academic achievement as shown by their matriculation or STPM cumulative grade point average (high and low), and having taken a biology paper during matriculation or for STPM. The fifty selected respondents were provided with background information of the study and everyone agreed to participate.

4.7.1.1 Reliabilily and validity of research instruments

(a) Reading comprehension assessments of texts A (RCA) and B (RCB)

Reading comprehension of texts A and B was assessed using MCQ and MTF statements and written summary which were developed by the researcher based on the two scientific texts. All MCQ and MTF statements were checked for validity and accuracy by four content experts, two from the faculty of science at the University of Malaya and two foreign experts from University of London and San Diego State University who edited the instruments through email correspondence (Appendix L). All the content experts had Ph.D qualifications and were the experts on both topics. The instruction and mark scheme for the written summary of each text were constructed and prepared by the researcher before they were checked and revised by two content experts (see appendix D2 and D4). Two raters who had a Master's degree in related areas and were lecturers in a public university in Malaysia scored the summaries independent of each other. Inter-rater reliability of written summary for text A (WSA) was .972 and written summary of text B (WSB) was .986.

The composite mark for MCQ, MTF and WSA which made up RCA was 68. The reliability of RCA was .698. The composite mark for MCQ, MTF and WSB which made up RCB was 66 and the reliability was .709. Both instruments demonstrated adequate internal consistency (Lee, Lim & Grabowski, 2009). In addition, Worthen et al. (1999) notes that the Cronbach's alpha as low as .50 is acceptable if the tests are used to make a decision about the group.

(b) Metacognitive Awareness Inventory (MAI)

Reliability of an instrument refers to the internal consistency of the items that make up a construct. Having internal consistency among the items means they have the tendency to correlate to one another. High internal consistency also shows the stability of scores of the construct. To establish the internal consistency of items in this inventory, coefficient alpha was used. Hair, Anderson, Tathan, & Black (1998, p. 118) maintain that Cronbach's alpha values above .70 are considered 'acceptable' reliability, above .80 'good' reliability, and above .90 to have 'excellent' reliability. Sekaran (1992), on the other hand, argues that Cronbach's alphas in the range of above .60 and .80 are acceptable while those above .80 are good.

MAI has been tested for its reliability and validity by the developers (Schraw & Dennison, 1994) as well as by other researchers using the inventory (Coutinho, 2007; Coutinho & Neuman, 2008; Magno, 2008; Saemah, 2004; Young & Fry, 2008). The reliability alpha indicated acceptable internal consistency with the Cronbach's alpha exceeded 0.5. The Cronbach's alphas for the components knowledge about cognition (Kcog), regulation of cognition (Rcog) and the overall MAI were 0.93, 0.88 and 0.95 (Schraw and Dennison, 1994).

MAI was piloted twice (N=40 and N=79) on first year ESL science undergraduates and reliability tests recorded a high internal consistency of Cronbach's $\alpha=0.88$ for the Kcog, $\alpha=0.92$ for Rcog, and $\alpha=0.95$ for the overall inventory. The main study (N=372) recorded Cronbach's α= .89 for Kcog, α= .93 for Rcog, and α= .96 for the overall MAI.

The validity of an instrument refers to the degree to which it measures what it claims to measure. The first step to ascertain of MAI's validity is to check if the composite variable represents a single underlying factor. If the items correlate to its composite variable (items to total) with *r* greater than .50, the items are homogeneous. In addition, each item should also correlate to other items within the single factor at *r* greater than .30 (Hair, Anderson, Tatham, & Black, 1998; 2006). The second step is to perform a Principle Component Analysis (PCA). This procedure should extract only one underlying component with eigenvalues greater than 1.0. The correlation values from PCA are called factor loadings. Hair et. al (1998, p. 111) suggest that for items to be useful and the construct to have validity, the absolute value of their component loading should be greater than .50. In contrast to Hair et. al, Tabachnick and Fidell (2007, p. 649), citing other researchers, write that loadings of .71 and above are excellent (suggesting 50% overlapping variance), .63 to be very good (40% overlapping variance), .55 good (30% overlapping variance), .45 fair (20% overlapping variance), and .32 poor as it suggests only 10% overlapping variance. Table 1 (appendix M) lists the loading factors for each item in MAI. Following Tabachnick & Fidell (2007), the loadings of all 52 items in MAI ranged from fair to excellent and thus were deemed acceptable for use in the main study.

(c) Scientific Prior Knowledge Inventory (SPKI)

Scientific prior knowledge inventory of first year ESL science undergraduates in this study was developed based on three selected topics in biology, as discussed under sub topic *Piloting Three Selected Scientific Texts* (see section 4.4.1.3). The initial three texts chosen by the content experts were labelled Text A (*Auxins and Elongation of cells*), Text B (*Biomaterials and Organ Regeneration*), and Text C (*Hormones and Signal Transduction*). To gauge respondents' prior knowledge on the three selected scientific texts, three focus group interviews were held with ten first year ESL undergraduates on three different days.

Three steps were taken in assessing respondents' scientific prior knowledge on the three topics. First, respondents were instructed to read the title of the text and write down everything they knew about the topic on a blank paper provided (Crain-Thorenson, Lippman, & McClendon Magnuson, 1997, p. 581). Second, a pilot scientific prior knowledge inventory (pilot SPKI) of 77 True and False statements on three topics was administered to each respondent. The pilot SPKI was subjected to scrutiny by four content experts, two each in University of Malaya and University Malaysia Terengganu. The first two steps in gauging respondents' prior knowledge were done before they began reading each of the three scientific texts. Third, three group interviews were held to gauge the prior knowledge that each ESL reader brought to the reading process and to identify which information were new and old knowledge in each text. Respondents were also requested to elucidate the researcher on the diagrams and the prior knowledge associated with each figure. All conversations were recorded on a digital recorder for transcription. The same routine was repeated for the next two texts with all the focus groups.

Based on the information gleaned from the three steps in assessing scientific prior knowledge possessed by the target sample above as well as advice received from four content experts, the researcher dropped 18 items from the piloted SPKI, rephrased 9 items, and added 21 new items. SPKI on the three biology topics was piloted twice (N=40; N=79) on first year ESL science undergraduates to test for internal consistency which yielded Cronbach's α= .71 for the overall Scientific Prior Knowledge Inventory. Following the use of only two scientific texts instead of three (see section 4.4.1.3) for the main study, items in the SPKI which assessed the third topic *(Biomaterials for Organ Regeneration)*were dropped from the final SPKI. The Cronbach's alpha of SPKI on the two biology topics used for the main study was recorded at .73, which was at a satisfactory level (Hair et al, 1998).

(d) Malaysian University English Test (MUET)

MUET is deemed a reliable English language proficiency test for Malaysian students at post-secondary level as it is a standardized examination administered by the Malaysian Examination Council. All public universities in Malaysia require MUET result to process admission applications from local students (David, 2004; Imran Ho, 2001) and use the MUET band to place first year undergraduates into their respective English courses (Mohd Noor, 2004). Local researchers (Goh, 2004; Imran Ho, 2001; Mohd Don, 2004; Nik Suriana, 2001) have always used MUET bands as an indicator of English language proficiency among their subjects at tertiary level.

(e) STARS Inventory

STARS inventory was modelled after Motivated Strategies for Learning Questionnaire or MSLQ (Pintrich, Smith, Garcia, & McKeachie, 1991) and thus it adheres to the seven point Likert scale used in MSLQ. In addition, a seven point scale was used to facilitate respondents' point of reference which was kept consistent to Metacognitive Awareness Inventory (Schraw & Dennison, 1994) used in this study.

STARS inventory is comprised of items adopted and adapted from MSLQ (ibid), MARSI (Mokhtari & Reichard, 2002), SORS (Sheorey & Mokhtari, 2001), Pritchard's reading processing strategies (Pritchard, 1990), Block's comprehension strategies (1986), Carrell's metacognitive questionnaire (Carrell, 1989), and science reading strategies (DiGisi & Yore, 1992; Koch, 2001; Anderson & Nashon, 2006; Lowe, 1989; Draper, 1997). The researcher also included a few items on strategies used by respondents based on their think aloud protocols from the pilot study. See Table 4.8 for details.

Table 4.8

Source of Items for STARS Inventory

Source of item for STARS inventory	Item number in STARS	No of items
MARSI (Mokhtari & Reichard, 2002) & SORS (Sheorey & Mokhtari, 2001)	5, 6, 7, **12**, 13, 14, **18**, **21**, 23, **24**, **25**, 27, 38, **43**, 44, 46, 51, 53, 54, **56**, **58**, 61, 66, **67**, 68, 69, 71, **72**, 73, **80**	30
Pritchard's reading processing strategies (Pritchard, 1990)	8, **9**, **10**, 16, 20, **21**, **22**, **24**, **25**, **29**, 32, **43**, 56, **57**, 65, **72**	16
Block's comprehension strategies (Block, 1986)	**1,** 2, 3, **12**, 15, 19, **21**, **29**, 34, 36, 37, 45, 49, **50**, 62, 75	16
Carrell 's metacognitive questionnaire (Carrell, 1989)	**9**, **22**, **26**, 41, 47, 63, 64, 70, 76	9
MSLQ (Pintrich et. al, 1991)	17, **18**, **31**, 30, **35**, **50**, **56**, **58**, **67**, 74, **79**	11
Science education (DiGisi & Yore, 1992; Koch, 2001; Anderson & Nashon, 2006; Lowe, 1989; Draper, 1997)	**1**, 4, **10**, 11, **22**, 28, 39, 42, 48, 52, 55, 57, 59, 60, **64, 79, 80**	17
TAP from pilot study	**12**, **18, 31**, 33, **35**, 40, **55**, 77, 78, **79**, **80**	11

As indicated in Table 4.8, STARS inventory consists of items adapted and adopted from numerous reading strategy inventories that examined respondents with varying L2 proficiency. The compilation was purposely and meticulously done to ensure that all possible strategies were included in the STARS inventory. Closer inspection of the items in Table 4.8 above reveals that some items (in bold) came from multiple sources. This means that certain strategies are so common among and frequently used by L2 readers while other strategies were unique but successfully tapped by the said researchers.

All items selected for the STARS inventory were written in English as were their original inventories. To produce a Malay version of STARS inventory, the items in English underwent a *back translation* (Neuman, 2006, p. 445) where the researcher translated them into Malay language before another ESL lecturer translated them back into English (appendix N). Whenever disagreements in translation occurred, conflicts were resolved through discussions. The instrument was checked by biology content experts before it was subjected to the scrutiny of twenty first year science undergraduates during a pre piloting stage. Both content experts and 20 volunteers read each of the 80 statements of the instrument and marked items that were confusing, unclear or redundant. A revision was made on problematic items before the final draft of the inventory was checked and evaluated by two Malay language experts (appendix O). Corrections on the language structure of the Malay version were done based on the feedback given by the two Malay language evaluators.

The inventory was piloted twice on first year ESL science undergraduates (N= 40; N=79) to ensure its internal reliability as well as predictive validity. The reliability of the STARS inventory was recorded at Cronbach's alpha 0.974. According to Neuman (2006), reliability means dependability and consistency. Therefore, instrument that yield high reliability alpha such as the STARS Inventory suggests that it has measured the construct accurately (Best & Kahn, 2003). To determine the validity of the items in STARS inventory, Principal Components Analysis (PCA) was performed. Table 2 (appendix M) lists the loading factor for each item in STARS inventory. All items have loadings greater than .50 except for LCD2 (.458). Tabachnick and Fidell (2007) write that a loading of .45 is considered fair and the item is interpreted as having 20% overlapping variance. Thus, item LCD2 remained in the inventory.

4.7.2 Qualitative study

To pilot the qualitative study, six respondents were chosen from those who enrolled in Marine Science and Marine Biology degree programmes. These respondents were chosen based on their MUET results, GPA obtained in Semester 1 and biology grades which the researcher obtained from the form described in section 4.7.1 above (p. 151). They were briefed on the objectives of the study and the research procedures which they needed to go through if they agreed to participate. Scheduled think aloud training sessions and pilot think aloud procedures were discussed and fixed.

4.7.2.1 Think aloud training session, think aloud procedure and semi structured retrospective interviews

Before the pilot training session, the researcher took a month to familiarize herself with the think aloud procedure. In order to make her practice natural and authentic, journal articles became the texts for the think aloud practice. Comments made while reading the articles were recorded and noted down for the use in the training sessions with the respondents. Three long scientific texts were chosen as practice texts for the training session which the researcher had ample practice before the start of the pilot study.

Pilot training session and pilot think aloud procedure were conducted on six respondents before both training session and think aloud procedure were carried out for the main study on ten respondents. Among the objectives of the pilot training session were to try out the steps and approaches in training ESL readers to think aloud, to look for shortcomings in the training and TAP procedures so that problems could be remedied before the main study begins, and to inform the researcher on the technical preparations as well as her role as the main instrument for qualitative data collection technique.

A few methodological concerns surfaced during the pilot training session. The first concern was regarding the number of respondents in each training session. It was found that respondents worked best and understood the think aloud procedure better when they were trained in a group. Individual training of think aloud procedure tended to make the respondents restless and at times bored. When questioned about their restlessness, they confided that they felt like learning to read the first time and disliked the feeling. When trained in a group of three, they felt more relaxed as the focus was not on each individual reader alone and they learnt how to read and thought aloud from other members in the group. The second concern was on the red dots placed at the end of two or three sentences (Crain-Thorenson et al, 1997, Pang, 2006). At times, respondents failed to notice the red diamond and continued reading without stopping to report their thinking. The third concern was about the silence period while reading the texts. It was found that respondents tended to answer 'I don't know' when prompted after a long silence. Pang (2006) noted that the silence period was when readers were struggling to comprehend the text and prompts from the researcher may interrupt the respondents' train of thoughts and the comprehension process.

All methodological concerns were considered and modifications were made. Three to four respondents formed a group for each think aloud training session for the main study. Each session lasted about two hours. There were three training sessions for three consecutive weeks prior to the data collection and a think aloud practice of 15 minutes took place every time before the respondents began reading the actual text. A red diamond used as a mark to prompt verbal reporting of the current thinking process during the pilot study was deemed too small and thus replaced by a stop symbol (⊖) (appendix P).

4.7.2.2 Pilot think aloud procedure & semi structured retrospective interview

Only three respondents completed all the pilot think aloud procedure (TAP, hereafter) sessions while the other three respondents pulled out in the last minute. Each respondent came for the TAP session individually and according to an agreed schedule. The TAP took place in a language laboratory. The video camera to record the TAP and interview sessions had to be installed by the laboratory technician. The TAP session began with each respondent completing the SPKI, demographic questionnaire, and MAI. Upon completion of all the three instruments, s/he was asked to read the first text aloud. A digital recorder was placed on the respondent's table. When s/he had finished reading, the first part of the retrospective interview questions was posed to act as a buffer between reading the text and completing the reading comprehension questions (Alexander, Jetton, & Kulikowich, 1995; Linderholm & van den Broek, 2002; Pritchard, 1990; Sharp, 2004). After ten minutes the interview was stopped to give way to the reading comprehension questions. The retrospective interview was resumed after the respondents had completed the comprehension questions. Interview questions focused on the difficulties encountered by the respondents while reading the scientific text, reading strategies used to solve comprehension problems, and the reasons for the choices in strategy use.

A few problems were immediately detected in administering the qualitative study during the pilot study. First, the language laboratory was not an ideal place since the video camera had to be installed and checked by the technician. Sometimes, the video had stopped running even before the TAP session ended. Thus, the researcher failed to obtain a video data on the last few minutes of the session. Second, conducting a retrospective interview as a buffer as mentioned above was a little chaotic. This was because, the discussion had to be stopped to give way to reading comprehension assessments before it was resumed later. Third, some questions asked during the interview needed to be rephrased and more questions to probe vocabulary and sentence difficulties had to be prepared and posed.

4.8 Procedures of data analyses

In order to fulfil the research objectives and answer the research questions posed in the study, the data were thoroughly analyzed to explain the types of strategies employed by first year science undergraduates when reading scientific texts in their second language. However, before any analysis on quantitative data could be carried out, the data file had to be screened for missing data and univariate and multivariate outliers as well as assessed for normality. As the study yielded both quantitative and qualitative data, the first were subjected to descriptive and inferential statistical analyses while the latter qualitative data analyses.

4.8.1 Screening of data and assessing normality

4.8.1.1 Identifying missing data

Missing data analyses were conducted on all variables pertinent to the outcomes of the data analyses. Univariate statistics and EM correlations revealed that all missing data were either characterized as MCAR (missing completely at random) or MAR (missing at random). According to Tabachnick & Fidell (2007), the two categories of missing data are ignorable and thus the deletion of cases with missing data is left to the default option in the SPSS programme.

4.8.1.2 Determining univariate and multivariate outliers

In an attempt to identify univariate outliers for the variables Metacognitive Awareness (MAI, hereafter), Scientific Text Reading Strategies for text A (STARS A), and Scientific Text Reading Strategies for text B (STARS B), histogram and box-plots were visually inspected and their standardized z-scores were calculated for each respondent. This analysis identified one potential outlier for MAI (case 60) and one for STARS A (case 133) and none for STARS B. Each of these respondents displayed standardized z-scores with an absolute value in excess of 3.29 ($p<.001$).

The presence of multivariate outliers was identified by calculating the Mahalanobis distance for each case (Tabachnick & Fidell, 2007, p.73). According to Tabachnick & Fidell, the Mahalanobis distance should be interpreted as a χ^2 statistics with the degree of freedom equal to the number of independent variables. Both the authors recommended that a criterion of $p < .001$ be used to evaluate whether a case is judged to be a multivariate outlier (p. 99). Table 4.9 displays the Mahalanobis distance that is greater than the value of χ^2 for each respondent for 33 variables.

Table 4.9

Multivariate Outliers Based on Mahalanobis Distance across 33 Independent Variables

	Scientific Text A	Scientific Text B
df 33	*p*= .001	*p*= .001
χ^2 value	59.703	59.703
Multivariate outliers identified based on Mahalanobis distance scores	16, 17, 60, 77, 79, 111, 115, 132, 149, 168, 169, 172, 174, 183, 235, 254, 269, 272, 279, 324, 343, 345.	17, 27, 32,33, 79, 128, 132, 139, 166, 169, 172, 174, 175, 183, 184, 235, 254, 256, 265, 272, 279, 323, 345
Total	22	23

Table 4.9 displays the multivariate outliers identified based on the Mahalanobis distance scores of 33 independent variables involved in the reading comprehension of the two scientific texts. The 33 independent variables were (i) the composite of MAI, (ii) eight subscales of MAI, (iii) SPK (scientific prior knowledge), (iv) L2 (English language proficiency), (v) the composites of MC (metacognitive strategies), (vi) HC (higher cognitive strategies) and (vii) LC (lower cognitive strategies), (viii) and 19 different strategies.

While the data on the independent variables MAI and L2 proficiency based on MUET were collected only once and should be the same when analysis was conducted on both texts, the 19 different reading strategies utilized by the respondents were likely to vary from one scientific text to the other. In addition, scientific prior knowledge as independent variable for texts A and B also differed. Thus, to determine the multivariate outliers that existed in the two reading situations, the Mahalanobis distance scores for each had to be calculated separately. It was found that in the reading of scientific texts A and B, 22 and 23 multivariate outliers were identified respectively. These outliers were deleted accordingly with respect to the specific analysis that was being conducted. In addition, four more cases had to be deleted due to incomplete information which was crucial to data analysis as shown in Table 4.10.

Table 4.10

Cases Deleted for Incomplete Information

Incomplete data on:	Cases
Marks for Written Summary for two Reading Comprehension assessment	37, 71,72, 91,

Of the 372 respondents who participated in the study, 36 cases were removed leaving a total of 336 respondents for data analyses.

4.8.1.3 Assessing normality

Normality of independent variables MAI (metacognitive awareness), aMC, aHC, aLC (strategies used in reading scientific text A), bMC, bHC, and bLC (strategies used in reading scientific text B) in this study was assessed using graphical methods (skewness and kurtosis) and statistical test (Kolmogorov-Smirnov statistic for sample size more than 100). Graphical method revealed that the distributions of all of the above variables were negatively skewed while each kurtosis was normal except for bLC. To test if the skew of the distribution significantly deviated from that of a normal distribution, the value of a skew was divided by the standard error of the skew. This yielded a z-score for the skewness of each variable. Table 4.11 summarizes the results of z-scores of skewness and kurtosis for each variable.

Table 4.11

The Results of Skewness, Kurtosis and z-Scores of 7 Independent Variables

				Skewness			Kurtosis		
	N	M	S.D	Statistic	S. E	z-score	Statistic	S.E	z-score
MAI	370	4.94	.739	-.296	.127	2.33	.463	.253	-
aMC	372	4.60	.908	-.178	.126	1.41	.326	.252	-
aHC	372	4.47	.873	-.091	.126	.722	.227	.252	-
aLC	372	4.57	.936	-.270	.126	2.14	.096	.252	-
bMC	372	4.60	.899	-.089	.126	.706	.210	.252	-
bHC	372	4.44	.895	-.155	.126	1.23	.028	.252	-
bLC	372	4.54	.914	-.163	.126	1.29	-.176	.252	.698

In this case, the z-scores for skewness did not exceed an absolute value of 3.29 (*p*<.001) which were then interpreted to be not significantly different to those of a normal distribution (Tabachnick & Fidell, 2007; p. 96). A similar procedure was conducted for the kurtosis of variable bLC where the value of the kurtosis (-.176) was divided by the standard error of the kurtosis (.252). The z-score (.698) did not exceed the absolute value of 3.29 (*p*>.001) which suggests that the negative kurtosis was not significant. The Kolmogorov-Smirnov statistics test of normality indicated that each of the independent variables displays a significance level of .200, which is greater than .05. Thus, normality is assumed.

4.8.2 Descriptive and inferential statistics for quantitative data

According to Neuman (2006) descriptive statistics are simple statistics employed to describe the basic patterns in the data by using frequency distribution and percentage counts. The results from descriptive statistics are reported using measures of central tendency (means, mode and median) and measures of variation (standard deviations and percentile). Inferential statistics such as t-tests, paired samples t-tests, ANOVA, MANOVA, correlation and multiple regression are used to test research hypotheses and to determine if sample results can be generalized to the sample population (Babbie, 2005; Gall, Gall, & Borg, 2003; Neuman, 2006).

Below are the research questions and statistical tests used to analyze the data in order to answer the research questions.

Research Question 1a:

Is there a significant relationship between metacognition and cognitive and metacognitive strategies utilized when reading the two scientific texts?

Analyzing parts of RQ 1a:	Tests
i) Computing metacognitive awareness (MAI) scores of respondents	• Descriptive Statistics
ii) Comparing the differences of MAI scores in three or more than three groups	• ANOVA or MANOVA • Post hoc & LSD tests
iii) Analyzing the relationship between MAI scores and types of strategies used to read texts	• Pearson Correlations

Research Question 1b:

Is there a significant relationship between metacognition and reading comprehension scores of the two scientific texts?

Analyzing parts of RQ 1b:	Tests
i) Computing reading comprehension (RC) scores of different groups	• Descriptive Statistics
ii) Comparing the differences of RC scores in three or more than three groups	• ANOVA or MANOVA • Post hoc and LSD tests
iii) Analyzing the relationship between MAI scores and RC scores	• Pearson Correlations

Research Question 2a:

Is there a significant relationship between scientific prior knowledge and cognitive and metacognitive strategies utilized when reading the two scientific texts?

Analyzing parts of RQ 2a:	Tests
i) Computing scientific prior knowledge (SPK) scores of different groups	• Descriptive Statistics
ii) Comparing the differences of SPK scores among three or more than three groups	• ANOVA or MANOVA • Post hoc and LSD tests
iii) Analyzing the relationship between SPK scores and types of strategies used to read texts	• Pearson Correlations

Research Question 2b:

Is there a significant relationship between scientific prior knowledge and reading comprehension scores of the two scientific texts?

Analyzing part of RQ 2b:	Test
i) Analyzing the relationship between SPK and RC scores	• Pearson Correlations

Research Question 3a:

What are the types of strategies commonly employed by high and low L2 proficiency first year ESL science undergraduates when reading the two scientific texts?

Analyzing parts of RQ 3a:	Tests
i) Computing the L2 proficiency of respondents	• Descriptive Statistics
ii) Computing the types of strategies used by different L2 proficiency groups	• Descriptive Statistics
iii) Comparing the differences in strategies used in different L2 proficiency groups	• MANOVA, Post hoc and LSD tests
iv) Comparing the differences in scores of MC, HC, LC in high (HP) and low (LP) L2 proficiency groups	• Independent t-test
v) Comparing the differences in strategies used in reading text A and reading text B	• Paired-Samples t-test
vi) Analyzing the relationship between L2 proficiency and strategy use	• Pearson Correlations

Research Question 3b:

Is there a significant relationship between L2 proficiency and cognitive strategies, metacognitive strategies, and RC scores of the two scientific texts?

Analyzing parts of RQ 3b:	Tests
i) Analyzing the relationship between L2 proficiency and types of strategies used	• Pearson Correlations
ii) Analyzing the relationship between L2 proficiency and RC scores	• Pearson Correlations

Research Question 4a:

What are the types of strategies commonly employed by first year ESL science undergraduates with high and low English proficiency when reading the two scientific texts?

Analyzing parts of RQ 4a:	Tests
i) Computing the composite of MC, HC and LC strategies used to read texts A and B by HP and LP learners in the three university groupings	• Descriptive Statistics
ii) Comparing the differences in the strategies used by the HP and LP learners and the differences in strategy use in reading texts A and B	• Independent t-tests • Paired-sample t-tests
iii) Comparing the differences in the strategies used by the HP and LP learners in the three university groupings.	• MANOVA, Post hoc and LSD tests

Research Question 4b:

What are the types of specific strategies (cognitive and metacognitive strategies) significantly contributed to reading comprehension of scientific texts?

Analyzing parts of RQ 4b:	Tests
i) Analyzing the relationship between the types of strategies used and RCA and RCB scores	• Pearson Correlations
ii) Analyzing the relationship between specific strategies used and RCA and RCB scores	• Pearson Correlations

Research Question 5:

Which variable (metacognition, scientific prior knowledge, L2 proficiency, or reading strategies) most influences reading comprehension of the two scientific texts?

Analyzing RQ 5:	Test
i) Analyzing the variables that predicted RC of scientific texts A and B	• Stepwise Multiple Regression

Research Question 6:

What are the characteristics of good ESL readers of scientific texts?

Analyzing parts of RQ 6:	Tests
i) Computing the RC scores of good and poor ESL readers of scientific texts	• Descriptive Statistics
ii) Determining the strategies used by good and poor readers	• Descriptive Statistics
iv) Comparing the difference in other variable scores between good and poor readers	• Independent T –test
v) Comparing the differences in strategy use between good and poor readers	• Independent T-test

Descriptive statistics, in particular means and standard deviation, were used to report findings involving respondents' metacognitive awareness level, scientific prior knowledge, L2 proficiency, strategy use, and reading comprehension scores of texts A and B.

Inferential statistics used in analyzing the data were independent t-tests, paired-samples t-tests, ANOVA, MANOVA, post hoc and LSD tests, Pearson correlations, and stepwise multivariate regressions. Independent t-tests were used to determine if two distributions differ significantly from each other. This test compares the means of two different samples, for example the means of reading comprehension scores obtained by high L2 proficiency (HP) and low L2 proficiency (LP) groups. Paired-samples t-tests, on the other hand, measures one group of respondents who experience two conditions of the variables that are being studied. One example from this study was analyzing if there was a significant difference between the strategies used while reading scientific text A and the strategies used in reading scientific text B in the HP group.

Analysis of variance (ANOVA) is a procedure to determine if there are significant differences between groups. One-way ANOVA compares the means of one dependent variable in many groups (one independent variable, eg. Ethnic groups) if they are significantly different from each other. One example was to find out if HP groups in University P, University Q, University R and University S differed from each other on their performance in reading comprehension of text A.

Multivariate analyses of variance (MANOVA) compares the means of several (more than two) multivariate populations. Tabachnick & Fidell (2007) elucidate that MANOVA requires a minimum data set of one or more independent variables (IV, hereafter) and each IV has two or more levels. In addition, there should be two or more dependent variables (DV, hereafter) for each level of IVs.

To use MANOVA, a few assumptions must be met. First, the data must meet the requirement of homogeneity of variance-covariance matrices which can be tested using *Box's M*, where if $p > 0.001$ the data is homogenous. Another requirement is the homogeneity of variances for each of the dependent variables. This assumption can be tested using Levene's tests, where if $p > 0.05$, the assumption is not violated. Post-Hoc comparisons are conduction to investigate the differences between groups for each DVs. The advantage of using MANOVA over separate ANOVAs is that it controls for *Type I* error. However, this error can be controlled using Bonferroni correction (Tabachnick & Fidell, 2007, p. 268).

Pearson correlations is used to show a relationship between two variables. A positive correlation indicates that as the value of one variable increases, the value of the other variable also tends to increase. A negative correlation indicate the the reverse, as the value of one variable increases, the value of the other tends to decrease. A zero correlation indicates a no relation between the two variables (Coakes, Steed & Price, 2008).

Multiple regression is an extension of bivariate correlation and is used to determine variables that can significantly predict or influence the dependent variable. In this study, stepwise multiple regression was employed. In stepwise selection, the IVs are added to the statistical equations one at the time and the decision to add or remove the IVs as well as the order of their entry to the equation are determined by the statistical considerations (Coakes, Steed & Price, 2008). The strength of relationship between the IVs and DV is indicated by R and R^2 represents the proportion of variation in the DV that is explained by the IVs (Kinnear & Gray, 2006).

4.8.3 Transcribing and coding protocols

The main purpose of conducting qualitative data collection technique was to triangulate and provide support for quantitative findings. In addition, qualitative data obtained through think aloud protocols, retrospective interviews and observations would give in depth insights on how ESL undergraduates negotiated English scientific texts independently. The final two research questions in this study that required qualitative data analyses are as follows:

Research Question 7

What are the types of cognitive and metacognitive strategies used by ESL undergraduates as revealed by the think aloud protocols?

Research Question 8

What are the difficulties they encountered while reading the two scientific texts and how did they overcome the problems?

Ten think aloud protocols (TAP, hereafter) from five respondents were digitally recorded and later transcribed verbatim. Video-recorded gestures and other observations were inserted in the transcription of the TAP to give the researcher and TAP coders a complete picture of respondents verbalization as well as the body language and activities during the TAP sessions. In order not to lose the spoken discourse features of the TAP, details such as speed, pauses and intonations as well as grunts and groans (Afflerbach, 1995) were noted down. The transcript of each TAP was placed into a table with five columns (appendix Q). The following is an extract from one of the transcripts.

Unit No.	**Protocol**	**Strategies in abbrev**	**Notes**	**Final Decision**
65.	*The major site of auxin synthesis in a plant is the **apical meristem** at the tip of a shoot.*			
66.	Emm…*The major site of auxin synthesis in a plant is the **apical meristem** at the tip of a shoot.* [read slowly]	LC-reread LC-Dspeed		LC-reread LC-Dspeed
67.	Apa…maksud ayat ni, err site yang majoriti yang berlaku auxin sintesis adalah pada apical meristem, pada hujung pucuk…	LC-translate	Or is it HC-Vsum?	LC-translate
68.	Saya terbayang…saya terbayang…saya lukis apa yang saya terbayang…[VCD: sketched small diagram of apical meristem on side of text]	HC-Vmen HC-Vsketch	She had mental visualization	HC-Vmen HC-Vsketch

The first column is the TAP unit number. The second column is the protocol. The normal font indicates respondent's own thoughts while the font in italic indicates the actual sentences in the text being read. Notes in brackets [ ] indicate video-recorded observations as well as other verbalization features. The third column was designated for strategy codes. Doubts or reasons for codes chosen could be written on the fourth column labelled 'notes' and the last column was designated for the final decision for the codes ascribed for each sentence in the TAP.

The coding scheme (appendix R1) for the TAP units developed for the pilot study and further improved for the main study was based on cognitive activities listed by Brown (1980) and the strategy categories as found in other reading strategy research instruments (Anderson & Nashon, 2006; Lowe, 1989; Block, 1986; Carrell, 1989; DiGisi & Yore, 1992; Draper, 1997; Koch, 2001; Mokhtari & Reichard, 2002, Pritchard, 1990; Sheorey & Mokhtari, 2001). Detailed descriptions of the coding scheme and procedures were adapted from Coiro & Dobler (2007), Salataci & Akyel (2002), and Scott (2008) (appendix R2).

Two independent coders were engaged to help code the TAP units. Both inter-coders hold a Master's degree in TESL and are English language lecturers at a Teachers' Training Institute (appendix R3). Two meetings were held with the inter coders for TAP coding training sessions. They were provided with the coding scheme, samples of coded TAP units (appendix R4), detailed description of the coding scheme, and a pen drive each containing recorded TAPs. The researcher was the third coder. The inter-coder reliability or agreement was .74 (218/295) when they practiced on the TAP practise provided during the training session. After much discussions and clarifications on confused items in the coding scheme, inter-coder agreement increased to .82 (216/249) as they coded the first actual TAP. The inter-coder reliability of the other nine TAPs fluctuated in the range of .82 to .85. Disagreements in coding were resolved through discussions.

Similarly, retrospective interview protocols were also transcribed verbatim, coded and categorized based on similar features or new themes found in the data (Neuman, 2006). The researcher invited a fellow Ph D student to help analyze the interview protocols, code similar features, and note emerging new themes. Similar features looked for in the interview protocols were (a) covert strategies (b) reasons and conditions for utilizing certain strategies (c) difficulties encountered (d) ways to resolve comprehension problems (e) other interesting themes. The Ph. D student and the researcher agreed on the themes and these data acted as back ups for TAPs as well as supplementary insights on respondents' reading processes and problems.

4.9 Chapter summary

This chapter outlines the method and research design that were employed in this study. There were approximately 372 first year science ESL undergraduates from four different universities who participated in the study. The study utilized quantitative as well as qualitative data collection methods. For quantitative data, the study used multiple questionnaires to tap into different variables such as L2 proficiency, scientific prior knowledge, metacognitive awareness, cognitive and metacognitive strategies, and reading comprehension of scientific texts.

For qualitative data, think aloud, retrospective interview, and observation methods were employed to get an in-depth understanding of strategy variations in processing the two scientific texts in English as a second language. SPSS software was used to analyse quantitative data using descriptive and inferential statistics and inter-coders were employed to score respondents' protocols.

CHAPTER FIVE

DATA ANALYSES AND FINDINGS OF QUANTITATIVE DATA

5.1 Overview

The findings of this study are presented in chapters five and six. This chapter describes the quantitative findings on the relationships between the independent variables (metacognition, scientific prior knowledge and English language (L2) proficiency) and mediating variables cognitive and metacognitive strategies used by first year ESL science undergraduates in Malaysia to read two scientific texts of different syntactic difficulty and topic familiarity. In addition, this chapter also describes the findings on the effects of reading strategies on reading comprehension scores and the characteristics of good and poor readers of scientific texts. The findings of this study will be analyzed and discussed according to the following outline:

a) Preliminary issues and considerations: Allocating respondents into two L2 proficiency groups and three university groupings
b) Comparing and correlating the independent variable metacognition to cognitive and metacognitive strategies used to read the two scientific texts as well as to reading comprehension scores of the two scientific texts.

c) Comparing and correlating the independent variable scientific prior knowledge to cognitive and metacognitive strategies used to read the two scientific texts as well as to reading comprehension scores of the two scientific texts.

d) Comparing and correlating the independent variable L2 proficiency to cognitive and metacognitive strategies used to read the two scientific texts as well as to reading comprehension scores of the two scientific texts.

e) Identifying the types of strategies used by ESL science undergraduates and determining the specific strategies that contributed to successful comprehension.

f) Identifying characteristics of good ESL readers of scientific texts

In doing do so, this chapter addresses the following research questions:

1. Is there a significant relationship between **metacognition** and
    a) cognitive and metacognitive strategies utilized when reading the two scientific texts?
    b) reading comprehension scores of the two scientific texts?
2. Is there a significant relationship between **scientific prior knowledge** and
    a) cognitive and metacognitive strategies utilized when reading the two scientific texts?
    b) reading comprehension scores of the two scientific texts?

3. Is there a significant relationship between **L2 proficiency** and
    a) cognitive and metacognitive strategies used to read the two scientific texts?
    b) reading comprehension scores of the two scientific texts?
4. a) What are the types of strategies commonly employed by first year ESL science undergraduates with high and low English proficiency when reading the two scientific texts?
    b) Which specific strategies (cognitive and metacognitive strategies) significantly contribute to reading comprehension of the two scientific texts?
5. Which variable (metacognition, scientific prior knowledge, L2 proficiency, or reading strategies) most influences the reading comprehension of the two scientific texts?
6. What are the characteristics of good ESL readers of scientific texts?

5.2 Preliminary issues and considerations: Allocating respondents into two L2 proficiency groups and three university groupings

This section reports on the preliminary data analyses done to find out the strengths and weaknesses of the data before any attempt was made to answer the research questions. Two major findings from the preliminary data analyses had compelled the researcher to regroup the samples into two L2 proficiency groups as well as to analyze the data according to university groupings instead of examining them as a collective group.

5.2.1 Issue 1: L2 proficiency groups

After data screening, a total of 336 respondents made up the final samples for data analysis. The data revealed that the samples were largely made up of modest and competent L2 proficiency learners (86.4%) and equivalent number of limited and good L2 learners (13.6%). Of the 336 respondents, 23 (6.8%) obtained MUET band 2, 189 (56.3%) MUET band 3, 101 (30.1%) MUET band 4, and 23 (6.8%) MUET band 5, as shown in Table 5.1.

Table 5.1
Frequency and percentage of English language (L2) proficiency among first year ESL science undergraduates

MUET Band	Description	Freq	Percent
2	Limited L2	23	6.8
3	Modest L2	189	56.3
4	Competent L2	101	30.1
5	Good L2	23	6.8
	Total	336	100.0

Since the samples were made up of uneven number of limited, modest, competent and good L2 learners, it was decided that the data should be divided into only two English proficiency groups, high L2 proficiency and low L2 proficiency groups. From a sample size of 336, 124 respondents obtained MUET bands 4 and 5 (Mean

=4.19; Standard Deviation = .39) and thus were considered high L2 proficiency learners (HP, hereafter). The remaining 211 respondents obtained MUET bands 2 and 3 (M=2.89; SD=.31) and were considered low L2 proficiency learners (LP, hereafter). Independent t-test (two-tailed) were performed and the result suggested that there was a significant difference in the English language proficiency between the HP and the LP learners at $t(333) = -33.33$, $p=0.001$ (see Table 5S1, appendix S1).

5.2.2 Issue 2: Lack of correlations between strategy use and reading comprehension in HP and LP learners (N = 336)

This section reports on the reasons to regroup respondents into three university groupings based on the preliminary data analysis instead of analyzing the 336 respondents as a collective group. The discussion begins with the analysis of descriptive statistics, independent t-tests and paired-samples t-tests on strategies used by HP and LP learners while reading both texts. Following that, Pearson correlation analysis between strategies used and reading comprehension scores of both scientific texts would reveal findings that compelled the researcher to regroup the respondents.

Table 5.2 shows the descriptive statistics of metacognitive, higher cognitive and lower cognitive strategies used by HP and LP learners while reading scientific texts A and B. In addition, independent t-tests were performed to determine if each strategy used by HP and LP learners was significantly different from each other.

Table 5.2

Descriptive Statistics and Independent T-tests on Strategies Used by HP and LP Learners to Read Two Scientific Texts (n=336)

Types of Strategies	HP		LP		t- test		
	Mean	(SD)	Mean	(SD)	df	t-value	p-value
				Text A *(Auxins and Elongation of Cells)*			
Metacognitive Strategies (MC)	4.60	(.84)	4.61	(.94)	333	.113	.910
Higher Cognitive Strategies (HC)	4.45	(.82)	4.49	(.89)	333	.437	.663
Lower Cognitive Strategies (LC)	4.42	(.87)	4.68	(.95)	333	2.576	.010*
N	123		211				
				Text B (*Hormones and Signal Transduction)*			
Metacognitive Strategies (MC)	4.65	(.83)	4.61	(.95)	333	-.396	.692
Higher Cognitive Strategies (HC)	4.43	(.83)	4.48	(.93)	333	.408	.684
Lower Cognitive Strategies (LC)	4.41	(.85)	4.66	(.94)	333	2.471	.014*
N	124		211				

* $p < 0.05$

Table 5.2 indicates that in the HP learners, the means for metacognitive strategies (MC, hereafter) used when reading texts A and B were somewhat higher compared to the means of higher cognitive (HC, hereafter) and lower cognitive (LC, hereafter) strategies. In addition, the mean score for LC strategies was the lowest compared to MC and HC strategies used by this group of HP learners. In contrast, the means for LC strategies in the LP learners were the highest compared to their MC and HC strategies. Based on the descriptive statistics, it shows that the LP learners exerted slightly more effort in the strategies they used compared to the HP group while reading scientific texts A and B. Nevertheless, independent t-tests revealed that there were no significant differences in the MC and HC strategies used by the HP and LP learners while reading texts A and B except for LC strategies, which was significant at $p < 0.05$. This means that students with less L2 proficiency tended to use more LC strategies, which consist of text bound strategies like decoding, rereading, translating and paraphrasing.

Table 5.3

Paired Samples T-test on Strategies Used to Read Texts A and B

Group of learners	Strategies used in Texts A and B	Paired Samples t- test		
		df	t-value	*p*-value
HP	aMC – bMC	123	-1.606	.111
	aHC – bHC	123	.469	.640
	aLC – bLC	123	.245	.807
LP	aMC – bMC	211	-.024	.981
	aHC – bHC	211	.464	.643
	aLC – bLC	211	.674	.501

Significant difference at $p < 0.05$

As shown in table 5.3, paired samples t-tests were then conducted to determine if the means of MC, HC and LC strategies used while reading scientific text A (less difficult/familiar) were significantly different from the means of the MC, HC and LC strategies used while reading scientific text B (difficult/ less familiar) in both HP and LP learners. The result indicates that there were no significant differences in the means of MC, HC and LC strategies used in reading texts A and B in both groups. This finding evidently contradicts previous studies

(Block, 1992; Sheorey & Mokhtari, 2001) in that more proficient ESL readers were able to reflect and monitor their reading processes especially when encountered with more difficult reading task and thus exerted significantly more MC strategies in such situation (Baker & Boonkit, 2001).

The data were further inspected to find out if there was significant relationship between MC, HC and LC strategies used by HP and LP ESL undergraduates and their reading comprehension scores of scientific texts A and B.

Table 5.4

Correlations between Types of Strategies and Reading Comprehension Scores

	Written Summary A	Reading Comp A (RCA)	Written Summary B	Reading Comp B (RCB)
	HP Learners (N = 121)			
Metacognitive Strategies (MC)	-.041	.092	.028	.043
Higher Cognitive Strategies (HC)	-.002	.094	.118	.177*
Lower Cognitive Strategies (LC)	-.047	.043	.030	.013
	LP Learners (N = 212)			
Metacognitive Strategies (MC)	.099	.113	.112	.094
Higher Cognitive Strategies (HC)	.112	.123	.114	.080
Lower Cognitive Strategies (LC)	.084	.082	.101	.069

* Correlation is significant at the 0.05 level (2-tailed)

Table 5.4 shows the Pearson correlation coefficients between MC, HC and LC strategies and four measures of reading comprehension in HP and LP learners. Contrary to expectation, there appeared to be a lack of correlation between all types of strategies and the four measures of comprehension in both HP and LP learners with only one exception. The result indicates that there was a very weak but significant correlation between HC strategy and reading comprehension B in the HP group. However, no assumption could be made based on this very weak correlation. Therefore, before any research question could be answered, the data were further scrutinized to avoid any oversights due to possible compounding effects and consequently making erroneous generalization.

5.2.3 Allocating respondents into universities PQ, R, and S

In order to reanalyze the data, the composite samples (n=336) were broken up into their respective universities; University P (n=47), University Q (n=109), University R (n=76) and University S (n=103). As the rule of thumb, there had to be a minimum of 20 observations per cell to be normal and representative (Hair, Anderson, Tatham, & Black, 2006, p. 11 & 288). Since there were only 47 respondents from University (Univ, hereafter) P, further analysis requiring the data to be divided into smaller groups (for example HP and LP learners; good versus poor readers) would render the data unsuitable for certain statistical tests for having too small samples. Thus, it was decided that they should be grouped together with respondents of another university that shared certain commonalities especially in the regional location of the university, their L2 proficiency, scientific prior knowledge

(SPK, hereafter) and metacognition. A between subjects multivariate analysis of variance (MANOVA) was conducted with university as the independent variable and L2 proficiency, SPK and metacognition as dependent variables. Box's M test was not significant, M=15.16, F (18, 171772) = .827, p > .001 and so was Levene's test of homogeneity of variance. The non-significance of both tests indicates that the assumptions of homogeneity of variance-covariance and homogeneity of variance are tenable. The results of multivariate analysis of variance among the four university groupings and their characteristics are presented in Table 5.5.

Table 5.5

Common Traits of Respondents in Four Universities

	N	Regional Location	Mean		
			Metacognition	Scientific Prior Knowledge (SPK)	L2 proficiency
Univ P	47	Midwest	249	25.57	3.23
Univ Q	109	Midwest	260	26.73	3.37
Univ R	76	Northern	251	31.01	3.60
Univ S	103	East coast	256	28.05	3.27

As shown in Table 5.5, MANOVA indicated a non significant effect for metacognition, $F(3,334) = 1.40$, $p < 0.213$. However, there was a significant effect for SPK $F(3,334) = 5.61$, $p < 0.01$ and for L2 proficiency $F(3,334) = 3.86$, $p < 0.01$. Pairwise post-hoc test revealed that respondents in Univ R possessed significantly higher L2 proficiency and SPK compared to respondents in Univ P as well as respondents in the other two remaining universities. This automatically made Univ R as an incompatible choice to be paired up with Univ P to form Univ PR. With

Univ R eliminated from the existing choices, the next alternative was to regroup Univ P with Univ Q thus forming Univ PQ or with Univ S and forming Univ PS.

The final consideration left before any decision was made to regroup Univ P with either Univ Q or Univ S was to look into their strategy use and how it correlated to their reading comprehension. This would help to indicate whether respondents in the respective universities shared common reading behaviours which helped them to understand the texts read. Table 5.6 shows the Pearson correlation coefficients between MC, HC and LC strategies used while reading scientific texts A and B and comprehension scores among respondents in Univ P, Q and S.

Table 5.6
Correlations between Strategies and Reading Comprehension Scores in Univ PQ, R and S

	Reading Comprehension A (RCA)			Reading Comprehension B (RCB)		
	Univ P	Univ Q	Univ S	Univ P	Univ Q	Univ S
Metacognitive Strategies (MC)	.243	.114	.102	.349(*)	.209(*)	-.114
Higher Cognitive Strategies (HC)	.297(*)	.067	.102	.404(**)	.203(*)	-.073
Lower Cognitive Strategies (LC)	.136	.038	.098	.329(*)	.061	-.086

*p < 0.05; **p < 0.01

The results revealed that there was only one significant correlation between HC strategy and reading comprehension of text A (RCA, hereafter) in Univ P whereas there was no significant correlation between any strategy and RCA in Univ Q and S. However, there were positive and significant correlations between at least two types of strategies and reading comprehension of text B (RCB, hereafter) in Univ P and Q. On the other hand, no correlation was again found between strategy use and RCB in Univ S. Based on the analysis above, it seemed that respondents in Univ P and Q shared somewhat similar reading behaviours in terms of the strategies used to read both scientific texts compared to those in Univ S.

Thus, three factors led to the decision in grouping respondents from Univ P with those in Univ Q and accordingly be labelled Univ PQ (n=157). First, both universities were located in the same regional area which was the mid region of the west coast of the Peninsular Malaysia. Second, multivariate analysis of variance (MANOVA) revealed that there were no significant differences in the L2 proficiency and scientific prior knowledge possessed by respondents in Univ P and Q. Third, data analyses revealed that respondents from both universities shared similar traits in strategy use. Respondents from Univ R, on the other hand, were found to be more superior in terms of their L2 proficiency and scientific prior knowledge while respondents from Univ S displayed completely different traits in strategy use than Univ P and Q. Thus, the succeeding data would be analyzed and the findings discussed according to the three university groupings (Univ PQ, Univ R, Univ S) as well as a collective group (n=336).

5.3 Research Question 1: The contribution of metacognition to strategy use and reading comprehension of two scientific texts

To answer research question one, the descriptive statistics on metacognitive awareness levels of HP and LP learners across the three university grouping were first computed before the correlations between metacognition and strategy use could be analyzed. Next, the means of reading comprehension scores for texts A and B were presented which was then followed by the correlation analysis between metacognition and reading comprehension scores.

5.3.1 Metacognitive awareness possessed by HP and LP learners in three university groupings

The means and standard deviations of HP and LP learners' knowledge of cognition (KNcog), regulation of cognition (REGcog) and metacognitive awareness (MAI) were first examined. Table 5.7 presents the descriptive statistics for respondents' perceived knowledge of cognition (KNcog), regulation of cognition (REGcog) and metacognitive awareness (MAI).

Table 5.7

Means and Standard Deviations of Three Measures of Metacognition for Collective Group (n=334) and in Univ PQ, R and S

(N)	Knowledge of Cognition (KNcog)		Regulation of Cogniiton (REGcog)		Metacognitive Awareness (MAI)	
	M	(SD)	M	(SD)	M	(SD)
			Collective Group (Univ PQRS)			
(334)	83.93	13.06	171.74	25.51	255.67	37.44
LP (211)	84.47	13.27	172.38	25.89	256.90	38.13
HP (123)	83.01	12.67	170.64	24.91	253.56	36.27
			Univ PQ			
LP (103)	84.29	12.46	173.56	23.44	257.85	34.76
HP (54)	84.15	12.48	171.91	22.49	256.06	33.61
			Univ R			
LP (37)	85.30	14.31	172.92	24.81	258.22	38.27
HP (39)	79.51	12.40	165.31	25.14	244.82	36.09
			Univ S			
LP (71)	84.30	14.02	170.38	29.80	254.83	42.91
HP(30)	85.50	12.81	175.30	28.15	260.43	40.01

For the collective group (n=334), the mean scores for knowledge of cognition (KNcog) and regulation of cognition (REGcog) were 83.93 and 171.74 respectively. The mean score for metacognitive awareness (MAI) was 255.67. The mean scores were considered very high compared to those obtained by undergraduates reported in other studies as displayed in Table 5.8.

Table 5.8

Metacognitive Awareness Scores of Undergraduates Reported in Previuos Studies

Study	Respondents	KNcog	REGcog	MAI
Young & Fry (2008)	178 undergraduate & graduate students (Texas)	68.69	138.16	206.85
Magno (2008)	159 freshmen (Manila)	73.07	66.69	139.76
Coutinho (2007)	179 undergraduates (USA)	NA	NA	254.42
Coutinho & Neuman (2008)	629 undergraduates (Illinois)	NA	NA	251.76
Kleitman & Stankov (2007)	296 freshmen in Psychology	NA	NA	3.98

A comparison between the mean of MAI score of 334 ESL undergraduates in this study and those in Table 5.8 revealed that the current respondents possessed similar metacognitive awareness level as those in Coutinho and Coutinho & Neuman's studies but definitely higher than those in other studies. It was evident the 334 ESL science undergraduates in this study displayed a very high awareness of their metacognition.

As shown in Table 5.7, the data were further divided into HP and LP groups of learners across the three university groupings. The means for KNcog, REGcog and MAI for HP and LP learners in the three university grouping were generally the same except for those recorded for HP learners in Univ R; KNcog (79.51), REGcog (165.31), and MAI (244.82). These means appeared to be lower than those reported by other groups in the study. To ascertain, multivariate analysis of variance (MANOVA) was performed to determine if the difference was significant.

Table 5.9

MANOVA for Metacognition Scores in HP and LP Learners in Univ PQ, R and S

Source	Dependent Variable	df	*F*	*p*
PQ/HP ; PQ/LP; R/HP; R/LP; S/HP; S/LP	Knowledge of Cognition (KNcog)	5	1.114	.352
	Regulation of Cognition (REGcog)	5	.753	.584
	Metacognitive Awareness (MAI)	5	.859	.509

F statistics from multivariate analysis of variance suggest that there were no significant differences in the mean scores of KNcog, REGcog and MAI in the HP and LP learners across the three university groupings. This means the difference observed in the means of KNcog, REGcog and MAI in the HP learners in Univ R were not significant.

5.3.2 *The relationship between metacognitive awareness and reading strategies*

In order to determine if there were significant relationships between the mean scores of the three measures of metacognition (KNcog, REGcog and MAI) and reading strategies used while reading scientific texts A and B, Pearson correlation analysis was computed on HP and LP learners across the three university groupings as shown in Table 5.10.

Table 5.10

Correlations between Metacognition and Reading Strategies among HP and LP Learners

	Scientific Text A			Scientific Text B			Scientific Text A			Scientific Text B		
	MC	HC	LC	MC	HC	LC	MC	HC	LC	MC	HC	LC
	Univ PQ/HP Learners (N=53)						Univ PQ/ LP Learners (N=103)					
KNcog	.579**	.579**	.559**	.643**	.599**	.549**	.495**	.499**	.446**	.445**	.398**	.392**
REGcog	.677**	.673**	.583**	.661**	.667**	.581**	.653**	.652**	.593**	.570**	.545**	.537**
MAI	.684**	.673**	.603**	.692**	.673**	.596**	.605**	.609**	.547**	.528**	.500**	.485**
	Univ R/ HP Learners (N = 39)						Univ R/ LP Learners (N = 37)					
KNcog	.582**	.578**	.509**	.607**	.481**	.467**	.611**	.703**	.485**	.604**	.686**	.539**
REGcog	.744**	.728**	.686**	.829**	.726**	.616**	.732**	.773**	.579**	.706**	.742**	.614**
MAI	.708**	.699**	.645**	.784**	.668**	.586**	.687**	.752**	.546**	.668**	.725**	.587**
	Univ S/ HP Learners (N=31)						Univ S/ LP Learners (N=71)					
KNcog	.742**	.734**	.667**	.715**	.715**	.648**	.668**	.664**	.631**	.611**	.591**	.628**
REGcog	.802**	.758**	.706**	.752**	.756**	.723**	.679**	.687**	.677**	.671**	.669**	.683**
MAI	.804**	.770**	.715**	.752**	.765**	.711**	.685**	.692**	.672**	.670**	.661**	.679**

* $p < 0.05$ level (2-tailed), ** $p < 0.01$ level

Table 5.10 presents the Pearson correlation coefficients between KNcog, REGcog and MAI and MC, HC and LC strategies used by HP and LP learners across the three university groupings in two reading tasks. In general, KNcog, REGcog and MAI have from modest ($r = .392$, $p < 0.01$) to strong correlations ($r = .804$, $p < 0.01$) to all three types of reading strategies in HP and LP learners across the three university groupings.

In the HP learners, correlation coefficients were the strongest between the three measures of metacognition and MC strategies. The correlations were observed very strong in HP learners in Univ R (R/HP learners, hereafter) with $r = .802$ ($p < 0.01$) and $r = .804$ ($p < 0.01$) between REGcog and MAI to MC strategies respectively and also very strong in R/HP learners with $r = .829$ ($p < 0.01$) between REGcog and MC strategies. Similar correlations in the other HP groups were moderate. The strength of correlations between KNcog, REGcog and MAI and MC strategies were found to increase from scientific text A to scientific text B in HP learners of Univ PQ and Univ R. In HP learners of Univ S (S/HP learners, hereafter), the correlation strength between metacognition and MC strategies dropped very slightly from text A to text B.

On the other hand, in the LP learners of Univ R (R/LP learners, hereafter), correlation coefficients were strongest between the three measures of metacognition and HC strategies. In the other LP groups, the correlation strength was about even. Surprisingly, in LP learners in Univ PQ (PQ/LP learners, hereafter), the correlations between KNcog and the three types of strategies in both reading tasks were modest.

In summary, the analyses on respondents' metacognitive awareness and its relationship to strategy use reveal the following findings:

(1) ESL science undergraduates of high and low L2 proficiency levels possess a very high level of metacognitive awareness which matches and at times exceeds the metacognitive awareness levels of undergraduates in previous studies.

(2) Knowledge of cognition, regulation of cognition and metacognitive awareness significantly contributed to the strategies used by ESL learners with high and low L2 proficiency. However, the strength was observed the strongest in the S/HP learners, followed by R/HP learners and R/LP learners. The correlations between metacognition and strategy use were moderately strong in S/LP learners followed by PQ/HP learners and PQ/LP learners.

(3) The strength of correlations between the three measures of metacognition (knowledge of cognition, regulation of cognition and metacognitive awareness) and MC strategies increased from text A (less difficult and more familiar text) to text B (more difficult and less familiar text).

5.3.3 The relationship between metacognitive awareness and specific reading strategies

Pearson correlation analyses were also conducted between the three measures of metacognition and 18 specific strategies to determine the contribution of metacognition on individual strategies (see appendix T for Pearson correlation analyses in Tables 5T1, 5T2, 5T3, and 5T4).

The data in Tables 5T1 to 5T4 indicate that almost all specific strategies correlated to the three measures of metacognition with the correlation strength ranges from modest to strong. The correlation strength between the measures of metacognition and specific strategies used in reading text A and those used in reading text B remained comparable in both HP and LP learners across the three university groupings.

The most interesting finding was on the correlation between metacognition and three types of specific strategies, which were HCGU, LCMN and LCLU, used by HP and LP learners while reading scientific texts A and B. Before the results in Tables 5.11 and 5.12 are discussed, it is best to describe the three strategies concerned.

The first is HCGU (higher cognitive strategy - reading for global understanding) which was employed by readers to read for overall meaning and understanding. In doing so, some readers may opt for the strategy skipping unknown words. Next is LCMN (lower cognitive strategy-memorizing and note taking). For this strategy, readers tended to underline, circle or highlight important points and later revise and memorize them. The final strategy is LCLU (lower cognitive strategy - reading for local understanding). Users of this strategy tried to understand every word and sentence in the text, reread information, and focus on getting the meaning of each word and phrase. Tables 5.11 and 5.12 present the Pearson correlations analyses between the three mentioned strategies and KNcog, REGcog and MAI in HP and LP learners across the three university groupings.

Table 5.11

Pearson Correlations between Metacognition and Specific Reading Strategies (Text A) among HP and LP learners

		HCGU	LCMN	LCLU
			HP Learners	
Univ PQ	KNcog	.235	.438**	.496**
	REGcog	.409**	.436**	.526**
	MAI	.330*	.457**	.533**
Univ R	Kncog	.362*	.117	.494**
	REGcog	.417**	.340*	.663**
	MAI	.409**	.238	.605**
Univ S	Kncog	.344	.683**	.462**
	REGcog	.421*	.708**	.580**
	MAI	.395*	.718**	.539**
			LP Learners	
Univ PQ	KNcog	.282**	.437**	.384**
	REGcog	.368**	.566**	.531**
	MAI	.335**	.517**	.471**
Univ R	KNcog	.397*	.397*	.179
	REGcog	.434**	.456**	.230
	MAI	.422**	.432**	.206
Univ S	KNcog	.268*	.595**	.585**
	REGcog	.233	.580**	.645**
	MAI	.256*	.601**	.629**

[1]HC strategy (reading for) global understanding;
[2]LC strategy memorizing and note taking;
[3]LC strategy (reading) for local understanding
* $p < 0.05$ level (2-tailed); ** $p < 0.01$ level (2-tailed)

Table 5.12

Pearson Correlations between Metacognition and Specific Reading Strategies (Text B) among HP and LP learners

		HCGU	LCMN	LCLU
			HP Learners	
Univ PQ	KNcog	.105	.427**	.434**
	REGcog	.258	.471**	.469**
	MAI	.184	.468**	.470**
Univ R	Kncog	.249	.274	.421**
	REGcog	.318*	.488**	.530**
	MAI	.297	.398*	.498**
Univ S	Kncog	.311	.373*	.588**
	REGcog	.438*	.477**	.589**
	MAI	.388*	.440*	.608**
			LP Learners	
Univ PQ	KNcog	.173	.348**	.260**
	REGcog	.257**	.499**	.407**
	MAI	.221*	.435**	.342**
Univ R	KNcog	.428**	.528**	.293
	REGcog	.505**	.553**	.353*
	MAI	.473**	.549**	.326*
Univ S	KNcog	.225	.399**	.583**
	REGcog	.299*	.374**	.658**
	MAI	.268*	.395**	.634**

* $p < 0.05$ level (2-tailed); ** $p < 0.01$ level (2-tailed)

Table 5.11 shows that there were no significant correlations between KNcog and HCGU in PQ/HP learners and S/HP learners. The same pattern was observed in

Table 5.12 (while reading text B) among HP learners in all university groupings as well as in LP learners of Univ PQ and S. However, these same learners were found to have their KNcog correlated positively to LCMN and LCLU. One would expect that as proficient users of English, the HP learners would have the knowledge of their own cognitive ability to read the text for overall understanding or skip a word or two during the process of reading. It has been widely accepted that proficient L2 readers tended to read texts for global understanding while less proficient read for local understanding (Hosenfeld, 1977; Block, 1986; 1992; Carrell, 1989; Baker & Boonkit, 2004). Yet, the finding above contradicts that rule of thumb laid out by L2 researchers. In fact, the opposite was true in this study when HP learners' KNcog correlated positively to LCLU and LCMN.

On the other hand, there were positive and modest correlations between KNcog and HCGU (text A) in R/HP learners (r = .362, $p < 0.05$) and PQ/LP learners (r = .282, $p < 0.01$), R/LP learners (r = .397, $p < 0.05$) and S/LP learners (r = .268, $p < 0.05$). When reading text B (Table 5.12), KNcog and HCGU no longer correlated in LP learners of Univ PQ and Univ S whereas the correlation was modest and positive in LP learners of Univ R. Unlike LP learners in the other two university groupings, there was no correlation between KNcog and LCLU in R/LP learners.

Respondents in Univ R seemed to exhibit a different pattern with regards to the correlation between KNcog and HCGU as well as KNcog and LCLU. While other learners showed a non significant effect for the KNcog and HCGU, those in

Univ R showed positive and modest correlation, and vice verse for KNcog and LCLU.

In summary, data analyses on the relationships between the three measures of metacognition and 18 specific strategies reveal three findings:

(1) The relationships between the three measures of metacognition and specific reading strategies were significant and the strength of the correlation ranged from modest to strong.

(2) The strength of positive and significant correlations between metacognition and strategy use was the same throughout the HP and LP learners across the three university groupings.

(3) A very interesting finding was that HC strategy-reading for global understanding did not correlate to knowledge of cognition in all groups except in R/LP learners while LC strategy-reading for local understanding did correlate to knowledge of cognition in all groups except in R/LP learners.

5.3.4 Reading comprehension scores of two scientific texts among HP and LP learners in the three university groupings

To answer the second part of research question one, reading comprehension scores of the two scientific texts obtained by the respondents were first presented. Two comprehension measures for each scientific text were a written summary (WS, hereafter) protocol on the biochemical process (30 marks) and the comprehension score from the multiple true and false statements and multiple choice questions (33 marks and 36 marks for texts A and B). Both reading measures gave a total of 63 and 66 marks for reading comprehension of text A (RCA, hereafter) and reading comprehension of text B (RCB, hereafter) respectively. Also included in the analysis was the total reading comprehension marks obtained by adding the scores obtained for RCA and RCB and thus named reading comprehension AB (RC AB) with a total of 129 marks.

Table 5.13

MANOVA and Mean Scores of Reading Comprehension Measures Obtained by HP and LP Learners in Univ PQ, R and S

	Mean			MANOVA		
	Univ PQ	Univ R	Univ S	*df*	*F*	*p*
HP Learners						
Written Summary A (WS A)	11.17	10.69	5.78	2	12.99	.000*
Reading Comprehension A (RCA)	31.77	32.41	25.34	2	10.62	.000*
Written Summary B (WS B)	7.80	6.10	4.85	2	6.17	.003*
Reading Comprehension B (RCB)	27.44	26.10	20.97	2	12.69	.000*
Reading Comprehension AB (RC AB)	59.21	58.51	46.31	2	15.08	.000*
LP Learners						
Written Summary A (WS A)	9.43	6.31	6.94	2	6.17	.002*
Reading Comprehension A (RCA)	27.71	25.42	24.81	2	3.81	.024*
Written Summary B (WS B)	6.42	4.63	4.86	2	3.74	.025*
Reading Comprehension B (RCB)	23.51	20.12	21.06	2	6.08	.003*
Reading Comprehension AB (RC AB)	51.22	45.54	45.87	2	6.42	.002*

*significant mean difference at $p < 0.05$

Table 5.13 presents the means of five measures of reading comprehension obtained by HP and LP learners across the three university groupings as well as the results of MANOVA. In general, it was found that the HP learners in Univ PQ and Univ R as well as LP learners in Univ PQ made up the top three groups of good comprehenders of scientific texts followed by HP learners in Univ S and LP learners in Univ R and Univ S.

A MANOVA between-subjects effects revealed that there were significant differences in the mean scores of all measures of reading comprehension among the HP learners as well as LP learners in the three university groupings. Among the HP learners, significant differences existed in the mean scores of WS A, $F(2, 121) = 12.99$, $p < 0.001$; RCA, $F(2, 121) = 10.62$, $p < 0.001$; WS B, $F(2, 121) = 6.17$, $p < 0.003$; RCB, $F(2, 121) = 12.69$, $p < 0.001$; and RC AB, $F(2, 121) = 15.08$, $p < 0.001$. Pairwise post hoc test of LSD (Table 5U1, appendix U) indicated that the mean scores of WS A, RCA and RC AB obtained by HP learners in Univ PQ and Univ R were not significantly different from each other. However, those obtained by HP learners in Univ S were different and thus significantly lower than those of their counterparts in Univ PQ and Univ R. On the other hand, HP learners in Univ PQ obtained significantly higher means on WS B and RCB than those in Univ R and Univ S.

Similar to the HP learners, the MANOVA between-subjects effects in the LP learners revealed that there were also significant differences in the means of all five measures of reading comprehension at *p*-value ranging from 0.002 to 0.025. In fact, LP learners in Univ PQ were observed to outperform their counterparts in Univ R and Univ S on all measures of reading comprehension while the means of those in Univ R and Univ S were comparable. Post hoc test of LSD (Table 5U2, appendix U) confirmed the observation and found that LP learners in Univ PQ had significantly higher means on all measures of reading comprehension compared to LP learners in Univ R and Univ S.

A third MANOVA was conducted on all six groups of learners comprising of the HP and LP learners in Univ PQ, Univ R and Univ S. The results as shown in Tables 5U3 and 5U4 (please see appendix 5U) indicate that the means of reading comprehension in HP learners in Univ PQ and R were not significantly different whereas the means in PQ/LP learners were significantly higher than those in S/HP learners. In addition, the means of the five reading comprehension measures in S/HP learners, R/LP learners and S/LP learners were not significantly different. What this means is that the LP learners in Univ PQ did significantly well and managed to outperform HP learners in Univ S.

5.3.5 The relationship between metacognitive awareness and reading comprehension scores of the two scientific texts

Table 5.14 presents the Pearson correlation coefficients between metacognition (KNcog, REGcog, MAI) and reading comprehension scores (WS A, RCA, WS B, RCB) among HP and LP learners in the three university groupings.

Contrary to expectation, the correlations between metacognition and reading comprehension were all not significant in three groups of learners (PQ/HP, S/HP and S/LP learners). Positive but weak correlations were recorded only in PQ/LP learners between REGcog and WS B (r = .224, $p < 0.05$), MAI and WS B (r = .209, $p < 0.05$), KNcog and RCB (r = .231, $p < 0.05$), REGcog and RCB (r = .249, $p < 0.05$), and MAI and RCB (r = .265, $p < 0.01$).

Table 5.14

Pearson Correlations between Metacognition and Reading Comprehension Among HP and LP Learners

	WS A	RCA	WS B	RCB	WS A	RCA	WS B	RCB
	Univ PQ/HP learners (N=53)				Univ PQ/LP learners (N=103)			
KNcog	-.019	.163	-.173	.113	.060	.090	.181	.231*
REGcog	-.061	.130	-.091	.065	.141	.176	.224*	.249*
MAI	-.040	.155	-.141	.086	.103	.159	.209*	.265**
	Univ R/HP learners (N=39)				Univ R/LP learners (N=37)			
KNcog	.009	-.213	-.243	-.424**	-.276	-.383*	-.171	-.275
REGcog	.120	-.065	-.017	-.211	-.285	-.343*	-.094	-.187
MAI	.066	-.126	-.139	-.336*	-.286	-.372*	-.140	-.213
	Univ S/HP learners (N=31)				Univ S/LP learners (N=71)			
KNcog	-.016	.126	-.090	.091	-.030	-.012	-.124	-.203
REGcog	-.187	.054	-.233	-.136	.013	.000	.013	-.157
MAI	-.107	.090	-.168	-.054	-.009	-.002	-.009	-.180

* $p<0.05$ level (2-tailed); ** $p < 0.01$ level

In addition, it was completely unexpected to find modest yet negative correlations between metacognition and RCA and RCB in HP and LP learners in Univ R. In R/HP learners, a modest but negative correlations were recorded between KNcog and RCB (r = -.424, $p < 0.01$) and between MAI and RCB (r = -.336, $p <$

0.05) while other correlations were not significant. In R/LP learners, KNcog, REGcog and MAI modestly yet negatively correlated to RCB with r = -.383, ($p <$ 0.05), r = -.343, ($p < 0.05$), and r = -.372, ($p < 0.05$), respectively. Other correlations were found not significant.

In summary, the data analyses on the relationships between the three measures of metacognition and reading comprehension scores of scientific texts A and B reveal three findings:

(1) Knowledge of cognition, regulation of cognition and metacognitive awareness did not correlate to comprehension scores of text A among HP and LP learners of Univ PQ and Univ S as well as HP learners of Univ R. The rationale may perhaps be that text A was syntactically easier than text B and on a familiar topic. Thus, for L2 proficient readers, the text did not demand problem solving strategies which would otherwise call for rigorous metacognitive scrutiny.

(2) The three measures of metacognition did not correlate to reading comprehension scores of text B (WS B and RCB) among LP learners of Univ R and Univ S. The reason may perhaps be contributed to again the role of metacognition which was thinking about ways to solve a problematic task. However, text B which was syntactically more difficult than text A and on less familiar topic was perhaps too challenging for LP learners to unpack. Therefore, metacognition did not play a direct role in their reading comprehension of a too difficult text.

(3) The three measures of metacognition correlated weakly to RCB in the LP learners of PQ. However, knowledge of cognition correlated negatively to RCB in the HP learners of Univ R. Even more surprising, knowledge of cognition, regulation of cognition and metacognitive awareness correlated negatively to RCA in the LP learners of Univ R. At this point, it could be assumed that the difficulty of text B might have been very challenging to LP learners of Univ PQ that compelled their metacognitive awareness to get into action and yet not too complicated that they gave up. However, the results in Univ R revealed that high metacognitive awareness among the readers did not guarantee successful comprehension of the two scientific texts. This assumption was further confirmed by the findings among HP and LP learners in Univ S where high or low metacognitive awareness did not seem to affect reading comprehension.

5.4 Research Question 2: The contribution of scientific prior knowledge to strategy use and reading comprehension of the two scientific texts

This section reports on the findings to address the two parts of the second research question, "Is there a significant relationship between scientific prior knowledge (SPK, hereafter) and cognitive and metacognitive strategies utilized when reading the two scientific texts?" and "Is there a significant relationship between scientific prior knowledge and reading comprehension scores of the two scientific texts?".

Respondents' scientific prior knowledge was assessed using an 80-item Scientific Prior Knowledge Inventory (SPKI, hereafter). The inventory administered to the respondents at the beginning of the study was divided into three scientific prior knowledge (SPK, hereafter) categories; (1) SPK on Text A (SPK A), (2) SPK on Text B (SPK B), and (3) SPK on scientific terminology used in both texts (SPK Scientific Term). The first two categories were further divided into four subcategories which were (1a) SPK on plant hormone, (1b) SPK on characteristics of auxins, (1c) SPK on the biochemical process of cell elongation, (1d) SPK on scientific terminology used in text A, (2a) SPK on human hormone, (2b) SPK on characteristics of human hormones, (2c) SPK on biochemical process of signal transduction, and (2d) SPK on scientific terminology in text B. Respondents' scores on the measures of SPK were correlated to their strategy use and reading comprehension scores of texts A and B. The data were analyzed using descriptive statistics and Pearson correlation analysis.

5.4.1 Scientific prior knowledge possessed by HP and LP learners in the three university groupings

The full mark for scientific prior knowledge inventory (SPKI) was 80 with 40 marks each for SPK on scientific texts A and B. The result of the SPK analysis indicates that, in general, respondents possessed about 23% to 46% of prior knowledge on the two scientific topics read in the two texts as shown in Table 5.15.

Table 5.15

Descriptive Statistics on Means of Scientific Prior Knowledge of Texts A and B

	Full mark	Mean		Std. Deviation	Range
SPK A	40	14.07	(35.18%)	4.53	24%-46.5%
SPK B	40	13.90	(34.75%)	4.73	23%-46.5%
SPKI	80	27.95	(34.94%)	8.38	24.5%-45.4%
N	336				

Table 5.16 shows the mean of scientific prior knowledge in each category and possessed by respondents in the three university groupings, as well as the results of the MANOVA conducted on each category.

Table 5.16

Means of SPK Possessed by ESL Learners in Univ PQ, R and S

No	Category (Full Mark)	Univ PQ (N=157) Mean *(%)*	SD	Univ R (N=76) Mean *(%)*	SD	Univ S (N=103) Mean *(%)*	SD	MANOVA *df*	*F*	*p*
1.	SPK A (40)	13.11 *(32.8)*	4.49	15.42 *(38.6)*	4.06	14.53 *(36.3)*	4.63	2	7.75	.000*
2.	SPK B (40)	13.32 *(33)*	4.73	15.59 *(39)*	4.38	13.47 *(34)*	4.74	2	6.69	.001*
3.	SPK Scientific Term (14)	5.87 *(42)*	2.16	6.99 *(50)*	2.14	5.65 *(40)*	1.97	2	10.04	.000*
4.	SPKI (80)	26.43 *(33)*	8.44	31.01 *(38.8)*	7.34	28.00 *(35)*	8.50	2	7.99	.000*

On the whole, respondents in Univ R seemed to have higher means on all measures of scientific prior knowledge (SPK A, SPK B, SPK scientific term, SPKI) compared to those in Univ PQ and Univ R, and *F* statistics from MANOVA suggest that there were significant differences in the mean scores at p-value < 0.05. Further analysis of respondents' SPK in each of the categories above is presented in Table 5V1 (appendix V). In general, respondents were lacking scientific prior knowledge on (1c) the biochemical process of elongation of cells (Text A) and (2c) biochemical process of signal transduction (Text B). Yet they shared almost comparable prior knowledge on human hormone and its characteristics. Again, respondents in Univ R showed higher means of SPK in subcategories 1a, 1b, 1d, 2a, 2b, 2c, and 2d compared to those in Univ PQ and Univ S. *F* statistics from the multivariate analysis of variance suggests that there were significant differences in the mean scores of five out of eight subcategories of SPK at p-value < 0.05. Pairwise post-hoc tests (Table 5V2, appendix V) were conducted on all SPK measures except for (1c), (2a), and (2b). The data indicate that respondents in Univ R had significantly higher means on seven measures of SPK than those possessed by ESL learners in Univ PQ and Univ S. In addition, those in Univ PQ had significantly lower means on four measures of SPK compared to those in Univ R and Univ S. Interestingly, the respondents in Univ S were found to have either comparable to or significantly higher SPK than those in Univ PQ. In sum, respondents in Univ R were found to have the highest SPK on both scientific texts, followed by those in Univ S and then Univ PQ.

5.4.2 Scientific prior knowledge possessed by HP and LP learners in the three university groupings

Scientific prior knowledge to be used for further analysis from this point onwards would be SPKI (total score of SPK from SPK A and SPK B), SPK A, SPK B and SPK Scientific Term. Table 5.17 displays the means for SPKI and its sub categories possessed by HP and LP learners across the three university groupings.

Table 5.17

Means of SPKI and its Sub Categories Possessed by HP and LP Learners in Univ PQ, R and S

Category/ subcategory	Univ PQ		Univ R		Univ S		MANOVA		
	Mean	SD	Mean	SD	Mean	SD	*df*	*F*	*p*
				HP Learners (N=124)					
SPKI	29.88	8.84	30.87	7.60	29.28	7.89	2	.35	.708
SPK A	14.58	4.59	15.00	4.08	15.47	4.27	2	.42	.661
SPK B	15.28	4.82	15.87	4.67	13.81	4.74	2	1.73	.182
SPK on Scientific Term	6.55	2.49	7.33	2.20	5.97	1.94	2	3.27	.042*
				LP Learners (N= 212)					
SPKI	24.67	7.69	31.16	7.16	27.42	8.70	2	9.47	.000*
SPK A	12.36	4.28	15.86	4.04	14.11	4.75	2	9.52	.000*
SPK B	12.32	4.37	15.29	4.10	13.31	4.76	2	6.14	.003*
SPK on Scientific Term	5.52	1.89	6.62	2.05	5.51	1.98	2	4.94	.008*

*Significant mean effect

The aim of the two multivariate analyses of variance performed separately on HP and LP learners in Univ PQ, Univ R and Univ S was to determine if there were significant differences in the mean scores of the four measures of SPK among the HP learners as well as the LP learners across the university groupings. The results in Table 5.17 show that there were no significant differences in all measures of the SPK possessed by HP learners except for SPK scientific term at $F = 3.27$, $p = 0.42$. Post hoc LSD test (Table 5V3, appendix V) revealed that the mean score of SPK scientific term possessed by R/HP learners was not significantly different from that obtained by PQ/HP learners but significantly higher than S/HP learners.

In the LP learners, however, significant differences existed in all measures of SPK across the three university groupings. Post hoc LSD test (Table 5V4, appendix V) revealed that the means of SPKI, SPK A, SPK B and SPK scientific term obtained by R/LP learners were consistently higher than those obtained by PQ/LP learners. Except for SPK A, all other SPK measures obtained by R/LP learners were higher than those obtained by S/LP learners. The means SPK measures in S/LP learners were similar to or higher than the means of SPK obtained by PQ/LP learners.

A third multivariate analysis of variance (see appendix V for Table 5V5) showed that significant differences were observed in the mean scores of SPKI ($F = 6.47$, $p < 0.001$), SPK A ($F = 5.57$, $p < 0.001$), SPK B ($F = 5.84$, $p < 0.001$) and SPK Scientific term ($F = 6.52$, $p < 0.001$) among the HP and LP learners across the three university groupings. Post hoc LSD test (Table 5V6, appendix V) revealed that the mean scores of the four measures of SPK in PQ/LP learners were significantly different from the other groups and appeared to be the lowest SPK mean scores across the six groups. S/LP learners' mean scores for the four measures of SPK were the second lowest among the six groups of learners. The mean scores of the four SPK obtained by R/LP learners were not significantly different from those obtained by HP learners in the three university groupings. Thus, the ranking of learners with the most to the least SPK among the six groups of learners is displayed in Figure 5.1. Surprisingly, the third multivariate analysis of variance revealed that the SPK possessed by R/LP learners was equivalent to those obtained by HP learners in Univ PQ, Univ R and Univ S.

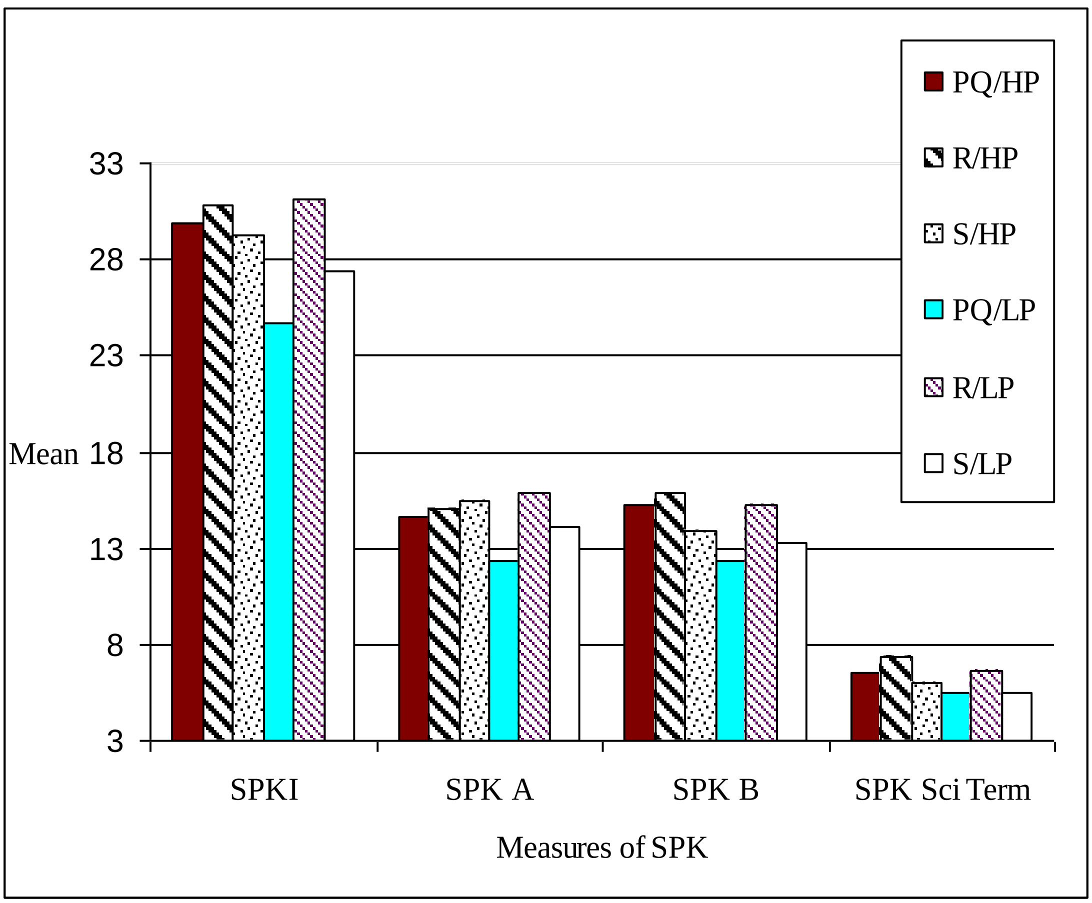

Figure 5.1 SPK scores possessed by HP and LP learners in Univ PQ, Univ R and Univ S

5.4.3 The relationship between scientific prior knowledge and reading strategies

Table 5.18 presents the correlations between the four measures of SPK and the three types of strategies used while reading two scientific texts by HP and LP learners.

Table 5.18

Correlations between Three Types of Strategies Used by HP and LP learners and Four Measures of SPK (N = 336)

Text	Strategies	SPKI	SPK A	SPK B	SPK Scientific Term
		HP Learners (N = 124)			
Scientific Text A	MC	.097	.156	.025	.038
	HC	.086	.138	.022	.052
	LC	.043	.090	-.008	.041
Scientific Text B	MC	.085	.148	.012	.010
	HC	.126	.189(*)	.045	.055
	LC	-.022	.033	-.068	-.022
		LP Learners (N = 212)			
Scientific Text A	MC	.178**	.089	.232**	.163*
	HC	.204**	.116	.254**	.191**
	LC	.135	.049	.195**	.080
Scientific Text B	MC	.189**	.073	.269**	.209**
	HC	.223**	.114	.289**	.225**
	LC	.150*	.036	.236**	.165*

*p< 0.05 level (2-tailed), ** p < 0.01 level (2-tailed).

The result indicates that in the HP learners, correlations between the four measures of SPK and MC, HC and LC strategies were absent. Whereas in the LP learners, correlations between three measures of SPK and strategy use were positive and significant but weak. In addition, the correlation coefficients tended to increase very slightly from scientific text A (less difficult/familiar) to text B (difficult/less familiar). However, there was no correlation between SPK A and MC, HC, and LC strategies while reading scientific text A in all LP learners.

Table 5.19

Correlations between Strategy Use and Measures of SPK among HP and LP Learners in Univ PQ, R and S

		Univ PQ				Univ R				Univ S			
	Strat-egies	SPKI	SPK A	SPK B	SPK Sci Term	SPKI	SPK A	SPK B	SPK Sci Term	SPKI	SPK A	SPK B	SPK Sci Term
		PQ/HP Learners (N =53)				R/HP Learners (N =39)				S/HP Learners (N = 32)			
Scientific	MC	.277*	.307*	-	.080	-.027	-.050	-	-.094	-.090	.091	-	.090
Text A	HC	.202	.249	-	.060	.039	.018	-	-.046	-.042	.095	-	.160
	LC	.161	.187	-	.110	-.107	-.108	-	-.119	.000	.111	-	.108
Scientific	MC	.262	-	.217	.127	.025	-	.028	-.098	-.132	-	-.260	-.009
Text B	HC	.196	-	.158	.041	.175	-	.149	.043	-.043	-	-.237	.177
	LC	.101	-	.070	.093	-.063	-	-.053	-.146	-.182	-	-.259	.014
		PQ/LP Learners (N =104)				R/LP Learners (N = 37)				S/LP Learners (N = 71)			
Scientific	MC	.033	-.065	-	.085	.235	.163	-	.138	.293*	.207	-	.218
Text A	HC	.073	-.031	-	.129	.331*	.221	-	.315	.266*	.199	-	.142
	LC	.008	-.082	-	-.034	.192	.063	-	.199	.207	.136	-	.110
Scientific	MC	.064	-	.181	.152	.175	-	.230	.099	.298*	-	.363**	.303*
Text B	HC	.108	-	.193*	.148	.203	-	.291	.174	.314**	-	.360**	.292*
	LC	.010	-	.133	.064	.106	-	.219	.100	.285*	-	.332**	.280*

* *p*< 0.05 level (2-tailed), ** *p* < 0.01 level

Table 5.19 displays the correlations between the four measures of SPK and the three types of strategies used by HP and LP learners in Univ PQ, Univ R and Univ S. The data presented in this table were intended to compare the correlations between strategy use and SPK among HP and LP learners in the three university groupings which have been shown to possess varying amount of scientific prior knowledge on each text.

In general, HP learners in Univ PQ, R and S did not show significant correlations between strategy use and the four measures of SPK except for those in Univ PQ. In PQ/HP learners, there were positive and significant but weak correlations between MC strategies used to read text A and SPKI ($r = .277$, $p < 0.05$), and SPK A ($r = .307$, $p < 0.05$). Being proficient in the English language as well as possessing higher SPK compared to the LP learners might have been enough for the HP learners to understand the two texts without having to use their SPK as a top down strategy.

LP learners in Univ PQ and Univ S too did not show many correlations between strategy use and the four measures of SPK while reading the two scientific texts except for one significant correlation in each group. In PQ/LP learners, there was a significant but very weak correlation between HC strategies used to read text B and SPK B ($r = .193$, $p < 0.05$). In R/LP learners, there was only one positive and modest correlation between HC strategies used to read text A and SPKI ($r = .331$, $p < 0.05$). In the case of PQ/LP learners, they were found to have lower SPK compared to R/LP learners. Thus, it could be assumed that their SPK was not sufficient for them employ any strategies to compensate for their limited L2 proficiency, hence the lack of correlation. On the other hand, since it was found earlier (Figure 5.1, pg. 215) that R/LP learners possessed high SPK and was comparable to those possessed by HP learners in all three university groupings, they may have employed top down strategies (HC strategies) to compensate for their limited L2 proficiency in the effort to comprehend the two scientific texts.

In the S/LP learners, MC and HC strategies used while reading text A correlated positively to SPKI, r = .293 ($p < 0.05$) and r = .266 ($p < 0.05$) respectively. There were no correlations between LC strategies of text A and SPKI as well as all types of strategies to SPK A. Since scientific text A was less difficult and on a familiar topic, these learners might not have needed to access their SPK to understand the text. On the other hand, MC, HC and LC strategies used to read text B correlated positively and significantly yet modestly to SPKI, SPK B and SPK scientific terminology. Compared to PQ/LP learners, S/LP learners possessed significantly higher SPK and thus they might have tried to compensate their limited L2 proficiency by employing not only top down strategies (HC strategy) but also to unpack problematic sentences and words (LC strategy) when reading scientific text B.

In summary, the analyses on respondents' scientific prior knowledge and its relationship to strategy use reveal the following findings:

(1) Scientific prior knowledge possessed by the ESL science undergraduates in the three university groupings was not comparable. Respondents in Univ R

possessed the highest mean in SPK followed by those in Univ S and then Univ PQ.

(2) Scientific prior knowledge correlated weakly to MC strategies in only HP learners of Univ PQ for scientific texts A and B. HP learners in Univ R and Univ S showed no correlations between scientific prior knowledge and strategy use in texts A and B. This could perhaps be attributed to the higher prior knowledge that they possessed which did not require them to strategize in order to understand the text. The prior knowledge was already internalized and the new information they read from both scientific texts may have unconsciously blended in with the old information.

(3) However, HC strategy correlated modestly to scientific prior knowledge in LP learners in Univ R and almost all strategies correlated modestly to scientific prior knowledge in LP learners of Univ S. One assumption may be that being low proficiency learners, these two groups with higher level of scientific prior knowledge were utilizing top down strategies such as accessing prior knowledge and inferring content in their attempt to make sense of the two scientific texts.

5.4.4 The relationship between scientific prior knowledge and specific reading strategies possessed by LP learners in Univ R and Univ S

The findings on these two groups of LP learners (of Univ R and Univ S) were significant especially since it partially confirms Stanovich's (1980) claim that less proficient readers may exert greater compensatory strategies by exerting greater effort to access their prior knowledge in their specialized area to make up for their inadequate linguistic knowledge. Therefore, it is noteworthy to determine the specific strategies which were likely to interact with the learners' prior knowledge.

Table 5.20
Pearson Correlations between Specific HC Strategies used by R/LP learners (N = 37) and Measures of SPK

	While Reading Text A			While Reading Text B		
	SPKI	SPK A	SPK Sci Term	SPKI	SPK B	SPK Sci Term
HC-Visualizing	.363*	.293	.356*	.200	.252	.281
HC-Analyzing Visual Diagram	.270	.175	.183	.173	.248	.073
HC-Analyzing Text	.232	.128	.223	.374*	.413*	.214
HC-Inferring Language	.126	-.029	.253	.135	.281	.173
HC-Inferring Content	.276	.215	.267	.196	.254	.111
HC-Accessing Prior Knowledge	.263	.196	.040	.274	.355*	.180
HC-Summarizing	.107	.110	.206	.010	.059	.027
HC-Questioning content	.276	.212	.202	.131	.211	.102
HC-Reading for Global Understanding	.237	.151	.304	.070	.181	.188

* $p < 0.05$ level (2-tailed).

Table 5.20 displays the correlations between specific HC strategies and the measures of SPK among LP learners in Univ R. Only HC strategies were examined in detail since earlier analyses revealed that the measures of SPK showed positive and significant correlations with only HC strategies. The data seem to suggest that R/LP learners' SPKI and SPK scientific terminology correlated significantly but moderately to HC visualizing ($r = .363$, $p < 0.05$) and ($r = .356$, $p < 0.05$) respectively, while reading scientific text A. On the other hand, SPKI correlated moderately to HC analyzing text ($r = .374$, $p < 0.05$) and SPK B correlated modestly to HC analyzing text ($r = .413$, $p < 0.05$) while they read text B. In addition, SPK B also correlated modestly to HC accessing prior knowledge ($r = .355$, $p < 0.05$). In sum, the data show that the higher SPK one possessed, the more intense the strategy s/he would utilize in an effort to comprehend the scientific texts. In the case of R/LP learners, they tended to compensate their inadequate L2 proficiency by using their SPK to visualize, analyze text, and compare the text to their prior knowledge.

Table 5.21 presents the correlations between specific strategies used by S/LP learners and three measures of SPK. In contrast to R/LP learners whose SPK correlated only to HC strategies, S/LP learners' three measures of SPK correlated to all MC, HC and LC strategies. As Table 5.21 shows, in general, when S/LP learners read text A (less difficult/ familiar topic), seven specific strategies correlated significantly to the measures of SPKI which were MC planning ($r = .242$, $p < 0.05$), MC evaluating ($r = .354$, $p < 0.01$), HC visualizing ($r = .406$, $p < 0.01$), HC analyzing ($r = .304$, $p < 0.01$), HC summarizing ($r = .315$, $p < 0.01$), LC decoding ($r = .355$, $p < 0.01$), and LC paraphrasing ($r = .237$, $p < 0.05$).

Table 5.21

Correlations between Specific Strategies used by S/LP learners (N = 71) and Measures of SPK

	Scientific Text A			Scientific Text B		
	SPKI	SPK A	SPK Sci Term	SPKI	SPK B	SPK Sci Term
MC- Planning	.242*	.227	.136	.197	.209	.178
MC-Monitoring	.233	.135	.210	.221	.279*	.294*
MC-Evaluating	.354**	.260*	.220	.349**	.432**	.308**
MC-Debugging	.204	.112	.205	.281*	.350**	.286*
HC-Visualizing	.406**	.313**	.288*	.351**	.362**	.397**
HC-Analyzing Visual Diagram	.211	.166	.212	.182	.229	.278*
HC-Analyzing Text	.304**	.245*	.143	.299*	.355**	.199
HC-Inferring Language	.182	.103	.052	.179	.240*	.021
HC-Inferring Content	.173	.097	-.035	.245*	.316**	.201
HC-Accessing Prior Knowledge	.207	.140	.162	.269*	.299*	.246*
HC-Summarizing	.315**	.258*	.127	.311**	.347**	.363**
HC-Questioning content	.229	.191	.119	.227	.292*	.071
HC-Reading for Global Understanding	-.178	-.131	-.079	.121	.081	.200
LC-Decoding	.355**	.320**	.088	.359**	.386**	.333**
LC-Translating	-.006	-.036	-.019	.074	.110	.001
LC-Questioning language	.067	.018	.041	.261*	.317**	.174
LC-Paraphrasing	.237*	.158	.130	.383**	.400**	.393**
LC-Memorizing & Taking Notes	.216	.156	.160	.103	.117	.262*
LC-Reading for Local Understanding	.195	.105	.152	.176	.239*	.166

* $p < 0.05$ level (2-tailed), ** $p < 0.01$ level (2-tailed)

In addition, SPK A correlated weakly to MC-evaluating ($r = .261$, $p < 0.05$), HC-analyzing text ($r = .245$, $p < 0.05$), and HC-summarizing ($r = .258$, $p < 0.05$), but correlated modestly to HC-visualizing ($r = .313$, $p < 0.01$) and LC-decoding ($r=.320$, $p <0.01$). In addition, SPK scientific term only correlated to HC visualizing ($r = .288$, $p < 0.05$).

Evidently, when S/LP learners read scientific text B, which was syntactically more difficult on a less familiar topic, more strategies correlated to the measures of SPK and the correlation strengths were stronger in text B compared to text A. Among the strongest correlations were recorded between SPK B and MC evaluating ($r = .432$, $p < 0.01$), SPK B and LC paraphrasing ($r = .400$, $p < 0.01$) as well as between SPK scientific term and HC visualizing ($r = .397$, $p < 0.01$) and SPK scientific term and LC paraphrasing ($r = .393$, $p < 0.01$). This finding shows that the score for strategies like evaluating, visualizing, analyzing text, summarizing, and decoding increases with increased text difficulty. This may perhaps indicate that having limited L2 proficiency to unpack a difficult text such as text B compels the ESL readers to process it from the top down. In other words, when the text increases in syntactic difficulty (text B), SPK was accessed more rigorously through many other types of HC strategies. In addition, ESL readers also accessed their SPK of scientific terminology through the use of MC, HC and LC strategies.

Therefore, in response to the first part of research question two on whether there is a significant relationship between scientific prior knowledge and cognitive and metacognitive strategies utilized when the ESL science undergraduates read two scientific texts, there are three findings:

(1) There were significant and positive yet modest relationships between SPK and cognitive and metacognitive strategies in learners with limited proficiency but high prior knowledge.

(2) The second significant finding is that the correlations between SPK and strategies were stronger in text B (difficult/ less familiar) which is consistent with Baker and Brown's (1984) claim that difficult reading tasks require rigorous problem solving strategies. Thus, the more difficult the text, the more rigorous the LP learners with ample SPK would strategize in order to comprehend the texts.

(3) The final finding is on the lack of correlations between scientific prior knowledge and strategies in learners with high prior knowledge and high L2 proficiency (R/HP, S/HP and PQ/HP learners) as well as in learners with low prior knowledge and low L2 proficiency (PQ/LP learners).

5.4.5 The relationship between scientific prior knowledge and reading comprehension scores of the two scientific texts

To recapitulate, the SPK possessed by the HP learners as well as their reading comprehension scores were consistently higher than those of the LP learners. Table 5.22 presents the result of independent t-test on SPK possessed by HP and LP learners.

Table 5.22

Independent T-test on SPK Possessed and Reading Comprehension Scores Obtained by HP and LP Learners

	t	*df*	*p*
SPK A	-2.73	334	.007
SPK B	-3.65	334	.000
SPK SciTerm	-3.93	334	.000
SPKI	-3.55	334	.000
Written Summary A	-2.67	330	.008
Written Summary B	-1.88	324	.061
RCA	-4.55	334	.000
RCB	-4.60	334	.000

Independent t-tests revealed that the means of the four measures of SPK possessed by HP and LP learners were significantly different at $p < 0.05$. Similarly, the means of reading comprehension scores obtained by HP and LP learners were also significantly different except for written summary B (the non significant difference is discussed further in section 5.5.4, pg. 245). Pearson correlation analyses were then conducted on the collective HP and LP learners to determine if there were significant relationships between the measures of SPK and the comprehension scores of the two scientific texts.

Table 5.23

Correlations between the Measures of SPK and Reading Comprehension Scores in the Collective Group (n=336)

Scientific Prior Knowledge	Reading Comprehension A (RCA)	Reading Comprehension B (RCB)
SPKI	.083	.111*
SPK A	.047	-
SPK B	-	.140*
SPK on Scientific Term	.182**	.205**

* *p* < 0.05 level (2-tailed).; **p* < 0.01 level (2-tailed).

Table 5.23 shows a correlation between SPK and reading comprehension scores in the collective group (n=336). It was found that SPKI and SPK A did not correlate to RCA. Significant yet very weak correlations were observed between RCB and SPKI (r =.111, p < .005) and SPK B (r =.140, p < .005). SPK on scientific term correlated weakly to RCA (r =.182, p < .001) and RCB (r =.205, p < .001).

Table 5.24

Correlations between the Measures of SPK and Reading Comprehension Scores in HP and LP Learners

Scientific Prior Knowledge	Written Summary A	Written Summary B	Reading Comprehension A (RCA)	Reading Comprehension B (RCB)
HP Learners (N = 121)				
SPKI	.086	.084	.020	.128
SPK A	.006	-	-.031	-
SPK B	-	.112	-	.165
SPK on Scientific Term	.289**	.089	.259**	.258**

Table continues…

Table 5.24 (continued)

Scientific Prior Knowledge	Written Summary A	Written Summary B	Reading Comprehension A (RCA)	Reading Comprehension B (RCB)
		LP Learners (N = 211)		
SPKI	.010	.086	.051	.030
SPK A	-.025	-	.038	-
SPK B	-	.099	-	.053
SPK on Scientific Term	.026	.112	.048	.092

** $p < 0.01$ level (2-tailed).

Table 5.24 presents the correlations between the measures of SPK and the measures of reading comprehension of texts A and B in the HP and LP learners. In the HP learners, only SPK scientific term correlated significantly but weakly to written summary A (r = .289, p < 0.01), RCA (r = .259, p < 0.01), and RCB (r = .258, p < 0.01). Contrary to expectation, SPKI, SPK A and SPK B did not correlate to any of the reading comprehension measures. In the LP learners, none of the SPK measures significantly correlated to the four measures of reading comprehension of scientific texts.

The data were further analysed by dividing the respondents into their respective university groupings. Table 5.25 displays the mean scores of each SPK and reading comprehension (RC, hereafter) measure across the three university groupings before Pearson correlation analyses were performed.

Table 5.25

Descriptive Statistics and Results of MANOVA on Reading Comprehension Scores and SPK across Three University Groupings

RC Scores / SPK	Univ PQ		Univ R		Univ S		MANOVA		
	Mean	SD	Mean	SD	Mean	SD	*Df*	*F*	*P*
				Reading Comprehension					
Written Summary A	9.91	5.84	8.44	5.49	6.47	4.81	2	11.93	.000*
Written Summary B	6.83	4.43	5.41	4.08	4.85	3.76	2	7.92	.000*
RCA	28.65	7.73	28.84	8.30	24.82	6.21	2	10.73	.000*
RCB	24.49	6.37	23.08	7.17	20.80	4.96	2	11.57	.000*
				Scientific Prior Knowledge					
SPKI	26.43	8.44	31.01	7.34	28.00	8.50	2	7.99	.000*
SPK A	13.11	4.49	15.42	4.06	14.53	4.63	2	7.75	.000*
SPK B	13.32	4.73	15.59	4.38	13.47	4.74	2	6.69	.001*
SPK on Scientific Term	5.87	2.16	6.99	2.14	5.65	1.97	2	10.04	.000*

*significant at 0.05 level

Analyses on sections 5.3.4 and 5.4.2 are presented again in Table 5.25. Earlier analyses have shown that the reading comprehension scores obtained by respondents in Univ PQ were not significantly different from those obtained by respondents in Univ R whereas the comprehension scores obtained by respondents in Univ S were consistently lower than the other two groups. Yet, the analyses on respondents' SPK indicated that the mean scores obtained by those in Univ PQ were consistently lower than those obtained by respondents in Univ R and also lower than or similar to those obtained by respondents in Univ S. In sum, the data above show that learners who possessed low SPK (Univ PQ) managed to outperform their counterparts who possessed higher SPK (Univ R and Univ S).

Table 5.26 presents the correlation analyses between the measures of SPK and the measures of reading comprehension of scientific texts A and B across three university groupings.

Table 5.26

Correlations between the Measures of SPK and Reading Comprehension Scores in Univ PQ, R and S

	Written Summary A	Written Summary B	RCA	RCB
		Univ PQ		
SPKI	.077	.192*	.068	.209**
SPK A	.038	.132	.046	.125
SPK B	.101	.222**	.077	.255**
SPK on Scientific Term	.123	.157	.114	.244**
		Univ R		
SPKI	.049	.058	.079	.118
SPK A	-.055	.082	.001	.048
SPK B	.133	.023	.132	.153
SPK on Scientific Term	.246*	.193	.273*	.254*
		Univ S		
SPKI	.148	.095	.131	.025
SPK A	.136	.091	.157	.095
SPK B	.132	.082	.081	-.048
SPK on Scientific Term	.129	.028	.135	.069

*$p < 0.05$ level (2-tailed); ** $p < 0.01$ level (2-tailed).

In Univ PQ, SPKI and SPK B correlated significantly but very weakly to written summary B at $r = .192$ ($p < 0.05$) and $r = .222$ ($p < 0.01$) as well as to RCB at $r = .209$ ($p < 0.01$) and $r = .255$ ($p < 0.01$) respectively. SPK on scientific terminology correlated weakly to RCB at $r = .244$ ($p < 0.01$).

In Univ R, only SPK on scientific term correlated to written summary A ($r = .246$, $p < 0.05$), RCA ($r = .273$, $p < 0.05$), and RCB ($r = .254$, $p < 0.05$). Other measures of SPK did not correlate to any measures of reading comprehension. While in Univ S, there was no correlation between SPK and reading comprehension scores of texts A and B.

Thus, there are three findings in response to the second part of research question two on whether there is a significant relationship between SPK and reading comprehension scores of the two scientific texts:

(1) First, SPK A did not correlate to any of the comprehension measures in any group. This may suggest that when learners read syntactically less difficult text and on a familiar topic, it does not necessitate them to consciously access their prior knowledge.

(2) Second, there was significant but weak relationship between SPK B and reading comprehension scores of text B. However, the relationship was observed in learners with low SPK (Univ PQ learners).

(3) Third, there was also a significant but weak relationship between SPK scientific terminology and comprehension scores among learners with relatively high SPK and high L2 proficiency (Univ R learners).

5.5 Research Question 3: The contribution of L2 proficiency to strategy use and reading comprehension of two scientific

This section reports on the findings to address research question three on whether (a) "there is a significant relationship between L2 proficiency and cognitive and metacognitive strategies used to read the two scientific texts" and whether (b) "there is a significant relationship between L2 proficiency and reading comprehension scores of the two scientific texts". Respondents' L2 proficiency, strategy use and reading comprehension scores of the two scientific texts were analyzed using descriptive statistics and multivariate analysis of variance (MANOVA) to determine the means of cognitive and metacognitive cognitive strategies used by respondents and to indicate whether any of the differences that emerged between the groups was significant. In addition, the data were also analyzed using Pearson correlation analysis to determine if there was any correlation between L2 proficiency and strategy use as well as between L2 proficiency and reading comprehension scores.

5.5.1 Cognitive and metacognitive strategies used by ESL learners with different L2 proficiency levels

Table 5.27 shows the mean scores of three types of strategies which were MC, HC, and LC strategies used by learners in four different levels of L2 proficiency in two reading tasks. The table also displays the results of the MANOVA conducted on each strategy.

Table 5.27

Descriptive Statistics and MANOVA on Strategies Used by ESL Science Undergraduates (N= 336) with Different Levels of L2 Proficiency

	Mean				MANOVA		
	Limited L2	Modest L2	Competent L2	Good L2	*F*	*df*	*P*
			Text A				
Metacognitive strategies (MC)	4.33	4.65	4.66	4.31	1.81	3	.146
Higher Cognitive Strategies (HC)	4.12	4.54	4.51	4.19	2.53	3	.057
Lower Cognitive Strategies (LC)	4.45	4.71	4.53	3.90	5.80	3	.001*
			Text B				
Metacognitive strategies (MC)	4.23	4.66	4.72	4.36	2.54	3	.057
Higher Cognitive Strategies (HC)	4.12	4.52	4.49	4.17	2.26	3	.082
Lower Cognitive Strategies (LC)	4.29	4.70	4.49	4.03	5.10	3	.002*

*Significant mean difference

In general, limited and good L2 learners had lower mean scores on all types of strategies compared to the modest and competent L2 proficiency groups. Yet, F statistics from multivariate analysis of variance suggests that there were no significant differences in means of MC and HC strategies across all L2 proficiency groups. However, the differences in the mean of LC strategies across the four L2 proficiency groups were indeed significant (p-value < 0.05). Table 5W1 (appendix W) shows pairwise post-hoc test for LC strategies. The data indicate that ESL undergraduates with good L2 proficiency tended to use the least LC strategies while reading both scientific texts. Modest L2 learners were found to exert the greatest LC strategies compared to other groups while reading scientific text B. This can also be seen from the estimated means in Figures 5.2 and 5.3.

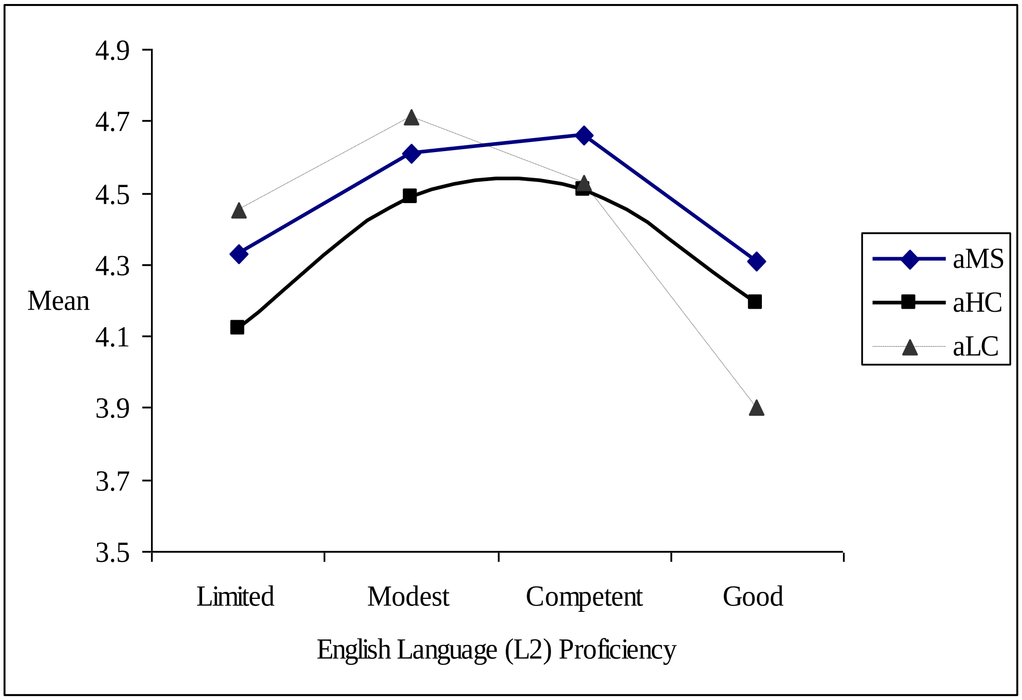

Figure 5.2 Estimated mean from MANOVA of MC, HC and LC strategies while reading scientific text A

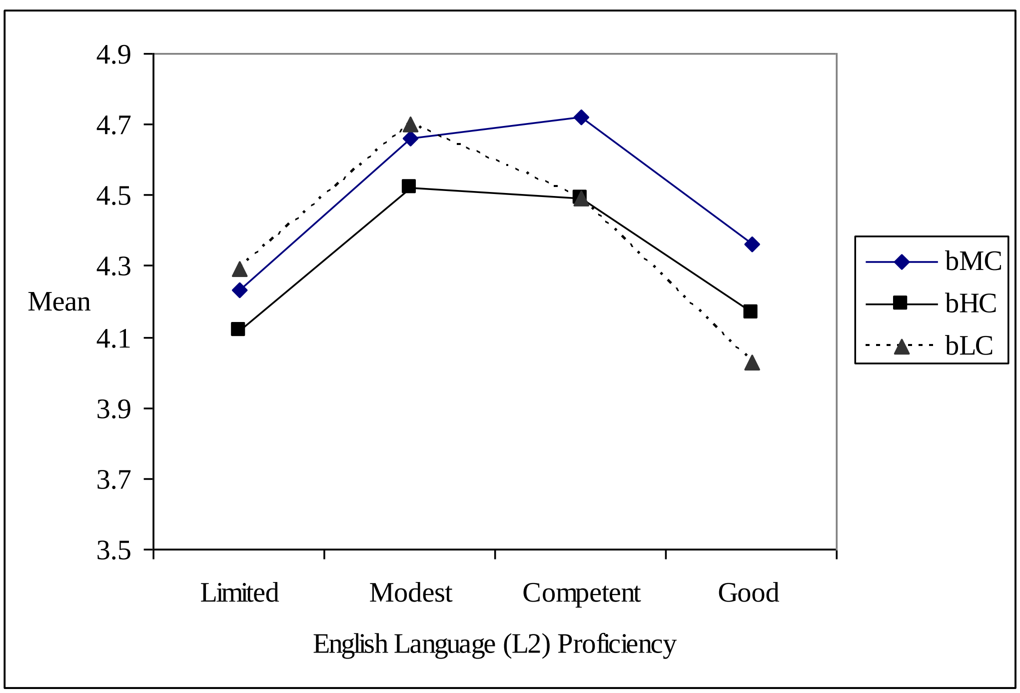

Figure 5.3 Estimated mean from MANOVA of MC, HC and LC strategies while reading scientific text B

Figures 5.2 and 5.3 on the previous page show that good L2 proficiency learners employed significantly less LC strategies in both reading tasks compared to the other three groups. Evidently, low proficiency learners (limited and modest L2) tended to use LC strategies the most followed by MC and HC strategies. In contrast, higher proficiency learners (competent and good L2) relied on MC strategies the most followed by the two cognitive strategies. It is also worth mentioning that competent L2 learners tended to exert equivalent emphasis on HC and LC strategies in the two reading tasks while MC strategies remained the highest to guide and monitor their reading comprehension.

5.5.2 The relationship between L2 proficiency and reading strategies among ESL science undergraduates (N = 336)

Pearson correlation analysis was then conducted to see if there was significant relationship between L2 proficiency and the three types of strategies used by the respondents while reading the two scientific texts. Table 5.28 presents the correlation coefficients between L2 proficiency and strategy use in the two reading situations.

Table 5.28

Correlations between L2 Proficiency and Strategy Use in Two Reading Tasks

	English language (L2) Proficiency	
	Scientific Text A	Scientific Text B
Metacognitive strategies (MC)	-.008	.028
Higher Cognitive Strategies (HC)	-.010	-.012
Lower Cognitive Strategies (LC)	-.151**	-.117*

* $p < 0.05$; ** $p < 0.01$

As the results in Table 5.28 reveal, the correlations between MC and HC strategies and L2 proficiency were not significant, but there was a very weak correlation between LC strategies and L2 proficiency, r = -0.151 ($p < 0.01$) in text A and r = -0.117 ($p < 0.05$) in text B. The non significant correlations between L2 proficiency and MC and HC strategies in both reading tasks indicate that ESL learners at all proficiency levels utilized comparable MC and HC strategies. This also confirms earlier findings (in section 5.5.1) that there were no significant differences in the MC and HC strategies used by ESL science undergraduates at all proficiency levels.

For a closer inspection of LC strategies, specific LC strategies which show significant correlations to L2 proficiency are reported below in Table 5.29. Interestingly, only LC strategy translating shows significant and modest yet negative correlations to L2 proficiency with r = -0.362 ($p < 0.01$) in text A and r = -0.287 ($p < 0.01$) in text B. In addition, very weak yet significant correlations were found between LC decoding and LC paraphrasing in scientific text B with r = -0.128 ($p < 0.05$) and r = -0.111 ($p < 0.05$) respectively.

Table 5.29

Correlations between L2 Proficiency and Specific LC Strategies

	English language (L2) Proficiency	
	Scientific Text A	Scientific Text B
LC-Decoding	-.098	-.128*
LC-Translating	-.362**	-.287**
LC-Questioning language	-.096	-.057
LC-Paraphrasing	-.111*	-.111*
LC-Memorizing & Taking Notes	-.044	.015
LC-Reading for Local Understanding	.054	.068

* $p < 0.05$; ** $p < 0.01$

As expected, ESL learners with lower L2 proficiency would employ more LC strategies compared to those with higher L2 proficiency, hence the negative correlation. The stronger correlation in text A may perhaps be due to text A being an easier text with regards to its sentence structure as well as on topic familiarity. Being an easier text, lower L2 proficiency learners would exert greater effort in translating the sentences and words in order to comprehend the text whereas more proficient learners tended to employ lesser effort on the same strategy as comprehension might have been somewhat automatic. On the other hand, with a more difficult text with regards to language as well as topic such as text B, every L2 proficiency group had to struggle and even high proficiency learners may have employed translating as a strategy to unpack difficult sentences or concepts, hence the weak and negative correlation observed in the second reading task.

Analyses of the first two parts of the data reveal three preliminary findings:

(1) There were no significant differences in the means of MC and HC strategies in all L2 proficiency groups. However, LC strategies were used the least by good L2 proficiency groups while modest L2 learners used LC strategies the most.

(2) LC translating correlated significantly but negatively to L2 proficiency, which indicates that this strategy decreases as the L2 proficiency of respondents increases.

(3) The r coefficient of the Pearson correlation between LC translating and L2 proficiency in text B decreases in strength compared to text A. This shows that as the language of the text becomes more difficult and topic less familiar, respondents from all proficiency levels tended to exert similar intensity in their strategy use. In other words, LC translating was exerted with greater intensity even by higher L2 proficiency groups.

5.5.3 The relationship between L2 proficiency and specific strategies among ESL learners in the three university groupings

While in general it was observed that the use of LC strategies was what differentiated lower from higher L2 proficiency learners, it would be crucial to find out if this general assumption holds when the correlations were done according to the three university groupings. Table 5.30 presents the Pearson correlation coefficients between L2 proficiency and specific strategies in the three university groupings.

Table 5.30

Correlations between L2 Proficiency and Specific LC Strategies across Three University Groupings

Strategies	L2 Proficiency					
	Scientific Text A			Scientific Text B		
	Univ PQ	Univ R	Univ S	Univ PQ	Univ R	Univ S
MC-Planning	-.089	-.231*	.013	-.031	-.232*	.076
HC-Visualizing	.041	-.241*	.009	.109	-.134	.016
HC-Inferring Content	-.137	-.309**	.002	-.050	-.298**	-.069
HC-Accessing Prior Knowledge	.074	-.195	.050	.059	-.295**	.091
HC-Summarizing	-.009	-.366**	-.061	.066	-.238*	-.044
HC-Questioning content	.022	-.203	.045	.021	-.227*	-.048
LC-Decoding	-.027	-.390**	-.003	-.068	-.353**	-.044
LC-Translating	-.332**	-.523**	-.273**	-.213**	-.527**	-.187
LC-Questioning language	-.096	-.302**	-.018	-.003	-.312**	.051
LC-Paraphrasing	-.027	-.350**	-.100	-.043	-.332**	-.044

*$p < 0.05$; ** $p < 0.01$

The data indicate that the correlations between L2 proficiency and specific strategies used in reading scientific texts A and B vary from one university setting to another. It was found that in the first reading task (text A), LC translating correlated negatively but modestly to L2 proficiency in Univ PQ (r = -0.332, p < 0.01), moderately strong to L2 proficiency in Univ R (r = -0.523, p < 0.01), and weakly to L2 proficiency in Univ S (r = -0.273, p < 0.01). While Univ PQ and S showed only one significant correlation in the first reading task, Univ R revealed eight significant yet negative correlations. They were between L2 proficiency and MC planning (r = -0.231, $p < 0.05$), HC visualizing (r = -0.241, $p < 0.05$), HC inferring content (r = -0.309, $p < 0.01$), HC summarizing (r = -0.366, $p < 0.01$), LC decoding (r = -0.390, $p < 0.01$), LC translating (r = -0.523, $p < 0.01$), LC questioning language (r = -0.302, $p < 0.01$), and LC paraphrasing (r = -0.350, $p < 0.01$).

In reading scientific text B, the correlation between L2 proficiency and LC translating in Univ PQ was negative but weak (r = -0.213, $p < 0.01$) whereas in Univ S, there was no correlation at all between L2 proficiency and any of the specific strategies. In contrast, data from Univ R indicate nine negative correlations ranging from weak to moderately strong. They were between L2 proficiency and MC planning (r = -0.232, $p < 0.05$), HC inferring content (r = -0.298, $p < 0.01$), HC accessing prior knowledge (r = -0.295, $p < 0.01$), HC summarizing (r = -0.238, $p < 0.05$), HC questioning content (r = -0.227, $p < 0.05$), LC decoding (r = -0.353, $p < 0.01$), LC translating (r = -0.527, $p < 0.01$), LC questioning language (r = -0.312, $p < 0.01$), and LC paraphrasing (r = -0.332, $p < 0.01$).

A negative correlation shows that as L2 proficiency increases, the mean of the particular strategy decreases. This implies that the strategies that correlated negatively to L2 proficiency were those highly used by LP learners but less used by HP learners in reading the two scientific texts. It is interesting to find that in Univ PQ and Univ S, there were no significant differences in the use of other specific strategies between HP and LP learners except for LC translating. This may perhaps mean that both HP and LP learners in these two university groupings equally utilized the specific strategies under study. However, in Univ R, LP learners were found to use more MC planning, HC visualizing, inferring content, summarizing, LC decoding, translating, questioning language and paraphrasing compared to their HP counterparts. Similar trend occurred in the second reading task with an exception with Univ S where there was an absence of association between L2 proficiency and specific strategies.

What does this mean? One assumption could be that the L2 proficiency level of LP learners in Univ R was significantly lower than their HP counterparts or lower than those in the other two university groupings. If this was so, their low L2 proficiency may be the reason that compelled them to exert greater intensity on certain strategies. To confirm this assumption, a one-way ANOVA was conducted on L2 proficiency of all six groups. The results are presented in Table 5.31.

Table 5.31
Descriptive Statistics and One-Way ANOVA on L2 Proficiency across Three University Groupings

	Descriptive Statistics			One-way ANOVA		
Univ	Mean	SD	N	*df*	*F*	*p*
Univ PQ HP learners	4.19	0.40	53	2	.139	.870
Univ R HP learners	4.21	0.41	39			
Univ S HP learners	4.16	0.37	32			
Univ PQ LP learners	2.88	0.32	104	2	.710	.493
Univ R LP learners	2.95	0.23	37			
Univ S LP learners	2.87	0.34	71			
Total	3.37	0.71	336			

* $p < 0.05$ level

As the data in Table 5.31 shows, the one-way ANOVA in both HP and LP groups showed *F* to be not significant beyond the .05 level: $F(2, 121) = .870$; $p > 0.05$ and $F(2, 209) = .493$; $p > 0.05$ respectively. The results suggest that there were no significant differences in the L2 proficiency level among HP learners as well as among the LP learners across the three university groupings. Therefore, the first assumption was rejected.

Another assumption could be that R/HP learners did not strategize as much as R/LP learners whereas HP learners in Univ PQ and S strategized with the same intensity. Therefore, while L2 proficiency did not dictate the use of specific strategies among HP and LP learners in Univ PQ and S except for LC translating, in Univ R, the result seemed to suggest that compared to HP learners, LP learners tended to use more MC planning, HC inferring content, HC accessing prior knowledge, HC summarizing, HC questioning content, LC decoding, LC translating, LC questioning language, and LC paraphrasing. On the contrary in Univ S, during the second reading task, L2 proficiency did not influence the type of reading strategies used.

Thus, there are three findings in response to the first part of research question three on whether there was significant relationship between L2 proficiency and reading strategies of the two scientific texts:

(1) There was no correlation between L2 proficiency and MC and HC strategies used while reading scientific texts A and B among ESL science undergraduates (N = 336). The non significant correlations between L2 proficiency and MC as well as HC strategies in both reading tasks indicated that ESL learners at all proficiency levels utilized comparable strength of HC and MC strategies.

(2) When the data were reanalyzed according to the three university groupings, it was found that in Univ PQ and Univ S, only LC strategy translating correlated negatively to L2 proficiency. This finding reflects the general finding when the data were analyzed collectively (N=336). However, the data from LP learners in Univ R revealed that in reading texts A and B, there were eight and nine specific strategies that correlated negatively to L2 proficiency respectively. This finding indicates that LP learners in Univ R exerted more intensity to their strategies than the HP learners. However, this pattern of strategy use between HP and LP learners was not evident among ESL science undergraduates in Univ PQ and Univ R.

(3) These findings suggest that on the whole, ESL science undergraduates of all L2 proficiency levels utilize similar strategies with two exceptions. First, LP learners tend to utilize more LC strategy translating than HP learners. Second, very proficient L2 learners (such as those in Univ R) do not utilize as many strategies as other learners when the language of the scientific texts matches their L2 proficiency and comprehension becomes automatic.

5.5.4 The relationship between L2 proficiency and reading comprehension scores of two scientific texts

Table 5.32 shows the means of written summaries (WS A and WS B) and total reading comprehension scores of texts A (RCA) and B (RCB) obtained by ESL undergraduates (N=336) in four L2 proficiency groups.

Table 5.32
Reading Comprehension Scores and MANOVA among Four L2 Proficiency Groups

	Mean				MANOVA		
	Limited L2	Modest L2	Competent L2	Good L2	*F*	*df*	*p*
			Scientific Text A				
WS A	7.74	8.10	8.97	12.23	4.07	3	.007*
RCA	25.44	26.47	28.98	35.79	13.32	3	.000*
			Scientific Text B				
WS B	4.41	5.74	6.23	7.52	2.38	3	.069
RCB	19.63	22.43	24.45	28.91	12.11	3	.000*

*Significant mean difference

In general, the data indicate that as learners' L2 proficiency increases, their reading comprehension scores of scientific texts also increase. F statistics from the multivariate analysis of variance suggest that there were significant differences in the mean scores of WS A ($p = .007$), RCA ($p <.001$), and RCB ($p < .001$). Interestingly, there was no significant difference in the mean score of written summary B across the four L2 proficiency groups. Pair-wise post-hoc test was conducted for WS A, WS B, RCA and RCB (Table 5W2, appendix W). The finding revealed that for dependent variable written summary A, the mean obtained by good

L2 learners was significantly different and thus higher than those obtained by the other three groups. However, there were no significant differences in the means of written summary A obtained by limited, modest and competent L2 learners. For RCA, the means scored by limited and modest L2 groups were not significantly different whereas the means obtained by competent and good L2 groups were significantly different from each other as well as from the two low proficiency groups.

For written summary B, the mean score obtained by good L2 learners was significantly different from and thus higher than limited L2 group. At the same time, the mean scores obtained by the limited, modest and competent L2 groups were not significantly different from each other. This means that for a difficult scientific text such as text B, it requires either advanced L2 proficiency or specific prior knowledge or perhaps other ‘x’ factors to comprehend the biochemical process of signal transduction. For RCB, each mean score obtained by the different L2 proficiency groups was significantly different from one another. This means that the mean score obtained by limited L2 learners was the lowest followed by modest, competent and good L2 groups.

Figure 5.4 displays the reading comprehension scores obtained by each L2 proficiency group. As expected, respondents did better on written summary and reading comprehension of scientific text A compared to the same comprehension measures of scientific text B. In addition, the figure shows a gradual increase in comprehension of both scientific texts as L2 proficiency increases. This implies that reading comprehension of the two scientific texts may greatly be influenced by respondents' English language proficiency.

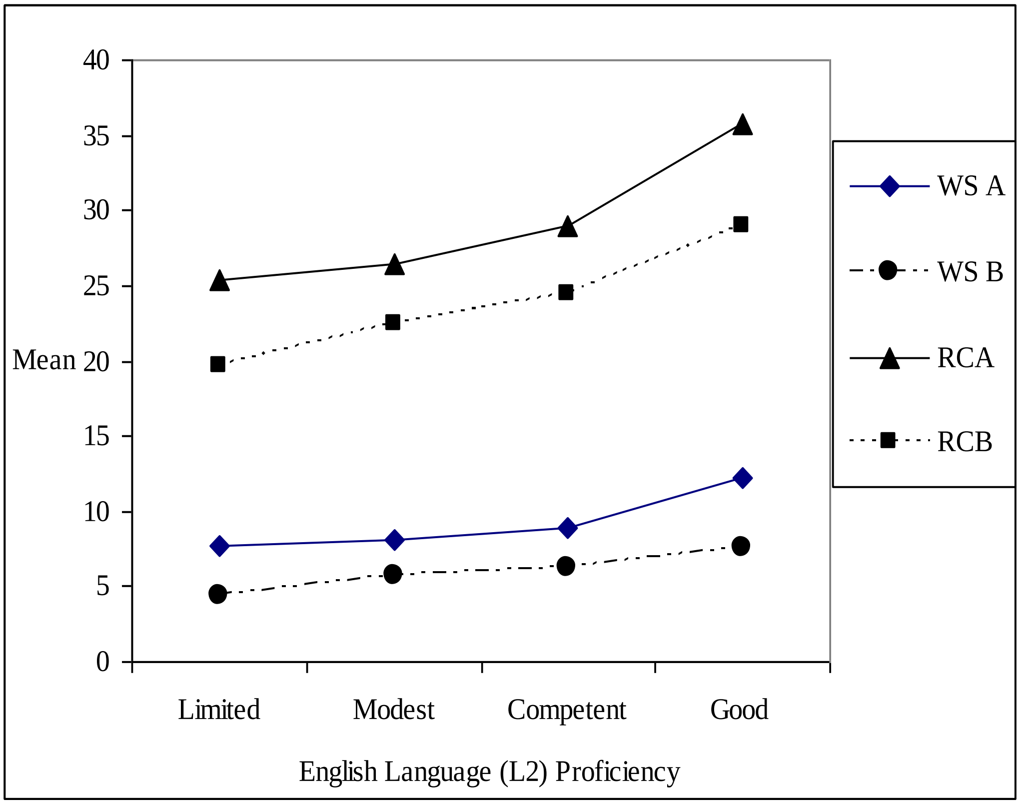

Figure 5.4 Estimated mean from MANOVA of four measures of reading comprehension among four L2 proficiency groups

Table 5.33 presents the Pearson correlation analysis between the four measures of comprehension and L2 proficiency. The data indicate that there was a significant yet very weak relationship between L2 proficiency and written summary A (r = .175, $p < 0.01$) and B (r = .142, $p < 0.05$).

Table 5.33

Correlations between L2 Proficiency and Four Measures of Reading Comprehension

	English language (L2) Proficiency
Written Summary A	.175**
Written Summary B	.142*
RCA	.295**
RCB	.306**
N	336

* $p < 0.05$; ** $p < 0.01$ level

Similarly, the relationship between L2 proficiency and RCA was significant but weak (r = .295, $p < 0.01$). However, the correlation strength increased to r = .306 ($p < 0.01$) between L2 proficiency and RCB. The stronger correlation between L2 proficiency and RCB may perhaps be due to the text syntactic difficulty as well as less familiar topic which gave proficient readers the advantage of understanding the text better compared to the less proficient.

Yet, the very weak correlation between written summary B and L2 proficiency was unexpected. This is because for written summary B, respondents were asked to write about the biochemical process of signal transduction, which was in fact 50%-60% of the total content of text B. The respondents were also allowed to write the biochemical process in the language they were most comfortable with, either in their mother tongue, in the Malay language, or in the English language or a mix of 2 or 3 languages. Therefore, if proficient L2 learners (competent and good L2) were indeed better able to comprehend the process described in text B, they should have been able to describe the biochemical process better and thus their written summary scores should have been significantly different from each other as well as from those obtained by the less proficient learners. If this were the case, the correlation between L2 proficiency and written summary B should have been stronger. Yet, the findings did not indicate the expected outcome.

Thus, before the second part of research question three could be answered, it would be crucial to look into the means of the four measures of reading comprehension against the six HP and LP learners across the three university groupings. Figure 5.5 displays the graphic summary of the findings.

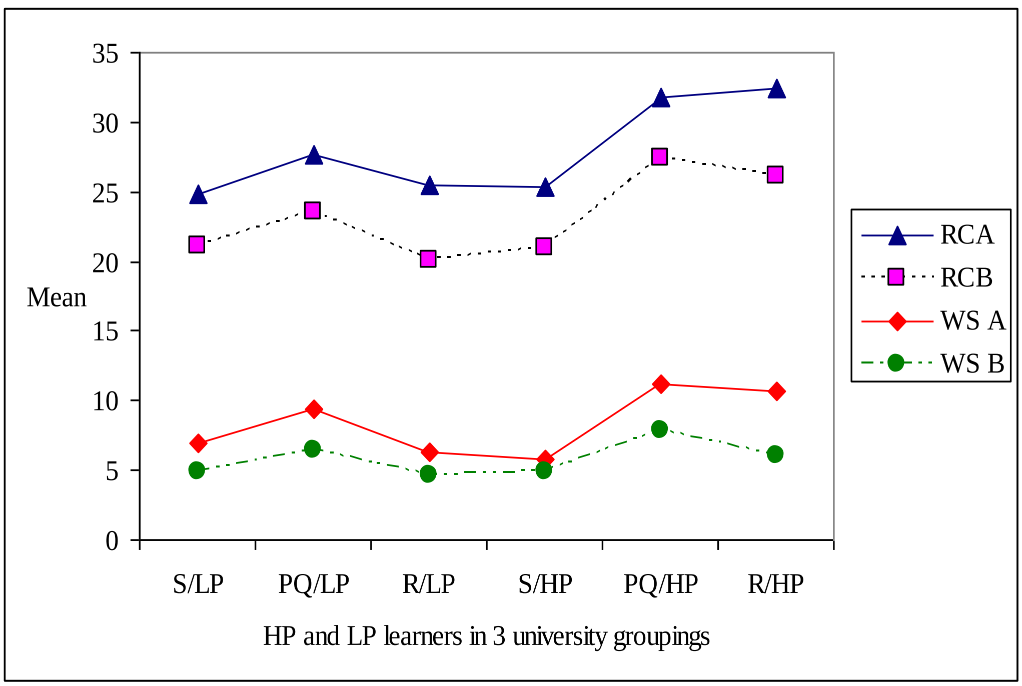

Figure 5.5 Estimated means of four measures of reading comprehension of scientific texts A and B in HP and LP learners

In Figure 5.5, the placement of HP and LP learners on the x-axis was determined by the mean of their L2 proficiency in the ascending order, as displayed in Table 5.34. This means that the mean of L2 proficiency in S/LP learners was the lowest among the six groups and the mean of L2 proficiency of R/HP learners was the highest. Figure 5.5 and Table 5.34 will be discussed simultaneously.

Table 5.34

The Means of L2 Proficiency and Four Measures of SPK Obtained by HP and LP Learners in Univ PQ, R, and S

	LP learners			HP learners		
	Univ S	Univ PQ	Univ R	Univ S	Univ PQ	Univ R
L2 Proficiency	2.87	2.88	2.95	4.16	4.19	4.21
[1]SPK A	14.11	12.36	15.86	15.47	14.58	15.00
SPK B	13.31	12.32	15.30	13.81	15.28	15.87
SPK SciTerm	5.51	5.52	6.62	5.97	6.55	7.33
[2]SPKI A+B	27.42	24.67	31.16	29.28	29.87	30.87

[1]SPK-scientific prior knowledge; [2]SPKI-scientific prior knowledge Inventory

The graphic result (Figure 5.5) indicates that the association between L2 proficiency based on university groupings and the mean of four measures of reading comprehension of scientific texts was not at all straightforward. Instead of a gradual increase in the reading comprehension scores as displayed in Figure 5.4 (pg. 247), the line graphs in Figure 5.5 are notched especially at R/LP, S/HP and R/HP. There are three interesting points in the line graphs which called for further discussion. The first point is at PQ/LP. Even though PQ/LP learners obtained the lowest marks for SPK A, SPK B, SPKI (discussed earlier in section 5.4.2) as well as low in L2 proficiency, these learners managed to outperform R/LP and S/HP learners on all four measures of reading comprehension.

The second point on the graph which must be highlighted is PQ/HP. Again, this group was less superior than R/HP in terms of L2 proficiency and on all counts of scientific prior knowledge. Yet, PQ/HP learners scored higher marks in three out of four measures of comprehension. The final issue which requires further understanding is on S/HP learners. S/HP learners were more superior than PQ/LP and R/LP in L2 proficiency and on all four measures of scientific prior knowledge yet the line graphs in Figure 5.5 suggest that R/HP learners' comprehension scores of the two texts were similar to R/LP and less than PQ/LP learners.

As metacognitive awareness was comparable in all HP and LP groups in this study (as found in section 5.3.1), two questions that arose would be as follows: (a) what caused the HP and LP learners in Univ PQ to be able to outdo their respective counterparts, and (b) what was lacking in S/HP and R/HP learners that they failed to do better than those in Univ PQ? Discussions in section 5.6 will try to answer these questions.

Thus, there are four findings in response to the second part of research question three on whether there was a significant relationship between L2 proficiency and reading comprehension of the two scientific texts:

(1) The data indicate that as learners' L2 proficiency increases, their reading comprehension scores of the scientific texts also increase. Very proficient L2 learners had the most advantage in reading and comprehending scientific texts.

(2) In addition, there were significant yet very weak correlations between L2 proficiency and written summaries of texts A and B. The weak correlation between L2 proficiency and written summary B was contrary to expectation. The expectation was that HP learners should have scored much higher means for WS B since they should have understood the biochemical process described in text B better than LP learners due to their language proficiency. In addition, they were able to write the summary of the biochemical process in the language they were most comfortable with. The advantage evidently lies with the HP learners, yet the correlation between the two variables was very weak. This suggests that both HP and LP learners could comprehend text B (difficult/less familiar) at about the same level which delineates the exclusive role of L2 proficiency in the reading comprehension of scientific text B.

(3) As opposed to the two written summaries, the relationship was significant and modest between L2 proficiency and RCB. Unlike written summary where learners had to write their comprehension on paper using a language they were most comfortable with, scores of RCA and RCB were the cumulative marks obtained by respondents on MCQ, MTF and written summaries. MCQ and MTF were constructed in the English language. Thus, there was a possibility that the LP learners might have understood the texts but not the rubrics of the MCQ and MTF. If this were the case, it could explain the very weak correlation between L2 proficiency and written summary B yet a modest correlation in RCB. Therefore, for LP

learners, there may perhaps be two reasons for obtaining a low mark on the RCA and RCB; (a) they might not have understood the scientific texts well due to their limited L2 proficiency and, (b) they might have understood the scientific texts but were having problem comprehending the rubrics of MTF and MCQ due to the language of the test itself.

(4) When the data were reanalyzed according to the three university groupings, it was found that the relationship between L2 proficiency and reading comprehension was not as straightforward as it was initially assumed. The results indicate that learners with less L2 proficiency and less prior knowledge (PQ/LP learners) managed to outperform those with higher L2 proficiency and higher scientific prior knowledge (R/LP learners and S/HP learners). Similar trend was observed in PQ/HP learners who outperformed R/HP learners on all reading comprehension measures.

5.6 Research Question 4: Types of strategies commonly used by ESL science undergraduates and the contribution of specific strategies to reading comprehension of scientific texts

This section reports on the findings to address the fourth research question, (a) “What are the types of strategies commonly employed by first year ESL science undergraduates with high and low English proficiency when reading the two scientific texts” and (b) “Which specific strategies (cognitive or metacognitive strategies) significantly contribute to the reading comprehension scores of the two scientific texts?”. For the first part of research question four, descriptive statistics on the composite MC, HC and LC strategies used to read texts A and B by high proficiency (HP, hereafter) and low proficiency (LP, hereafter) learners were first computed before other inferential statistics could be performed. For the second part of the research question, Pearson correlation analysis was performed on the data to determine if the strategies used by the HP and LP learners significantly contributed to the reading comprehension of the two scientific texts.

5.6.1 Overall metacognitive, higher cognitive and lower cognitive strategies used by HP and LP learners

This section describes the findings on the composite MC, HC, and LC strategies used to read texts A and B by HP and LP learners in the three university groupings using descriptive statistics and independent t-tests. Following that, paired-sample t-tests were conducted to determine if there were significant differences in the use of MC, HC, and LC strategies by both HP and LP learners while reading text A compared to the strategies used while reading text B. Finally multiple analysis of variance (MANOVA) was performed to determine if the HP and LP learners in the three university groupings differed in their use of MC, HC, and LC strategies in both reading tasks. Table 5.35 displays the descriptive statistics and t-tests on the MC, HC, and LC strategies used by respondents from Univ PQ, Univ R and Univ S.

Table 5.35

Descriptive Statistics and Independent T-Tests on MC, HC and LC Strategies Used by the HP and LP Groups When Reading Two Scientific Texts

	Types of Strategies	Univ PQ (N=157)				Univ R (N=76)				Univ S (N=103)			
				t-tests (*df* = 155)				t-tests (*df* = 74)				t-tests (*df* = 101)	
		HP	LP	t	*p*	HP	LP	t	*p*	HP	LP	t	*p*
Text A	Metacognitive Strategies (MC)	M: 4.52 *SD: 0.84*	M: 4.58 *SD: 0.96*	.387	.704	M: 4.66 *SD: 0.74*	M: 4.89 *SD: 0.87*	1.241	.218	M: 4.65 *SD: 0.96*	M: 4.51 *SD: 0.95*	-.668	.506
	Higher Cognitive Strategies (HC)	M: 4.45 *SD: 0.77*	M: 4.48 *SD: 0.88*	.233	.816	M: 4.45 *SD: 0.79*	M: 4.82 *SD: 0.76*	2.008	.048*	M: 4.46 *SD: 0.95*	M: 4.36 *SD: 0.96*	-.457	.649
	Lower Cognitive Strategies (LC)	M: 4.59 *SD: 0.84*	M: 4.63 *SD: 0.98*	1.662	.099	M: 4.42 *SD: 0.76*	M: 4.99 *SD: 0.73*	3.289	.002*	M: 4.48 *SD: 1.04*	M: 4.60 *SD: 0.99*	.529	.598
Text B	Metacognitive Strategies (MC)	M: 4.60 *SD: 0.82*	M: 4.52 *SD: 0.97*	-.532	.596	M: 4.59 *SD: 0.76*	M: 4.85 *SD: 0.99*	1.254	.214	M: 4.80 *SD: 0.91*	M: 4.62 *SD: 0.88*	-.942	.349
	Higher Cognitive Strategies (HC)	M: 4.44 *SD: 0.83*	M: 4.42 *SD: 0.92*	-.153	.878	M: 4.37 *SD: 0.85*	M: 4.78 *SD: 0.98*	1.978	.052	M: 4.51 *SD: 0.83*	M: 4.42 *SD: 0.89*	-.494	.623
	Lower Cognitive Strategies (LC)	M: 4.44 *SD: 0.83*	M: 4.58 *SD: 0.98*	1.136	.258	M: 4.29 *SD: 0.83*	M: 4.95 *SD: 0.88*	3.349	.001*	M: 4.56 *SD: 0.83*	M: 4.62 *SD: 0.87*	.292	.771
	N	54	103			39	37			32	71		

*$p < 0.05$ level (2-tailed)

In general, the data in Table 5.35 show that the means of MC, HC and LC strategies utilized by HP and LP learners across the three university groupings were similar. Independent t-tests indicate that there were no significant differences in the MC, HC and LC strategies used by HP and LP groups in Univ PQ and S. However, in Univ R, significant differences existed in the HC strategies, $t(74) = 2.008$, $p = 0.048$ and LC strategies $t(74) = 3.289$, $p = 0.02$ used by HP and LP groups while reading scientific text A. In addition, significant difference also existed in the LC strategies used by these two groups to read scientific text B, $t(74) = 3.349$, $p = 0.01$. The Cohen's *d* equals to 0.48, 0.78 and 0.77 respectively. The effect was small for the first difference but medium in the two latter differences (Kinnear & Gray, 2006).

The results seem to indicate that the LP learners in Univ R exerted significantly more HC and LC strategies to comprehend text A and LC strategies for text B than their HP counterparts. The questions that arose as a result from this finding are (i) whether the HP learners in Univ R exerted significantly lower intensity of strategy use from other HP learners in Univ PQ and S or that (ii) LP learners in Univ R exerted significantly higher intensity of strategy use compared to other LP learners across the three universities.

If the earlier analyses compared HP and LP learners within the same university groupings, multiple analyses of variance below compared HP learners and LP learners across the three university groupings. Table 5.36 presents the results of the MANOVA tests on both L2 proficiency groups.

Table 5.36

MANOVA for MC, HC and LC Strategies used to Read Scientific Texts A and B across Three University Groupings

	Mean			MANOVA		
	Univ PQ	Univ R	Univ S	*F*	df	*p*
<u>Text A</u>		HP Learners				
MC	4.52	4.66	4.65	.55	2	.580
HC	4.45	4.45	4.46	.04	2	.961
LC	4.59	4.42	4.48	.25	2	.783
<u>Text B</u>						
MC	4.60	4.59	4.80	.89	2	.412
HC	4.44	4.37	4.51	.36	2	.700
LC	4.44	4.29	4.56	1.02	2	.365
<u>Text A</u>		LP Learners				
MC	4.58	4.89	4.51	2.04	2	.133
HC	4.48	4.82	4.36	3.20	2	.043*
LC	4.63	4.99	4.60	2.37	2	.096
<u>Text B</u>						
MC	4.52	4.85	4.62	1.60	2	.204
HC	4.42	4.78	4.42	2.41	2	.092
LC	4.58	4.95	4.62	2.32	2	.101

* $p < 0.05$

As presented in Table 5.36, *F* statistics from the multivariate analysis of variance suggest that while there were no significant differences in all three types of strategies among the HP learners across the three groups of universities, significant differences were observed in the means of HC strategies in the LP groups in three universities (*p* <0.05). Table 5.37 shows the pairwise post-hoc test for HC strategies used to read text A.

Table 5.37

Post Hoc Test for HC Strategies Used to Read text A (LSD test) among LP Learners across Three University Groupings

Dependent Variable	(I) Univ grouping	(J) Univ grouping	Mean Differ (I-J)	Std. Error	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
HC	Univ PQ	Univ R	-.3398*	.17027	.047	-.6754	-.0041
(Text A)		Univ S	.1117	.13693	.415	-.1582	.3817
	Univ R	Univ PQ	.3398*	.17027	.047	.0041	.6754
		Univ S	.4515*	.18035	.013	.0960	.8070
	Univ S	Univ PQ	-.1117	.13693	.415	-.3817	.1582
		Univ R	-.4515*	.18035	.013	-.8070	-.0960

* $p < 0.05$ level.

The results in Table 5.37 indicate that the LP learners in Univ R exerted significantly higher HC strategies in reading text A compared to LP learners in Univ PQ and Univ S. In addition, there were no significant differences in the HC strategies used by LP learners in Univ PQ and Univ S. The results displayed in Tables 5.35, 5.36 and 5.37 reveal that HP and LP learners utilized similar intensity of MC, HC and LC strategies in reading the scientific texts with one exception. R/LP learners seemed to exert the most effort in their use of HC strategies while reading scientific text A compared to the HP learners in the same university as well as LP learners across other universities. This can also be seen from the estimated means in Figures 5.6 and 5.7.

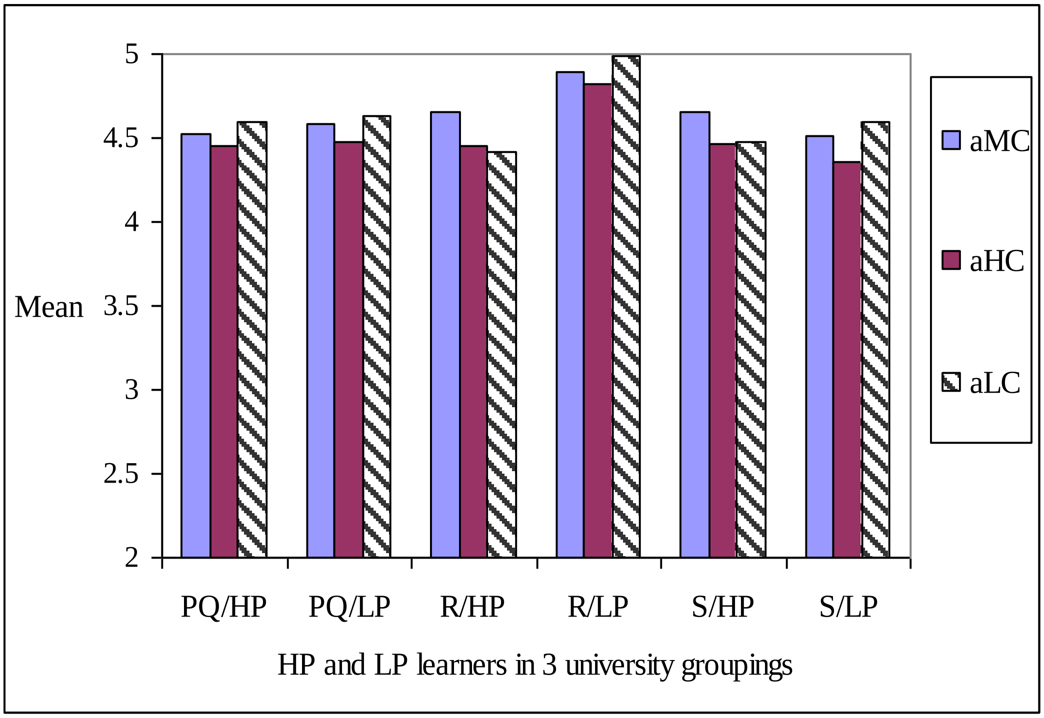

Figure 5.6 Estimated mean of MC, HC and LC strategies used by HP and LP learners while reading scientific text A

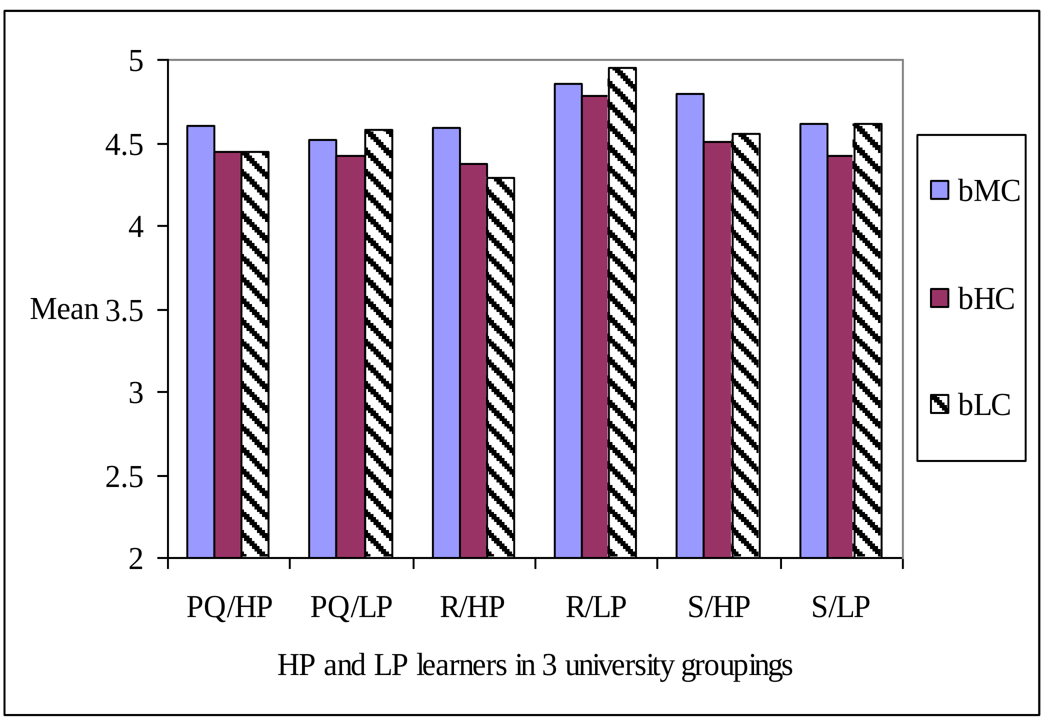

Figure 5.7 Estimated mean of MC, HC and LC strategies used by HP and LP learners while reading scientific text B

The bar graphs in Figures 5.6 and 5.7 show the level MC, HC and LC strategies usage while reading scientific texts A and B among HP and LP learners across the three university groupings. It could be observed that the intensity of each strategy use was comparable in both reading tasks. However, to confirm the visual observation, the data set were reanalyzed using paired samples t-tests to determine if there were in fact significant differences in the intensity of strategy use while reading text A and text B and the results are presented in Table 5.38.

Table 5.38

Paired Samples t-test on the Mean Scores of Strategies Used to Read Texts A and B

University	Group	Strategies used in Texts A and B	Paired Samples t- test		
			df	*t*	*p*
Univ PQ	HP	aMC – bMC	52	-2.001	.049*
		aHC – bHC	52	.083	.934
		aLC – bLC	52	-.430	.669
	LP	aMC – bMC	103	1.159	.249
		aHC – bHC	103	1.137	.258
		aLC – bLC	103	.969	.335
Univ R	HP	aMC – bMC	38	.967	.340
		aHC – bHC	38	1.203	.236
		aLC – bLC	38	1.948	.059
	LP	aMC – bMC	36	.777	.442
		aHC – bHC	36	.438	.664
		aLC – bLC	36	.553	.583
Univ S	HP	aMC – bMC	31	-2.067	.047*
		aHC – bHC	31	-.355	.411
		aLC – bLC	31	-1.061	.315

Table continues…

Table 5.38 (Continued)

		Strategies used to read texts A and B	*df*	*t*	*p*
Univ S	LP	aMC – bMC	70	-1.391	.169
		aHC – bHC	70	-.629	.532
		aLC – bLC	70	-.244	.808

*$p < 0.05$ level

The results displayed in Table 5.38 indicate that the mean score of MC strategies used by the HP group in Univ PQ in reading text A was significantly different from the MC strategies used to read text B, $t(52) = -2.001$, $p = 0.049$. The Cohen's *d* equals to 0.1, which means the effect size was deemed very small (Kinnear & Gray, 2006). Similar finding was observed in the HP group of Univ S with $t(31) = -2.067$, $p = 0.047$. The Cohen's *d* equals to 0.2 and thus the effect size was again small but significant nevertheless.

The finding that shows HP learners in Univ PQ and Univ S were exerting more MC strategies when reading text B is consistent with those reported previously (Block, 1992; Li and Munby, 1992; Young & Oxford, 1997). It lends support to the assumption that the difference between proficient and less proficient readers is the ability to plan their reading, monitor their comprehension and select appropriate strategies (Zhang & Wu, 2009). However, the same paired-samples t-tests revealed no significant differences in the types of strategies utilized to read text A with those strategies used to read text B by HP and LP learners in Univ R.

Thus, in response to research question four (a) on the types of strategies commonly employed by HP and LP first year ESL science undergraduates when reading scientific texts, the findings are as follows:

(1) It was found that HP and LP first year ESL science undergraduates did not differ in their choices and use of MC, HC, and LC strategies while reading scientific texts A and B. This finding is not consistent with previous findings in reading strategy research (Block, 1992; Carrell, 1989; Horiba, 1990; Pang, 2006; Phakiti, 2003; Young & Oxford, 1997; Zhang & Wu, 2009). Most studies, other than Anderson (1991) and Chen & Donin (1996), found that HP readers tended to use more HC strategies like making inferences and hypothesizing while LP readers were predominantly involved in 'local' or LC strategies like decoding and translating.

(2) The results also indicate that HP learners tended to exert more effort in their use of MC strategies when reading text B (more difficult/less familiar topic). Even though the effect size was small, this finding confirms the notion that MC strategies only emerge when readers encounter reading difficulties (Brown & Baker, 1984). This finding is consistent with those reported in previous studies (Block, 1992; Carrell, 1989; Pang, 2008; Zhang & Wu, 2009) in that L2 proficiency dictates the use of MC strategies. Yet, the analysis of strategies used by HP learners in Univ R found that the intensity of MC strategies used to read texts A and B were not significantly different.

At this point, there were many possible factors that led to the insignificant difference in strategy use among the learners in Univ R. As noted by Anderson (1991), besides L2 proficiency level, strategy choices may be attributed to the reader's prior knowledge in the text content, interest and motivation in the field, and learning styles of each individual and each domain area.

5.6.2 The contribution of specific cognitive and metacognitive strategies to reading comprehension of scientific texts

Pearson correlation analysis was performed on the data to determine if the strategies used by the HP and LP learners significantly contributed to the reading comprehension of the two scientific texts. Table 5.39 presents the Pearson correlation coefficients between three types of strategies and reading comprehension of scientific texts A and B in HP and LP learners in the three university groupings. The result indicates that with an exception of Univ PQ, there were no significant correlations between the overall MC, HC, and LC strategies and reading comprehension of scientific texts A and B in Univ R and Univ S.

Table 5.39

Correlations between Three Types of Strategies and RCA and RCB in HP and LP Learners in Univ PQ, R, and S

	Univ PQ		Univ R		Univ S	
	HP	LP	HP	LP	HP	LP
	Reading Comprehension Scores A (RCA)					
Metacognitive Strategies (MC)	.295*	.237*	-.110	-.271	.007	.134
Higher Cognitive Strategies (HC)	.284*	.237*	-.098	-.213	.037	.123
Lower Cognitive Strategies (LC)	.232	.141	-.218	-.124	.069	.110
	Reading Comprehension Scores B (RCB)					
Metacognitive Strategies (MC)	.409**	.259**	-.183	.040	-.184	-.071
Higher Cognitive Strategies (HC)	.475**	.295**	-.022	-.072	.002	-.104
Lower Cognitive Strategies (LC)	.347*	.187	-.183	.022	-.232	-.027
N	53	104	39	37	32	71

* $p < 0.05$; ** $p < 0.01$

Nevertheless in Univ PQ, as shown in Table 5.39, the strategies utilized by the HP group had stronger correlations to their comprehension assessments, and this was especially evident in the MC and HC strategies in RCB. MC and HC strategies weakly correlated to RCA at $r = 0.295$ and 0.284 ($p< 0.05$) but the correlation coefficients increased considerably to 0.409 and 0.475 ($p<0.01$) in text B. The LC strategies used by the HP group did not correlate to their RCA but correlated modestly to RCB at r = 0.347 (p<0.05). In the LP group, the correlation coefficients between RCA and MC and HC strategies were both at r = 0.237 (p<0.05). The correlations between RCB and MC strategies as well as RCB and HC strategies were at r = 0.259 (p<0.01) and 0.295 (p<0.01) respectively. However, unlike the HP group, LC strategies in the LP group did not correlate to either RCA or RCB.

Even though there were no correlations between the three types of strategies and RCA and RCB among HP and LP learners in Univ R and Univ S, further analyses were conducted to determine if there were any correlations between specific strategies and the two comprehension scores. Table 5.40 presents the correlations between specific types of MC, HC and LC strategies and RCA and RCB in the HP learners across the three university groupings while similar correlations in the LP learners are presented in Table 5.41.

Table 5.40
Pearson Correlations between Specific Strategies Utilized by HP Learners and RCA and RCB

	Reading Comprehension of Scientific text A			Reading Comprehension of Scientific text B		
Specific Strategy/ correlation	Univ PQ	Univ R	Univ S	Univ PQ	Univ R	Univ S
MC-Planning	.076	-.165	.099	.302*	-.268	-.155
MC-Monitoring	.307*	.025	.058	.444**	-.036	-.049
MC-Evaluating	.337*	-.175	-.078	.318*	-.171	-.204
MC-Debugging	.314*	-.016	-.037	.386**	-.115	-.228
HC-Visualizing	.419**	.048	.075	.530**	.114	.111
HC-Analyzing Visual Diagram	.256	.031	.179	.485**	.334*	-.030
HC-Analyzing Text	.236	-.206	.077	.410**	.077	.005

Table continues…

Table 5.40 (Continued)

Specific Strategy/ correlation	Reading Comprehension of Scientific text A			Reading Comprehension of Scientific text B		
	Univ PQ	Univ R	Univ S	Univ PQ	Univ R	Univ S
HC-Inferring Language	-.008	-.073	.086	.483**	-.091	.110
HC-Inferring Content	.148	-.271	.042	.262	-.203	-.099
HC-Accessing Prior Knowledge	.243	-.113	-.072	.312*	-.118	.040
HC-Summarizing	.210	-.101	-.048	.464**	-.037	-.006
HC-Questioning content	.293*	.140	.012	.389**	-.005	-.118
HC-Reading for Global Understanding	-.014	-.161	-.098	-.214	-.236	.010
LC-Decoding	.141	-.284	-.263	.176	-.267	-.151
LC-Translating	-.181	-.304	.192	-.063	-.337*	-.203
LC-Questioning language	.213	-.074	.094	.324*	-.008	-.076
LC-Paraphrasing	.208	-.296	.248	.379**	-.047	-.047
LC-Memorizing & Taking Notes	.296*	.238	.040	.363**	.171	-.239
LC-Reading for Local Understanding	.396**	-.082	-.053	.411**	-.225	-.316

* $p < 0.05$ level (2-tailed); ** $p < 0.01$ level (2-tailed).

Table 5.40 presents the correlation coefficients between specific types of MC, HC and LC strategies and RCA as well as RCB in the HP learners in Univ PQ, R and S. In general, the data indicated that many of the strategies utilized by HP learners in Univ PQ correlated significantly and positively to RCA and RCB. The same cannot be said about HP learners in Univ R and Univ S.

MC strategies used by the HP learners in Univ PQ which significantly correlated to RCA were MC-monitoring (r = .307, $p < 0.05$) MC- evaluating (r = .337, $p < 0.05$), and MC-debugging (r = .314, $p < 0.05$). However, MC-planning did not correlate to their RCA and one explanation may be because text A was not very demanding in terms of language and topic. Therefore, the HP learners in Univ PQ may not have bothered to plan their reading process (Baker & Brown, 1984; McCormick, 2003). When reading a more challenging text (text B), all MC strategies correlated significantly to their reading comprehension scores. In fact the correlation coefficients for MC- monitoring increased from r =0.307 (p<0.05) in RCA to r = 0.444 (p<0.01) in RCB.

The HC strategies found to correlate significantly to RCA in the HP group were only visualizing (r = .419, $p < 0.01$) and questioning content (r = .293, $p < 0.05$). While lower cognitive strategies (LC) that correlated to RCA were memorizing and taking notes (r = .296, $p < 0.05$) and reading for local understanding (r = .396, $p < 0.01$). The number of HC strategies used by the HP group which correlated to RCB increased to seven which were visualizing (r = .530, $p < 0.01$), analyzing visual diagram (r = .485, $p < 0.01$), analyzing text (r = .410, $p < 0.01$), inferring language (r = .483, $p < 0.01$), accessing prior knowledge (r = .312, $p < 0.05$), summarizing (r = .464, $p < 0.01$) and questioning content (r = .389, $p < 0.01$).

As anticipated, the types of specific LC strategies used by HP learners in Univ PQ increased to four when they read text B; LC-questioning language (r = .324, $p < 0.05$), paraphrasing (r = .379, $p < 0.01$) , memorizing- taking notes (r = .363, $p < 0.01$) and reading for local understanding (r = .411, $p < 0.01$). However, HP learners in Univ R and Univ S did not show any correlations between specific strategies and RCA. In reading scientific text B among HP learners in Univ R, HC analyzing visual diagram showed positive but modest correlation to RCB (r = .334, $p < 0.05$) and LC translating showed modest but negative correlation to RCB (r = -.337, $p < 0.05$). No correlations were found in HP learners in Univ S.

Table 5.41 presents the correlation coefficients between specific strategies and comprehension scores of texts A and B in LP learners across the three university groupings.

Table 5.41

Pearson Correlations between Specific Strategies Utilized by LP Learners and RCA and RCB

	Reading Comprehension of Scientific text A			Reading Comprehension of Scientific text B		
Specific Strategy/ correlation	Univ PQ	Univ R	Univ S	Univ PQ	Univ R	Univ S
MC-Planning	.270**	-.325*	.179	.153	.017	-.088
MC-Monitoring	.168	-.295	.121	.211*	.110	-.053
MC-Evaluating	.202*	-.168	.076	.267**	-.009	-.100
MC-Debugging	.227*	-.161	.109	.309**	.044	-.009
HC-Visualizing	.225*	-.097	.124	.294**	.104	-.041
HC-Analyzing Visual Diagram	.293**	-.032	.186	.282**	.070	-.103
HC-Analyzing Text	.232*	-.185	.142	.245*	-.070	-.052

Table continues…

Table 5.41 (Continued)

Specific Strategy/ correlation	Reading Comprehension of Scientific text A			Reading Comprehension of Scientific text B		
	Univ PQ	Univ R	Univ S	Univ PQ	Univ R	Univ S
HC-Inferring Language	.048	-.038	.103	.241*	-.110	-.150
HC-Inferring Content	.155	-.282	.110	.204*	-.136	-.072
HC-Accessing Prior Knowledge	.183	-.233	-.008	.194*	.056	-.084
HC-Summarizing	.280**	-.001	.128	.378**	-.099	.095
HC-Questioning content	.196*	-.307	.106	.243*	-.113	-.236*
HC-Reading for Global Understanding	.062	-.196	-.011	.004	-.235	-.138
LC-Decoding	.169	-.224	.015	.154	-.091	-.010
LC-Translating	-.041	-.033	.091	-.128	.144	-.027
LC-Questioning language	.064	-.306	.115	.186	-.150	-.196
LC-Paraphrasing	.164	-.011	.052	.246*	-.039	.044
LC-Memorizing & Taking Notes	.240*	-.002	.153	.275**	.094	.001
LC-Reading for Local Understanding	.133	.031	.101	.230*	.147	.045

* $p < 0.05$; ** $p < 0.01$

It is evident from Table 5.41 that the trend of strategies used which were observed in HP learners (Table 5.40) was replicated in LP learners. In general, only LP learners in Univ PQ showed a number of correlations between specific strategies and comprehension scores while in Univ R and S, correlations were almost nil.

In contrast to PQ/HP learners, the MC strategies in the PQ/LP learners that correlated to RCA were MC-planning (r = .270, $p < 0.01$), MC-evaluating (r = .202, $p < 0.05$), and MC debugging (r = .227, $p < 0.05$). It was surprising that MC-monitoring did not correlate to their RCA. It may be that for LP learners, they had some prior knowledge on text A and did not find the text very confusing which would otherwise require close monitoring. However, when the same group was reading text B, there were significant but weak correlations between RCB and MC-monitoring (r = .211, $p < 0.05$), evaluating (r = .267, $p < 0.01$), and debugging (r = .309, $p < 0.01$). It should also be noted that the correlation coefficients increased slightly in MC evaluating and MC debugging in text B.

In addition, five HC strategies and one LC strategy correlated to RCA in PQ/LP learners. They were HC visualizing (r = .225, $p < 0.05$), HC analyzing visual diagram (r = .293, $p < 0.01$), HC analyzing text (r = .232, $p < 0.05$), HC summarizing (r = .280, $p < 0.01$), HC questioning content (r = .196, $p < 0.05$), and LC memorizing and taking notes (r = .240, $p < 0.05$). As the scientific text became more demanding such as text B, the HC strategies of LP group that correlated to RCB increased to eight types which included HC inferring language (r = .241, $p < 0.05$), HC inferring content (r = .204, $p < 0.05$), and HC accessing prior knowledge (r = .194, $p < 0.05$). As for LC strategies and the correlations to RCB, only three strategies showed significant correlations; LC paraphrasing (r = .246, $p < 0.05$), LC memorizing & taking notes (r = .275, $p < 0.01$), and LC reading for local understanding (r = .230, $p < 0.05$).

The result shows that PQ/LP learners were capable of utilizing a number of HC-strategies to compensate for their limited L2 proficiency, albeit modest correlations. In addition, LC strategies such as translating and decoding appeared to have no correlation either positively or negatively to reading comprehension of RCA and RCB. It may be that those who scored and did not score in the RCA and RCB among the PQ/LP learners exerted similar intensity of translating and decoding strategies, hence the reason for both strategies not showing significant correlation to comprehension. It is also worth mentioning that most correlation coefficients in PQ/LP learners were weak which perhaps indicate their knowledge and awareness about strategic reading. They may be aware of strategic reading but perhaps their effort was unsuccessful due to their inferior L2 proficiency and scientific prior knowledge (see Table 5.40 for details). Their less successful effort may also be attributed to lack of practice in independent and self-regulated reading.

On the other hand, MC planning in the LP learners of Univ R showed a significant but negative correlation to RCA (r = -.325, $p < 0.01$) while LP learners in Univ S showed no correlation at all. With RCB, there was no correlation to any of the specific strategies in R/LP learners but in S/LP learners there was a weak and negative correlation to HC questioning content (r = -.236, $p < 0.05$).

The correlation analyses performed on both HP and LP learners across the three university groupings above reveal three findings. First, both HP and LP learners in Univ PQ were capable of employing reading strategies that helped them to comprehend the two scientific texts. In other words, regardless of their L2 proficiency level as well as their inferior scientific prior knowledge (Table 5.34, page 250), respondents in Univ PQ somehow had the awareness of reading strategies and were able to make the right choices in utilizing them which in turn contributed to their reading comprehension of the two texts.

Second, among readers who had their knowledge and experience in using reading strategies to comprehend reading texts, the data suggested that they tended to utilize more strategies with higher intensity when they encountered with a more difficult text in terms of language structure and topic. Those with higher L2 proficiency seemed to succeed in their strategy use as revealed by the higher correlation coefficients whereas among LP learners, their limited L2 proficiency rendered some of the successful strategies they employed inefficient.

Third, even though HP learners in Univ R and Univ S were found to utilize similar strategies with comparable intensity as those in Univ PQ (section 5.6.1; Table 5.35; pg. 255), their strategies failed to influence their reading comprehension of both texts. One assumption for the lack of correlations between strategies and comprehension scores in HP learners in Univ R and S would be that they had no need to strategize when reading the two scientific texts since they were highly proficient in their English language. In addition, HP learners in Univ R were also found to have superior scientific prior knowledge compared to the other groups (Table 5.17, pg. 213). Thus, it could be assumed that they were able to read and understand the texts without having to strategize at all. If these were the reasons for the lack of correlations between strategy use and comprehension scores in R/HP and

S/HP learners, limited L2 proficiency in R/LP and S/LP learners should reveal some significant correlations. On the contrary, the correlation analyses in R/LP and S/LP learners showed similar results as in R/HP and S/HP learners, lack of association between strategy use and comprehension scores.

Another assumption for the findings on strategy use and comprehension scores among respondents in Univ R and Univ S would be that they were not accustomed to independent reading or familiar with reading strategies to read L2 or scientific texts on their own. They might have reported using certain reading strategies during the survey, but how much they actually used and applied during the actual reading tasks may be questionable.

Thus, there are four findings in response to the fourth research question on strategies which significantly contribute to reading comprehension scores of the two scientific texts:

(1) There were no correlations between MC, HC and LC strategies and reading comprehension scores of scientific texts A and B in HP and LP learners in Univ R and Univ S.

(2) Significant yet weak correlations were found between MC and HC strategies and reading comprehension scores of scientific text A (less difficult/ familiar) in HP and LP learners of Univ PQ. The correlations were stronger between MC, HC and LC strategies and reading comprehension scores of scientific text B (difficult/less familiar) in the HP learners of Univ PQ, whereas the correlations remain weak in LP learners of the same university

grouping. The data suggest that PQ/LP learners did try to strategize while reading a more difficult text (text B) but their low L2 proficiency might have hampered their attempts and rendered their strategies ineffective. PQ/HP learners, on the other hand, had recognized that they were having comprehension problem while reading text B, thus employed all three types of strategies. Their high L2 proficiency may have had a facilitative effect on the strategies they utilized which contributed to their reading comprehension of text B. The increase in the strength of correlations between strategy use from RCA to RCB in HP learners of Univ PQ suggests that these readers had the awareness about reading strategies and understood that they had to employ rigorous problem solving strategies when confronted with reading difficulty such as while reading text B (difficult/less familiar).

(3) There were positive and significant correlations between almost all of the strategies and RCB in the HP and LP learners of Univ PQ except for HC-inferring content, HC-reading for global understanding, LC-translating, and LC- decoding. This perhaps indicates that unlike reading non-scientific texts where inferring content and reading for global understanding are successful strategies and promoted to ESL readers, reading scientific texts requires a different approach like reading for local understanding (Koch, 2001), and memorizing facts and taking notes (Bonner & Holliday, 2004).

(4) This may perhaps be the ‘x’ factor that helped PQ/LP learners to outperform R/LP learners and S/HP learners as well as PQ/HP learners to outperform

R/HP learners in the reading comprehension of both scientific texts as discussed in section 5.5.4 (pg. 250).

5.7 Research Question 5: The independent variables that contributed to reading comprehension of the two scientific texts

This section reports on the findings that address research question five on "Which independent variable (metacognition, scientific prior knowledge, L2 proficiency, cognitive and metacognitive strategies) most influences the reading comprehension scores of the two scientific texts? To determine which variable(s) contributed to the reading comprehension scores of the two scientific texts, a stepwise multiple regression was performed on the collective group (N = 336) as well as on the three university groupings; Univ PQ (N=157), Univ R (N = 76), and Univ S (N = 103). Descriptive statistics on L2 proficiency, metacognitive awareness, scientific prior knowledge and each type of strategies utilized by the collective respondents as well as by HP and LP learners in the three university groupings have already been discussed in the previous sections.

In order to answer research question five, on which variables can predict reading performance of two scientific texts, the independent variables were regressed against reading comprehension scores. For reading comprehension text A (RCA), the independent variables entered into the regression equation were L2 proficiency, metacognitive awareness, SPK A, SPK scientific term, SPKI, aMC (metacognitive strategies for text A) , aHC (higher cognitive strategies for text A), and aLC (lower cognitive strategies for text A).

Table 5.42 displays the summary of stepwise multiple regression analysis for independent variables that were predicted to contribute to reading comprehension scores of scientific text A.

Table 5.42
Summary of Stepwise Multiple Regression Analysis for Variables Predicting Reading Comprehension Scores of Scientific Text A (RCA)

	Model Summary		ANOVA		Coefficients		
Variables	R^2	Adjusted R^2	*F*-*value*	*p*	Beta	*t*	*p*
			Collective Group (N = 333)				
1. L2 Proficiency	.087	.084	31.56	.000*	.267	5.01	.000*
2. L2 Proficiency + SPK Sci Term	.102	.096	18.78	.000*	.126	2.36	.019*
			Univ PQ (N = 156)				
1. L2 proficiency	.058	.052	9.49	.002*	.241	3.17	.002*
2. L2 proficiency + aMC	.115	.103	9.89	.000*	.238	3.13	.002*
			Univ R (N = 76)				
1. L2 proficiency	.234	.223	22.57	.000*	.483	4.75	.000*
			Univ S (N = 102)				
Not Available	-	-	-	-	-	-	-

*Significant mean effect

For the collective group (N = 333), with all variables entered into the equation, L2 proficiency yielded an adjusted R^2 of .084 ($F(1, 332) = 31.56$, $p <$ .005). SPK scientific term produced an adjusted R^2 of .096 ($F(2, 332) = 18.78$, $p <$ .005). No other variables entered the equation. For the collective group (N=333), L2 proficiency was the primary predictor for comprehension of scientific text A, accounting for 8.4 per cent of the variance. Scientific prior knowledge on scientific terminology contributed only 1.2 per cent. Other independent variables did not achieve significance.

In Univ PQ, L2 proficiency yielded an adjusted R^2 of .052 (F(1, 153) = 9.49, p < .005). Metacognitive strategies (aMC) produced an adjusted R^2 of .103 (F(1, 153) = 9.89, p < .005). No other variables entered the equation. Thus, for respondents Univ PQ, L2 proficiency accounted for 5.2 per cent of the variance followed by MC strategies which contributed 5.1 per cent to RCA. Other independent variables were not significant.

In Univ R, only L2 proficiency achieved significance with adjusted R^2 equal to .223 (F(1, 74) = 22.57, p < .005). Other independent variables did not enter the equation. This means that L2 proficiency was the sole predictor of reading comprehension scores of scientific text A that accounts for 22.3 per cent of the variance. Surprisingly, in Univ S, none of the independent variables achieved significance.

Table 5.43 on page 278 presents the summary of stepwise multiple regression analysis for independent variables that may perhaps contribute to reading comprehension scores of scientific text B. The results of a stepwise multiple regression for RCB in the collective group (N = 333) were similar to RCA in that L2 proficiency yielded an adjusted R^2 of .090 (F(1,332) = 34.07, p < .005) whereas SPK scientific terminology produced an adjusted R^2 of .109 (F(2,332) = 21.31, p < .005). This means that similar to RCA, L2 proficiency contributed only 9 per cent of the variance while SPK scientific terminology contributed less, only 1.9 per cent.

Both L2 proficiency and SPK scientific terminology saw an increment of only 0.6 per cent and 0.7 per cent respectively from text A to text B.

Table 5.43

Summary of Stepwise Multiple Regression Analysis for Variables Predicting Reading Comprehension Scores of Scientific Text B

Variables	Model Summary		ANOVA		Coefficients		
	R^2	Adjusted R^2	*F-value*	*P*	Beta	t	*p*
Collective Group (N = 333)							
1. L2 Proficiency	.093	.090	34.07	.000*	.273	5.14	.000*
2. SPK Sci Term	.114	.109	21.31	.000*	.149	2.80	.005*
Univ PQ (N = 156)							
1. bHC	.117	.112	20.47	.000*	.312	4.36	.000*
2. bHC + L2 Proficiency	.202	.191	19.34	.000*	.257	3.53	.001*
3. bHC + L2 Proficiency + SPK Sci term	.228	.213	14.97	.000*	.166	2.27	.024*
Univ R (N = 76)							
1. L2 proficiency	.253	.243	25.09	.000*	.460	4.57	.000*
2. L2 proficiency + Metacognitive Awareness	.293	.274	15.13	.000*	-.204	-2.03	.046*
Univ S (N = 102)							
Not Available	-	-	-	-	-	-	-

*Significant mean effect

As the Table above shows, in Univ PQ HC strategies in reading scientific text B yielded an adjusted R^2 of .112 (F(1,153) = 20.47, $p < .005$). L2 proficiency was entered second and produced an adjusted R^2 of .191 (F(2,153) = 19.34, $p < .005$). SPK scientific terminology was entered third with adjusted R^2 equals to .213

(*F*(3,153) = 14.97, $p < .005$). The results of the stepwise multiple regression in Univ PQ reveal that HC strategies contributed 11.2 per cent of the variance in RCB, L2 proficiency 7.9 per cent, and SPK scientific terminology 2.2 per cent.

In Univ R, L2 proficiency produced an adjusted R^2 of .243 (*F*(1,74) = 25.09, $p < .005$) and metacognitive awareness yielded an adjusted R^2 of .274 (*F*(2,74) = 15.13, $p < .005$). All other independent variables did not achieve significance level. This result suggests that among the learners in Univ R, L2 proficiency accounted for 24.3 percent of the variance in RCB and metacognitive awareness accounted for 3.1 per cent. Again in Univ S, none of the independent variables achieved significant level.

Thus, there are six findings in response to research question five on identifying the independent variables that significantly contributed to reading comprehension of the two scientific texts:

(1) In general, it could be concluded that the contribution of independent variables to reading scientific text A in a second language to be between only 10.3 to 22.3 per cent and the percentage increased to between 21.3 to 27.4 per cent for scientific text B. The substantial increment may be due to the nature of text B which was syntactically more difficult and on a less familiar topic. With such L2 text, readers were required to exert more effort in utilizing their linguistic knowledge as well as other means such as using strategies and tapping onto their prior knowledge of scientific terminology to make sense of the text. With about 20 to 27 per cent of the variance

accounted for, it leaves about 70 per cent of the variance in reading scientific texts in a second language unknown.

(2) L2 proficiency made up only 5.2 per cent and 7.9 per cent in learners with intermediate L2 proficiency (Univ PQ) while reading texts A and B. On the other hand, more proficient learners (Univ R) tended to have L2 proficiency contributing 22.3 per cent to 24.3 per cent to reading comprehension of scientific texts A and B respectively. One unexpected finding is on the contribution of metacognitive awareness of 3.1 per cent to RCB in the more proficient learners.

(3) Earlier findings on strategy use in this study revealed that only respondents in Univ PQ employed reading strategies which significantly contributed to their reading comprehension of the two scientific texts. As expected, MC strategies were found to contribute 5.2 per cent to reading comprehension of scientific text A while HC strategies contributed 11.2 per cent to reading comprehension of scientific text B in respondents of Univ PQ.

(4) SPK on scientific terminology contributed only 1.2 per cent to RCA and 1.9 per cent to RCB in the collective group analysis (N = 336). However, SPK on scientific terminology did not contribute to RCA in Univ PQ and R but did contribute to RCB in Univ PQ up to 2.2 per cent.

(5) The knowledge of scientific terminology used in the two scientific texts yielded a very small variance to reading comprehension while none from the other measures of SPK contributed to the variance in reading comprehension of scientific texts A and B in all the groups.

(6) An unexpected finding was the lack of contributions of all independent variables on reading comprehension of scientific texts in respondents in Univ S.

5.8 Research Question 6: Characteristics of good ESL readers of scientific texts

To answer research question six, the data from the HP and LP learners from the collective group (N = 336) were divided into good and poor readers based on the scores of RCA and RCB. The mean scores of both RCA (Mean=27.52) and RCB (Mean=23.04) were used as the cut off points to divide participants into good/poor groups (Tan, 1986). Those who scored below the means were considered poor readers (RCA: n =157; RCB: n =162) and those who scored above the means were good readers (RCA: n =159; RCB: n =150).

5.8.1 Characteristics of good readers of text A and good readers of text B

Figure 5.8 displays the mean scores of RCA and RCB obtained by good and poor readers in both groups.

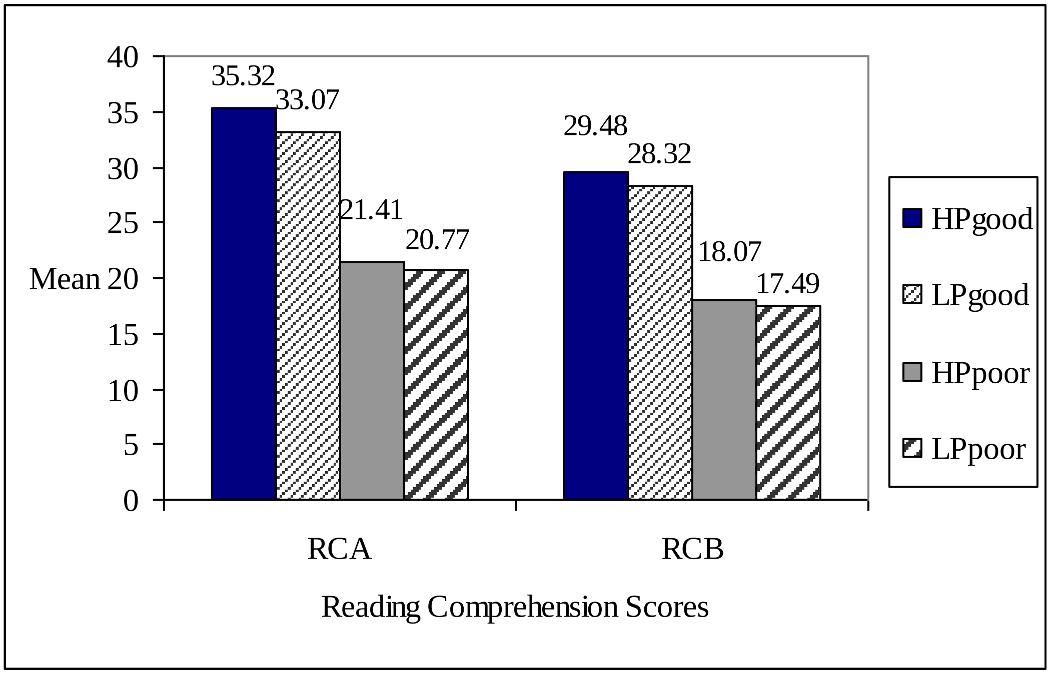

Figure 5.8 Mean scores of reading comprehension of text A (RCA) and text B (RCB) obtained by good and poor readers in HP and LP groups

Figure 5.8 shows the mean scores of reading comprehension of texts A and B obtained by good and poor readers in both HP and LP groups. The data shows that good readers in the HP and LP groups obtained a mean score of 35.32 and 33.07 respectively for RCA and 29.48 and 28.32 for RCB. On the other hand, for the poor readers in the HP and LP groups, the mean scores for RCA were 21.41 and 20.77 and 18.07 and 17.49 for RCB.

Independent t-test conducted on the mean scores of RCA obtained by HP/LP good readers indicated that there was a significant difference between the mean score obtained by HP and LP good readers, $t(157) = -3.07$, $p = 0.003$. Similar test was conducted on the means of RCA of HP/LP poor readers and the result revealed that there was no significant difference in the mean scores of RCA between poor readers of HP and LP groups, $t(155) = -0.91$, $p = .364$.

Independent t-tests were also performed on the mean scores of RCB obtained by HP/LP good and poor readers The results indicated that there was no significant difference in the mean score of HP and LP good readers, $t(148) = -1.87$, p = .0.64. Similar finding was obtained for HP/LP poor readers, $t(160) = -1.08$, p = .283. Except for the significant difference in the mean scores of RCA in the HP and LP good readers, the other three findings from the independent t-tests suggest that HP and LP good readers as well as HP and LP poor readers were compatible in understanding the two scientific texts. Thus, while L2 proficiency may be an instrumental variable in reading comprehension of scientific texts in a second language, it may not be the critical predictor to successful execution of the reading tasks. This is because LP good readers managed to match HP good readers in both RCA and RCB and HP poor readers did as badly as LP poor readers in both reading tasks. What is more interesting is that the LP good readers managed to outperform HP poor readers in both reading tasks. This finding suggests that there may be other factors at work that influence L2 reading comprehension of scientific texts besides L2 proficiency.

So what made LP good readers good at comprehending both scientific texts and HP poor readers poor at the same tasks other than L2 proficiency? Figure 5.9 presents the line graphs on the mean scores for three types of strategies utilized by good and poor readers of HP and LP groups while reading scientific texts A and B.

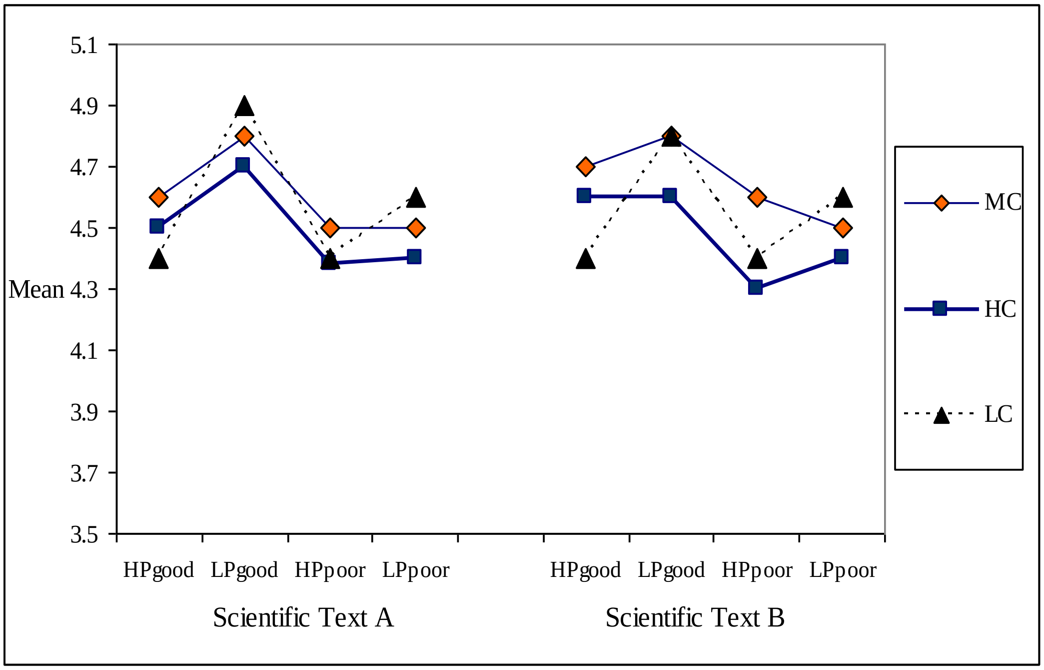

Figure 5.9 MC, HC, and LC strategies utilized by HP/LP good readers and HP/LP poor readers in reading scientific texts A and B

Figure 5.9 shows the level of strategy use among four groups of readers (HP-good readers, LP-good readers, HP-poor readers, LP-poor readers) while reading scientific texts A and B. The data from the graph indicate that good readers exerted more effort in each type of strategies they admitted to using compared to poor readers in both HP and LP groups. LP good readers tended to exert the most effort in using each strategy and maintained the same intensity in both reading tasks. LP poor readers exerted more effort in their strategy use compared to HP poor readers when reading text A and maintained the same intensity in text B. To confirm the assumptions made on the levels of strategy use based on Figure 5.9, an independent t-test was conducted on two critical groups; LP good readers and HP poor readers. The reason for looking into these two groups was to identify possible independent variables other than L2 proficiency that were at work that influenced the reading performances of these two groups.

Table 5.44

Means and Independent T-Tests on Variables of LP Good and HP Poor Readers While Reading Scientific Text A

Independent Variables	Mean		Independent t-test (df = 127)	
	LP Good Readers	HP Poor Readers	*t*	*p*
Metacognitive Awareness	260	254	.839	.403
SPK Sci Term	5.73	5.95	-.600	.550
SPK Text A	13.58	15.05	-1.73	.087
Metacognitive Strategies (MC)	4.84	4.52	1.96	.052
Higher Cognitive Strategies (HC)	4.70	4.35	2.26	.026*
Lower Cognitive Strategies (LC)	4.88	4.38	3.03	.003*
MC-Planning	4.81	4.42	2.11	.037*
MC-Monitoring	5.10	4.87	1.39	.165
MC-Evaluating	4.40	4.15	1.18	.241
MC-Debugging	5.06	4.65	2.34	.021*
HC-Visualizing	4.83	4.39	1.95	.054
HC-Analyzing Visual Diagram	5.01	4.39	3.35	.001*
HC-Inferring Content	4.54	4.21	.662	.054
HC-Accessing Prior Knowledge	4.59	4.41	.97	.336
HC-Summarizing	4.71	4.09	2.92	.004*
HC-Questioning content	4.69	4.08	2.98	.003*
HC-Reading for Global Understanding	4.50	4.44	.319	.751
LC-Translating	4.93	3.98	3.87	.000*
LC-Questioning language	4.96	4.41	2.61	.010*
LC-Paraphrasing	4.83	4.35	2.24	.027*
LC-Memorizing & Taking Notes	5.30	4.73	2.79	.006*
LC-Reading for Local Understanding	5.05	4.82	1.09	.279
N	85	44		

*significant difference at $p < 0.05$

Table 5.44 presents the means for independent variables metacognitive awareness, scientific prior knowledge, and the three types of strategies possessed and utilized by LP good readers and HP poor readers which may have contributed to their reading comprehension scores of scientific text A. Independent t-test was conducted to determine if there was significant difference in the means of each variable between the two groups. It was found that there was no significant difference in the means of metacognitive awareness, scientific prior knowledge and MC strategies between LP good readers and HP poor readers. However, significant differences existed in the HC and LC strategies utilized by both groups at $p < 0.05$. It appeared that LP good readers used HC and LC at greater intensity compared to the HP poor readers.

Closer inspection of the specific strategies used by LP good readers and HP poor readers revealed that there were significant differences in the means of nine strategies used by LP good and HP poor readers at $p < 0.05$. It appeared that the LP good readers compared to HP poor readers exerted more intensity in the use of MC planning, MC debugging, HC analyzing visual diagram, HC summarizing, HC questioning content, LC translating, LC questioning language, LC paraphrasing, and LC memorizing and taking notes. In addition to those strategies used by LP good readers which were significantly different from those utilized by HP poor readers, both groups of readers also utilized a great intensity of MC monitoring and LC reading for local understanding.

Table 5.45 presents the means for independent variables metacognitive awareness, scientific prior knowledge, and the three types of strategies possessed and utilized by LP good readers and HP poor readers which may have impacted their reading comprehension of scientific text B.

Table 5.45

Means and Independent T-Tests on Variables of LP Good and HP Poor Readers While Reading Scientific Text B

Independent Variables	Mean		Independent t-test (df = 119)	
	LP Good Readers	HP Poor Readers	*t*	*P*
Metacognitive Awareness	261	257	.631	.529
SPK Sci Term	5.90	6.08	-.512	.609
SPK Text B	13.48	13.86	-.488	.627
Metacognitive Strategies (MC)	4.76	4.60	1.01	.314
Higher Cognitive Strategies (HC)	4.63	4.29	2.18	.032*
Lower Cognitive Strategies (LC)	4.75	4.43	2.01	.047*
MC-Planning	4.70	4.53	.859	.392
MC-Monitoring	4.97	4.82	.950	.344
MC-Evaluating	4.35	4.25	.502	.617
MC-Debugging	5.03	4.79	1.35	.181
HC-Visualizing	4.69	4.13	2.51	.013*
HC-Analyzing Visual Diagram	5.01	4.54	2.40	.018*
HC-Inferring Content	4.48	4.10	2.19	.030*
HC-Accessing Prior Knowledge	4.55	4.23	1.62	.107
HC-Summarizing	4.60	4.00	2.83	.005*
HC-Reading for Global Understanding	4.47	4.55	-.39	.690
LC-Translating	4.58	4.17	.94	.094
LC-Questioning Language	4.71	4.39	.224	.111
LC-Paraphrasing	4.86	4.28	2.68	.008*
LC-Memorizing & Taking Notes	5.08	4.77	.74	.130
LC-Reading for Local Understanding	5.01	4.94	.86	.743
N	73	48		

*significant difference at $p < 0.05$

Table 5.45 shows that there were no significant differences in the means of metacognitive awareness, scientific prior knowledge, and MC strategies between LP good and HP poor readers. However, significant differences existed in the means of HC and LC strategies between the two groups at $p < 0.05$ level. The specific strategies were reanalyzed and subjected to another independent t-test. It was found that LP good readers exerted significantly more intensity on HC visualizing, HC analyzing visual diagram, HC inferring content, HC summarizing and LC paraphrasing. In addition to those strategies which were significantly different from each other, both HP poor and LP good readers also utilized a great intensity of MC monitoring, MC debugging, LC memorizing and taking notes, and LC reading for local understanding.

The findings displayed in Tables 5.44 and 5.45 suggest four important points. First, regardless of L2 proficiency, readers who used higher means or intensity of strategies obtained higher marks in reading comprehension of the two scientific texts. This finding accords with Anderson's (1991) who noted that greater strategy use seemed to contribute to higher scores in reading comprehension measures. What this means is that good readers appeared to be aware of the processes that could lead to successful comprehension and their L2 proficiency is the one variable that could either facilitate or slow down that process (Block, 1992).

Second, it was evident that LP good readers changed their reading tactics between text A (less difficult/more familiar) and text B (more difficult/less familiar). Stanovich (1980) claimed that less proficient readers may exert greater compensatory strategies especially in utilizing their prior knowledge (a higher cognitive strategy) in specialized area to make up for their inadequate linguistic knowledge. This claim was partially supported. LP good readers were found to employ greater effort on four LC strategies which were significantly different from those of HP poor readers while reading scientific text A. However, when encountered with a difficult text and on a less familiar topic such as text B, LP good readers were found to employ less LC strategies like translating and questioning the language of the text, instead tended to use more HC strategies like analyzing visual diagram, visualizing and inferring content. However, while the LP good readers did in fact utilize more HC strategies and less LC strategies while reading text B, their prior knowledge was not accessed to a great extent. This may perhaps be due to their already limited knowledge on the topic *Signal Transduction*. Thus, there was not much prior knowledge on the topic to access to help them understand the text.

Third, even though LC strategies were repeatedly found to be unsuccessful strategies and used by poor readers (Block, 1986; Carrell, 1989; Davis & Bistodeau, 1993; Horiba, 1990; Hosenfeld, 1977), LP good readers' utilization of these strategies proved otherwise. One reason which could have made these LC strategies worked for LP good readers may perhaps be because LP good readers have constantly complemented these strategies with HC strategies like summarizing, visualizing and analyzing visual diagram.

Fourth, be it good or poor readers, HC strategies inferring content and reading for global understanding which includes guessing meaning of words, skipping unknown words, and reading for overall meaning of the text did not appear to be exerted at greater intensity. Even though these strategies were successful strategies in reading non-scientific texts (Block, 1986; 1992; Carrell, 1989; Hosenfeld, 1977), they were not the strategies of choice among ESL science undergraduates. Based on the means of both HC strategies of inferring and reading for global understanding reported by both groups of readers in reading texts A and B, it was evident that these two strategies were used in moderation. In contrast, both groups, and more so in LP good readers, were found to exert much effort on LC strategies memorizing and taking notes as well as reading for local understanding which includes reading for details, understanding every word, and rereading.

5.8.2 Characteristics of good readers of scientific texts

To determine the characteristics of good readers of scientific texts, the data were further divided into two groups of readers based on the scores of RCA and RCB; good readers of scientific texts (N = 93) were those who obtained a score above the mean for both RCA and RCB, and poor readers (N = 103) were those who obtained a score below the mean for both RCA and RCB. The good reader group consisted of 52 HP and 41 LP learners while the poor reader group was made up of 25 HP and 78 LP learners.

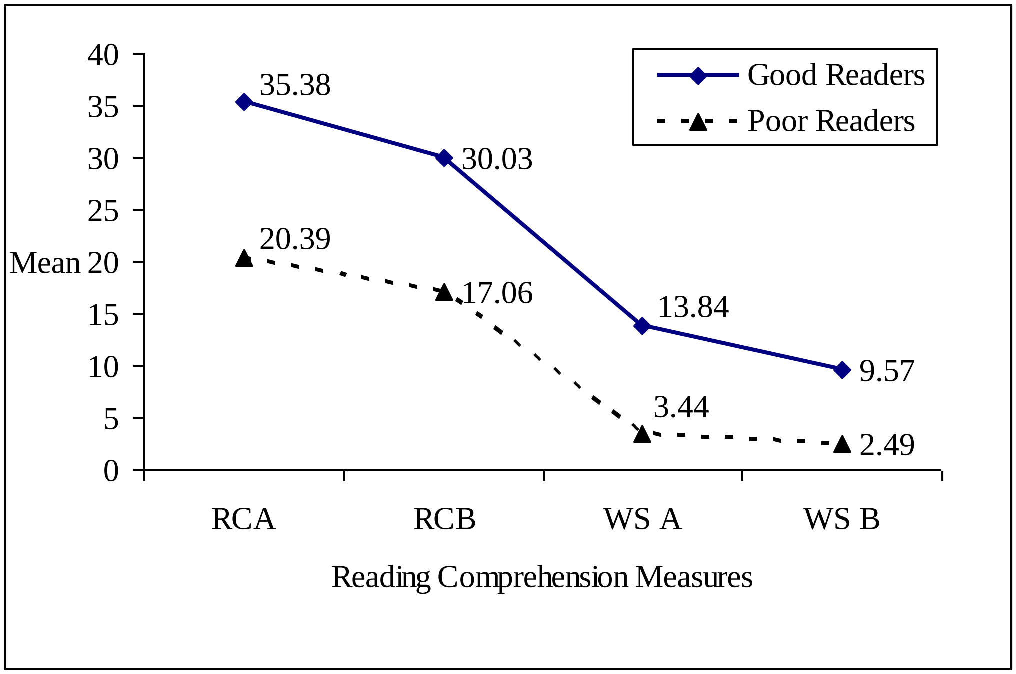

Figure 5.10 Mean scores of reading comprehension measures of text A (RCA, WSA) and text B (RCB, WSB) obtained by good and poor ESL readers

Figure 5.10 presents the mean scores of RCA, RCB and written summaries A and B obtained by good and poor ESL readers. Independent t-tests indicated that the mean scores obtained by both groups were significantly different at $p < 0.001$. As expected, scientific text A was an easier text compared to scientific text B. This was apparent based on the comprehension scores received by the two groups which shows that both groups consistently obtained higher marks for RCA and WS A compared to RCB and WSB. The results of paired samples t-test reveal that differences in the mean scores between RCA and RCB as well as WS A and WS B in both groups were significant at $p < 0.001$.

So what made good readers good at comprehending both scientific texts and poor readers poor at the same tasks? Besides motivation and reading interest, there are four variables that may have contributed to successful or unsuccessful reading comprehension of scientific texts namely L2 proficiency, metacognitive awareness, scientific prior knowledge and strategy use.

Table 5.46

Means and Independent T-tests on Variables of Good and Poor Readers of Scientific Texts

Variable	Mean		Independent t-test (df: 193)	
	Good Readers	Poor Readers	*t*	*p*
Metacognitive Awareness	258.56	255.29	-.602	.825
SPK Text A	14.22	14.17	-.080	.937
SPK Text B	14.81	13.12	-2.60	.010*
SPK Scientific Terms	6.78	5.73	-3.51	.001*
L2 Proficiency	3.73	3.17	-5.73	.000*
MC strategies (in Text A)	4.81	4.51	-2.34	.020*
HC strategies (in Text A)	4.70	4.39	-2.45	.015*
LC strategies (in Text A)	4.67	4.56	-.84	.405
MC strategies (in Text B)	4.80	4.53	-1.981	.049*
HC strategies (in Text B)	4.66	4.33	-2.57	.011*
LC strategies (in Text B)	4.63	4.50	-.954	.341

*Significant mean difference

Table 5.46 presents the means of independent variables which may have influenced the reading comprehension of scientific texts between good and poor readers. Independent t-tests revealed that there were no significant differences in the means of metacognitive awareness and SPK Text A between good and poor readers. However, there were significant differences in the means of SPK text B, SPK scientific terms, L2 proficiency, MC and HC strategies between good and poor readers at $p < 0.05$ level. From this analysis, it was found that good readers possessed more scientific prior knowledge on the topic of text B (*Hormones and Signal Transduction*) and scientific terminology used in both scientific texts. Good readers were also more proficient in the English language which helped to explain their advantage of understanding the scientific terminology used as well as comprehending the scientific texts better. Surprisingly, even with higher L2 proficiency, good readers were found to strategize more while reading compared to poor readers. The results indicate that good readers exerted more effort compared to poor readers on MC and HC strategies while reading both scientific texts.

Before the characteristics of good readers could be identified, more tests are required to determine the types of strategies utilized by good compared to poor readers of scientific texts. Table 5.47 presents the specific MC and HC strategies used by both groups of readers while reading scientific texts A and B. Independent t-tests indicated which mean difference was significant. The data indicate that good readers exerted more effort on MC strategies monitoring and debugging with a mean of above 5.00 on the Likert scale and it was sustained throughout the two reading tasks. In addition, specific strategies like HC visualizing, HC analyzing visual diagram, HC analyzing text, and HC summarizing were used with greater intensity compared to poor readers while reading texts A and B and these strategies may have been the contributing factors to successful comprehension of the two scientific texts.

Table 5.47

Means and Independent T-tests on MC and HC Strategies Utilized by Good and Poor Readers

Strategies	Mean		Independent t-test	
	Good Readers	Poor Readers	t	p
	Scientific Text A			
MC- Planning	4.65	4.38	-1.90	.059
MC-Monitoring	5.14	4.86	-2.11	.036*
MC-Evaluating	4.40	4.12	-1.85	.066
MC-Debugging	5.06	4.69	-2.57	.011*
HC-Visualizing	4.91	4.39	-3.10	.002*
HC-Analyzing Visual Diagram	5.05	4.31	-4.99	.000*
HC-Analyzing Text	4.58	4.19	-2.28	.023*
HC-Inferring Language	4.84	4.71	.43	.413
HC-Inferring Content	4.35	4.32	-.22	.824
HC-Accessing Prior Knowledge	4.63	4.49	-.965	.336
HC-Summarizing	4.62	4.23	-2.27	.025*
HC-Questioning content	4.68	4.36	-1.93	.055
HC-Reading for Global Understanding	4.59	4.53	-.376	.708
	Scientific Text B			
MC- Planning	4.69	4.52	-1.08	.282
MC-Monitoring	5.12	4.76	-2.55	.012*
MC-Evaluating	4.34	4.16	-1.14	.256
MC-Debugging	5.05	4.66	-2.51	.013*
HC-Visualizing	4.86	4.27	-3.38	.001*
HC-Analyzing Visual Diagram	5.18	4.57	-3.87	.000*
HC-Analyzing Text	4.55	4.05	-2.84	.005*
HC-Inferring Language	4.97	4.65	-2.05	.041*
HC-Inferring Content	4.32	4.20	-8.10	.419
HC-Accessing Prior Knowledge	4.62	3.28	-2.17	.031*
HC-Summarizing	4.55	4.03	-2.74	.006*
HC-Questioning content	4.60	4.26	-1.92	.056
HC-Reading for Global Understanding	4.32	4.62	1.93	.055

*Significant mean difference

It is also noteworthy to mention that while reading scientific text B (difficult/less familiar), good readers tended to infer the meaning of the text through the language used (HC inferring language). Yet HC inferring the meaning of content was used only moderately, not just by good readers but also by poor readers. This is consistent with the findings by Koch (2001) in that scientific texts must be understood word for word without skipping which implies that inferring the meaning of scientific content is not encouraged in reading science.

In addition, good readers were also found to access their prior knowledge (HC prior knowledge) on *hormone and signal transduction* in order to assist them in comprehending the text. The combination of MC strategy monitoring, MC debugging and HC strategy accessing prior knowledge suggests that good readers were employing problem solving strategies when encountered with reading difficulties (Block, 1992; Brown and Baker, 1984; Li and Munby, 1992; Young & Oxford, 1997). This finding is also consistent with those reported by Sheorey and Mokhtari (2001) and Block (1992) in that skilled readers are more able to reflect and monitor their reading processes.

One more step before research question six is answered is to look at specific LC strategies which were used by both good and poor readers of scientific texts as presented in Table 5.48.

Table 5.48

Means and Independent T-Tests on LC Strategies Utilized by Good and Poor Readers of Scientific Texts

Strategies	Mean		Independent t-test	
	Good Readers	Poor Readers	*t*	*p*
	Scientific Text A			
LC-Decoding	4.09	4.01	-.55	.585
LC-Translating	4.11	4.65	2.71	.007*
LC-Questioning language	4.74	4.67	-.41	.683
LC-Paraphrasing	4.71	4.50	-1.23	.219
LC-Memorizing & Taking Notes	5.23	4.78	-2.86	.005*
LC-Reading for Local Understanding	5.13	4.73	-2.83	.010*
	Scientific Text B			
LC-Decoding	4.09	4.05	-.27	.791
LC-Translating	4.13	4.53	2.09	.038*
LC-Questioning language	4.72	4.54	-1.11	.269
LC-Paraphrasing	4.65	4.44	-1.20	.231
LC-Memorizing & Taking Notes	5.13	4.69	-2.56	.011*
LC-Reading for Local Understanding	5.06	4.74	-1.89	.060

*Significant mean difference

Table 5.48 presents the means as well as the results of independent t-tests of specific LC strategies used by good and poor readers while reading scientific texts A and B. The results indicate that good readers used LC strategies of memorizing and taking notes as well as reading for local understanding at a very high intensity which was above 5.00. Except for translating strategy, good readers tended to use almost all strategies with greater intensity than poor readers. The findings in this study are consistent with previous findings in science education which maintained that ‘good strategies’ in reading scientific texts include effective note-taking strategies (Bonner & Holliday, 2006), rereading (Burdick, 1991), and understanding each word (Koch, 2001).

In sum, it was found that good readers generally possessed higher L2 proficiency level and were very much aware of their reading processes. They constantly monitored their reading comprehension and tried to repair reading difficulties. In addition, good L2 readers exerted greater intensity into certain 'good' strategies for reading scientific texts such as HC visualizing, HC analyzing visual diagrams, HC analyzing text, HC accessing prior knowledge, HC summarizing, LC memorizing and taking notes, and LC reading for local understanding.

5.8.3 Characteristics of HP good readers versus LP good readers

In order to find out the characteristics of good readers regardless of their L2 proficiency, the data on good readers were further divided into HP and LP good readers. The result yielded 52 HP good readers and 41 LP good readers. Figure 5.10 presents the comparisons of four reading comprehension measures between the two groups.

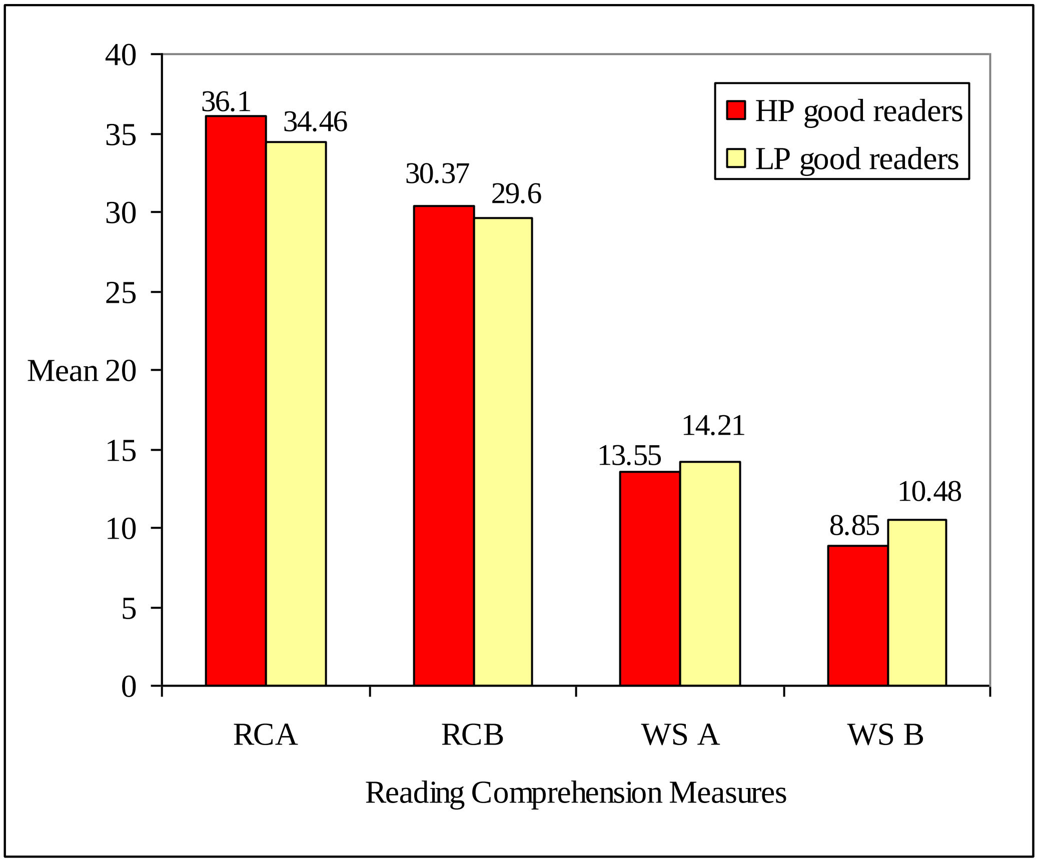

Figure 5.11 Mean scores of reading comprehension of text A (RCA) and text B (RCB) obtained by good HP and LP readers

Figure 5.11 presents the mean scores of reading comprehension of texts A and B obtained by HP and LP good readers of scientific texts. It could be observed from the illustration above that HP good readers scored slightly higher means in RCA and RCB compared to LP good readers. Yet, LP good readers were found to outperform HP good readers in WS A and WS B. Independent t-test was conducted and the result indicates that the mean scores of RCA and RCB obtained by HP and LP good readers were not significantly different, with $t(91) = -1.69$, $p = .095$ and $t(91) = -.97$, $p = .332$ respectively. Similarly, the difference in the means of WS A between HP and LP good readers was also not significant, $t(91) = .77$, $p = .442$.

Surprisingly, there was a significant difference in the means of WS B between the two groups of good readers, $t(91)= 2.50$, $p = .014$. This means that LP good readers scored significantly higher means in the written summary of scientific text B which has been shown as more difficult syntactically and less familiar in topic. This implies that LP good readers may perhaps have understood both scientific texts. However, the use of their L2 as the language of the test for multiple choice questions (MCQ) and multiple true and false (MTF) statements may have stymied their comprehension of each test itself, but not the texts. This is also evident when LP good readers managed to explain their understanding of the biochemical process of *cell elongation* (WS A) and *signal transduction* (WS B) as well as and also better than HP good readers.

The finding above indicates that good readers of scientific texts, regardless of L2 proficiency, were comparable in their comprehension of the two scientific texts. So, a rhetorical question to ask would be 'what was the plus factor possessed by LP good readers that made it possible for them to match HP good readers in comprehending the two scientific texts of different syntactic difficulty and topic familiarity?'

As L2 proficiency has been eliminated from acting as one of the decisive variables in determining the characteristics of good readers of scientific texts, the two groups of good readers were compared in terms of their metacognitive awareness, scientific prior knowledge, and strategy use. Table 5.49 displays the contributing variables that may have influenced HP and LP good readers' reading performance of scientific texts. The data demonstrate that HP and LP good readers were comparable in metacognitive awareness, scientific prior knowledge of text A as well as MC and HC strategy use for both texts. HP good readers had significantly more scientific knowledge on *hormones and signal transduction* and knowledge of scientific terminology used in both scientific texts.

Table 5.49

Descriptive Statistics and Independent T-Tests on Variables Possessed and Utilized by HP and LP Good Readers of Scientific Texts

Variable	Mean Good Readers		Independent t-test (df: 91)	
	HP	LP	*t*	*p*
Metacognitive Awareness	254.12	264.20	1.42	.159
SPK Text A	14.94	13.29	-1.80	.075
SPK Text B	16.19	13.05	-3.45	.001*
SPK Scientific Terms	7.42	5.98	-3.04	.003*
MC strategies (in Text A)	4.71	4.95	1.44	.153
HC strategies (in Text A)	4.60	4.81	1.34	.183
LC strategies (in Text A)	4.46	4.93	2.71	.008*
MC strategies (in Text B)	4.71	4.92	1.27	.209
HC strategies (in Text B)	4.60	4.75	.94	.348
LC strategies (in Text B)	4.45	4.86	2.41	.018*

*significant mean difference at $p < 0.05$ level

Again, surprisingly even with these two advantages possessed by HP good readers, LP good readers could still match in their reading comprehension of both texts as well as outperform HP good readers in the written summary of text B. The only difference observed in the LP good readers was their great intensity in utilizing LC strategies.

Even though the difference between HP and LP good readers lies in the use of LC strategies, this analysis would also look closely at specific MC and HC strategies used by these two groups. Table 5.50 compares the mean of each specific strategy used by HP and LP good readers.

Table 5.50

Means of Specific Strategies Utilized by HP and LP Good Readers to Read Two Scientific Texts

	Mean			
	Scientific text A		Scientific text B	
Strategies	HP-good	LP-good	HP-good	LP-good
MC-Planning	4.46	4.89	4.53	4.89
MC-Monitoring	**5.12**	**5.17**	**5.12**	**5.14**
MC-Evaluating	4.29	4.54	4.26	4.43
MC-Debugging	**4.96**	**5.18**	**4.92**	**5.21**
HC-Visualizing	**4.92**	**4.91**	**4.89**	**4.82**
HC-Analyzing Visual Diagram	**5.01**	**5.09**	**5.20**	**5.16**
HC-Analyzing Text	4.61	4.45	4.57	4.52
HC-Inferring Language	**4.96**	**4.96**	**4.96**	**4.98**
HC-Inferring Content	4.09	4.69	4.14	4.55
HC-Accessing Prior Knowledge	4.59	4.69	4.50	4.78
HC-Summarizing	4.42	4.88	4.46	4.87
HC-Questioning content	4.55	4.84	4.48	4.76
HC-Reading for Global Understanding	4.48	4.73	4.19	4.48
LC-Decoding	3.87	4.38	3.83	4.42
LC-Translating	3.60	4.76	3.70	4.67
LC-Questioning language	4.56	4.96	4.68	4.77
LC-Paraphrasing	4.56	4.90	4.41	4.95
LC-Memorizing & Taking Notes	**5.11**	**5.38**	**5.05**	**5.22**
LC-Reading for Local Understanding	**5.07**	**5.21**	**5.03**	**5.10**
N	52	41	52	41

Table 5.50 presents the means of specific MC, HC and LC strategies utilized by HP and LP good readers when reading scientific texts A and B. In general, LP good readers exerted greater intensity in most strategies they reported using compared to HP good readers. This is reasonable since HP good readers are proficient and comprehension may have become very automatic which did not require them to strategize as much as LP good readers. The results of independent t-test (Table 5X1, appendix X) on strategies to read scientific text A between these two groups show that LP good readers used significantly higher MC planning, HC inferring content, HC summarizing, LC decoding, translating, questioning language, memorizing and taking notes compared to HP good readers. However, upon close inspection, the intensity of LC decoding and translating was in fact moderate. This may perhaps imply that LP good readers were using these strategies to compensate for their limited L2 proficiency when comprehension was at stake. However, the strategies which they used rigorously that were significantly different from HP good readers were LC paraphrasing and HC summarizing. The result of a second independent t-test (Table 5X2, appendix X) on strategies to read scientific text B between HP and LP good readers reveals that LP good readers used significantly higher ($p<0.05$) HC strategy of inferring content and LC strategies of decoding, translating and paraphrasing.

What made LP good readers were able to match the reading comprehension of HP good readers may perhaps lie in the intensity of their strategy use. Closer inspection of each of the specific strategies in Table 5.50 reveals that LP good readers consistently used higher intensity for each strategy compared to HP good readers except for HC strategies visualizing, analyzing text, and inferring language.

It is also worth mentioning that a comparison between HP and LP good readers' strategy use as presented in Table 5.50 shows that good readers of scientific texts tended to use MC monitoring, MC debugging, HC visualizing, HC analyzing visual diagram, HC inferring language, LC memorizing and taking notes, and LC reading for local understanding. On the contrary, HC reading for global understanding and HC accessing prior knowledge were used only moderately.

Therefore, to answer research question six on the characteristics of good ESL readers of scientific texts, it is found that:

(1) More than half of good L2 readers of scientific texts or 55.9% were proficient in their L2. Surprisingly, 44.1% of good readers of scientific texts were made up of low proficiency L2 learners. These LP good readers tended to compensate their limited L2 proficiency by employing LC strategies like translating and paraphrasing and later employed a higher level processing strategy such as HC strategy of summarizing.

(2) Good L2 readers of scientific texts, regardless of their L2 proficiency levels, were very much aware of their reading processes. They possessed comprehension monitoring competence that enables them to select and carry out not only effective cognitive strategies (Pang, 2008; Yang, 2002) but also problem solving strategies in their attempt to comprehend the specific text in hand. This finding also lends support to the claim that

good as opposed to poor L2 readers were more metacognitively strategic in reading (Baker & Brown, 1984; Li & Munby, 1996).

(3) Good L2 readers of scientific texts tended to exert greater intensity in each strategy they used compared to poor readers. LP good readers exerted more effort in strategy use than HP good readers.

(4) Good L2 readers used cognitive strategies relevant to the specific domain area which were reading details, taking notes and analyzing scientific diagrams.

(5) In addition, good L2 readers exerted greater intensity into each strategy that they used compared to poor readers. Good readers were also determined readers in that they sustained a high intensity of strategy use even when faced with a demanding text.

(6) Finally, perseverance may perhaps be another characteristic of good L2 readers. Good L2 readers were found to sustain or increase the intensity of their strategy use in order to stride through the complexities of the texts to get to the core message with correct interpretation.

5.9 Chapter summary

This chapter describes the how the data were analysed and the findings provided answers for quantitative research questions 1 to 6. It should be noted that even though for some questions the respondents had to be divided into three university groupings, it did not at all suggest that one university group is superior to the other. Instead, it reflects the rich nature of the data and the complexities in understanding the phenomenon involved in reading comprehension of scientific texts among ESL readers. However, the findings provide a better understanding on how strategies were used by ESL science undergraduates while attempting to comprehend the two scientific texts. The information in this chapter will be more meaningful after it is triangulated with the findings from qualitative data in chapter 6.

CHAPTER SIX

DATA ANALYSES AND FINDINGS ON FIVE CASE STUDIES

6.1 Overview

This chapter describes the data analyses and findings of five case studies in order to obtain a more complete understanding of how individual ESL undergraduates used reading strategies while reading the two scientific texts. The qualitative data on individual strategy use were obtained from ten think aloud protocols and ten retrospective interview protocols. The findings in this chapter address the seventh and eighth research questions:

7. How do ESL readers with different levels of L2 proficiency negotiate the two scientific texts?
8. What are the difficulties they encountered while reading the two scientific texts and how did they overcome the problems?

6.2 Respondents' profile

Five first-year ESL science undergraduates participated in the second phase of the study. This phase made use of think aloud protocol to collect data on strategy use. Besides, the respondents were also interviewed to provide the researcher with an in depth understanding of their strategy choices, the difficulties they encountered, and the steps taken to overcome them while reading both texts. They were enrolled in a bachelor's degree programme in biological science and were in their second semester when the study was conducted. Their ages ranged between 19 to 22 years old. Their L2 proficiency, Grade Point Average (GPA) of the first semester, prior knowledge (in terms of grade in biology course in the first semester) are tabulated in Table 6.1 as follows:

Table 6.1

Respondents' profile

	Az ([1]F)	**Zeti (F)**	**Di (F)**	**Wan (M)**	**Riz (M)**
L2 ([2]MUET)	3 (Modest User)	2 (Limited user)	4 (Competent User)	4 (Competent User)	2 (Limited User
GPA	3.49	3.15	2.88	3.35	2.67
Post Sec. Edu	STPM (2 years)	Matric (1 year)	STPM (2 years)	Matric (1 year)	Matric (1 year)
[3]Biology grade (PK)	A	B+	B	A-	B-
[4]MAI Score	287	258	317	242	256

[1]F – Female; M- Male;
[2]MUET- Malaysian University English Language Test
[3]Biology grade obtained in STPM/Matriculation; PK – Prior Knowledge
[4]MAI-Metacognitive Awareness Inventory (Schraw & Dennison, 1994)

6.2.1 Respondent #1: AZ

Az was 21 years old at the time of the study. She had had two years of pre university studies (Lower and Upper Sixth Form) before sitting for the *Sijil Tinggi Persekolahan Malaysia (MalaysianCertificate of Higher Education).* This means that she had had two years of exposure in learning and reading science in English before commencing her undergraduate study. With a MUET band 3, Az was categorized as a modest English user and could be labeled an LP (low L2 proficiency) learner. Yet, she managed to get a grade of A in her biology paper and the highest GPA among the five respondents which was 3.49. In addition, she had a score of 287 for her metacognitive awareness level which was assessed using the metacognitive awareness inventory (MAI, hereafter) (Schraw & Dennison, 1994).

Az admitted that she was only aware of her use of lower cognitive (LC, hereafter) strategies such as reading slowly, rereading, underlining and the higher cognitive (HC, hereafter) strategy of verbal summary and accessing her scientific prior knowledge (semi-structured retrospective interview, SSRI 1A, p.23). Az's think aloud protocols of the two scientific texts revealed that she was actively using HC strategies especially reflecting and relating the information in the texts to her prior knowledge of science as well as to other paragraphs of the text. She monitored her understanding of the texts vigorously and took steps to solve her comprehension problems (metacognitive strategies; MC, hereafter). She checked, crosschecked and confirmed her understanding (MC) of the points 11 times in text A and 19 times in text B.

There was evidence from her think aloud protocols (TAP, hereafter) that Az compensated her inadequate L2 proficiency with HC strategies and her lack of prior knowledge with LC strategies (TAP 1A & 1B). However, her LC strategies were confined to only rereading sentences and occasionally breaking up long sentences into small parts. Evidence from her TAP also revealed that Az did not translate the whole problematic sentences into her L1 but instead tended to code switch to her L1 in order to summarize lengthy English clause that precedes the key point in a particular sentence. This is consistent to Kern's (1994) finding that L2 readers tended to opt for L1 translation as a mental scratch pad or semantic buffer. Excerpts 1 and 2 illustrate this phenomenon.

Excerpt 1

	<u>Scientific Text A: Sentence 8</u> : **The term auxin is used to describe a class of chemicals whose chief function is to promote the elongation of developing shoots.**
LC-switching to L1	...Chief function <u>*dia untuk*</u> auxin promote elongation of developing shoots… (TAP 1A, 277) [Translation: chief function <u>it is for</u> auxin (to) promote elongation…]

Excerpt 2

	<u>Scientific Text B: Sentence 22(i)</u>: **...the same chemical messenger may have different effects at different concentrations…**
LC-switching to L1	"…<u>*Dia ada*</u> different effect at different concentration... " (TAP 1A, 167) [Translation: ... <u>It has</u> different effect at different concentration…]

In both excerpts above, the L1 word *'dia'* refers to '**the term auxin is used to describe a class of chemicals'** and '**the same chemical messenger'** respectively.

Az was an example of a reader with low L2 proficiency but possessed high metacognitive awareness. She was highly aware of her reading ability as well as her reading comprehension problems. This was evident from her TAP analysis when she was observed to utilize more MC strategies (36.9%) and LC strategies (43.8%) compared to only 19.3% on HC strategies while reading text A. However, she was found to change her reading strategy choices when confronted with text B which was more challenging in terms of sentence structure. Az's TAP analysis of text B revealed that she negotiated text B by employing 32.7% of her total strategy use on MC strategies, 41.6% on HC strategies, and 25.7% on LC strategies. This change in strategy choices resulted in a better comprehension of the text B compared to text A as revealed by her reading comprehension scores (RC) of both texts (see Table 6.5).

6.2.2 Respondent # 2 Zeti

Zeti was one of the two respondents who obtained MUET band 2 which categorized her as a limited English user. She earned an average of B+ for biology papers in semester one and managed to obtain a GPA of 3.15. In addition, she obtained a score of 258 for MAI. Zeti had had only one year exposure to learning and reading science in English at a science matriculation centre before commencing her undergraduate studies.

Zeti admitted to being very comfortable with the think aloud procedure as reading academic texts aloud to herself was already her regular routine (SSRI2B, p. 3). During a retrospective interview, Zeti revealed that her most valuable strategy to comprehend scientific text besides reading aloud was taking down notes and making mind maps (SSRI2B, pp. 5-9). Zeti claimed that the strategy was highly efficient for her. Zeti's TAP analyses of both texts indicated that she utilized a very large number of LC strategies (47.4% and 43.2% for text A and B respectively), most of which were translating into Malay language (L1) and rereading. This was inevitable since being a low L2 proficiency reader, her only option to process both scientific texts was going bottom up. Yet, after breaking up the complex scientific English sentences, decoding words and phrases, and translating each piece into her L1, she had a good sense to employ HC strategies (32.6% and 28.4% for texts A and B respectively) like summarizing pieces of information, comparing new information to science prior knowledge, and synthesizing the ideas and concepts . Excerpt 3 illustrates Zeti's reading routine which started with normal reading and followed by translating (LC), rereading (LC), employing a few HC and MC strategies in-between before ending her reading routine with a verbal summary (HC) of the sentence(s).

Excerpt 3

	<u>Scientific Text A: Sentence 24</u> **One hypothesis is that auxins initiate elongation by weakening cell walls by stimulating certain proteins in a plant cell's plasma membrane to pump hydrogen ions into the cell wall.**
LC-translating	*Ada hypotesis kata, auxin akan memulakan pemanjangkan dengan mengejutkan cell wall dengan merangsang protein pada plant cell membrane untuk pump hydrogen ke dalam cell wall…*(TAP 3A, line 201) [Translation: There is an hypothesis that says that auxin will commence elongation by wakening up the cell wall by stimulating the protein at the cell membrane of the plant to pump hydrogen into the cell wall]

LC-rereading	**One hypothesis is that auxins initiate elongation by weakening cell walls by stimulating certain proteins in a plant cell's plasma membrane to pump hydrogen ions into the cell wall..** (TAP 3A, line 424-426)
HC-analyzing visual diagram & HC-verbally summarizing diagram	*Kalau tengok pada gambar, err ..bila bila proton ni dia jumpa dengan protein…auxin distimulate… distimulate… lepas tu H^+ ni masuk dalam cell wall. Bila dia masuk dalam cell wall, dia akan aktifkan enzim, aktifkan enzim err…aktifkan enzim… di mana enzim ni akan menyebabkan sel memanjang….*(TAP 3A, line 429-432)
	[Translation: Looking at this diagram, err…when this proton meets the protein, auxin is stimulated….is stimulated…then this H^+ enters the cell wall. When it enters the cell wall, it will activate enzyme, will activate enzyme…err..activate enzyme…where this enzyme will cause the cell to elongate…]

This routine of employing LC strategies to process sentences before taking the ideas up to a higher cognitive level was done repeatedly throughout both reading tasks of texts A and B as evidenced in her TAP. In an interview with Zeti, she admitted that her preference for detailed understanding of the text compelled her to reread slowly, translate details into L1, read and explain the sentence to herself aloud, and created mind map for each topic read (SSRI2B, pp. 6, 23-26). Her approach to reading scientific texts seemed to help her get detailed as well as holistic meanings of both texts as revealed in her successful comprehension of both texts (see Table 6.5).

6.2.3 Respondent # 3 Di

Di was a competent English user based on her MUET band 4 but she believed that she was more comfortable reading materials in the Malay language (SSRI3A, p. 1). She obtained a B grade for her biology paper, a GPA of 2.88 in semester one but scored the highest marks for MAI which was 317. Like Az, Di had two years exposure to learning and reading science in English and thus had the advantage of having more science prior knowledge compared to those who went to matriculation centres for their post secondary education.

Di's TAP analysis revealed that she was reading both texts very closely by applying bottom-up reading processes and predominantly using lower cognitive strategies. She was constantly rereading problematic sentences and translating them into Malay language. When translation failed to help her comprehend the sentence, she chose a higher cognitive strategy of guessing the meaning of words, phrases, or sentences. For text A, Di repeatedly utilized a HC strategy of verbal summary (29 times). Below is excerpt 4 that illustrates her summarizing strategy which was usually translated into the Malay language.

Excerpt 4

	<u>Scientific text A: Sentences 18 & 19</u>
	Above certain level (0.9g of auxin per liter of solution, in this case), it usually inhibits cell elongation in stems. **This inability effect probably occurs because a high level of IAA makes the plant cells synthesize another hormone, ethylene, which generally counters the effects of IAA.**
HC-summarizing	*Semakin tinggi kepekatan, proses pemanjangan juga kurang* (TAP 3A, line 476)
	Err IAA, IAA akan menyebabkan sel menghasilkan hormone yang lain iaitu ethylene apabila kepekatan terlalu tinggi (TAP 3A, line 480)
	[Translation: As the concentration rises, elongation process decreases. Err IAA, IAA will cause the cell to produce another hormone which is ethylene when concentration is too high.]

The excerpt above shows that Di summarized the pieces of information that she had understood in Malay language which was her regular reading tactic when reading scientific text A. In a retrospective interview, Di revealed that she summarized the ideas in Malay language not only to thoroughly understand the text but also to memorize the points (SSRI3A, pg. 16). However, she dramatically reduced the frequency of her summarizing strategy when reading text B to only three times. Di also monitored her understanding (MC) of text A very closely and explained to herself points which she felt she understood. However, when she was reading text B, she did not try to explain certain points that she said she understood as she did with text A. This evidence of changing strategy use strongly suggests that text B was a difficult text for her, thus she was not able to summarize the ideas or explain to herself the points which she thought she understood. The analyses of her

TAP for text B also showed that she found at least five sentences to be too long and difficult to understand, compared to only one in text A.

Di had a lot going for her in reading to comprehend both scientific texts successfully. She was somewhat competent in the English language and had two years of exposure to learning biology in English in form six. However, she seldom leaned on her science prior knowledge to help her understand the texts. She preferred to tackle the texts with lower cognitive strategies especially translation. She admitted during the retrospective interview that translating sentences helped her grasp and retain the meaning longer in her memory (SSRI3A, p. 13). Translation (LC) seemed to be working very well when she immediately summarized (HC) the points in her own words as she did when reading text A. However, when her translation (LC) was not accompanied with summarization (HC) as she did with text B, the first strategy seemed less effective. It could also be that the reason that she could not summarize the points she was reading was because she did not really understand the concept after all.

6.2.4 Respondent # 4 Wan

Wan is another competent English user as he obtained band 4 for MUET. His exposure to learning science in English prior to becoming a first year undergraduate was only one year at a science matriculation centre. He obtained an A- for a biology paper, a GPA of 3.35 in the first semester, and scored 242 marks for MAI. Even though Wan rarely reflected on his scientific prior knowledge of the two topics in his TAP, the mental images that he reported forming in his mind throughout the think aloud procedure revealed that he was building numerous images of what he read with what he knew about the topic (his prior knowledge). Based on the retrospective interview with Wan, he admitted that the images were actually from diagrams he had seen in biology textbooks (SSRI4A, pp. 17 & 26). The following excerpt 5 shows that Wan constantly forming images, at times colourful images, of what he read.

Excerpt 5

HC-visualizing	Scientific Text A: Sentence 19 **This inability effect probably occurs because a high level of IAA makes the plant cells synthesize another hormone, ethylene which generally counters the effects of IAA.** *"…So, benda ni saya terbayangkan iskk… ada satu sel, lepas tu ada bintik-bintik kecil, ada dua kelompok, satu color kuning satu merah, yang satu tu IAA, satu lagi ethylene…"* (TAP 4A, 180) [Translation: So, this thing I am visualizing iskk… there is a cell, and then there are small dots, there are two groups, one in yellow another in red, one is IAA and the other is ethylene…]

His ability to visualize the scientific concepts as he was reading and put colour to these images were evidence that a reader's prior knowledge stored in his mind tended to automatically integrate with the information in the text. However, when the relevant prior knowledge was lacking in a reader's stored memory, the images ceased to form. This was what happened to Wan when he failed to visualize images of what he was reading in the following excerpt 6.

Excerpt 6

	<u>Scientific Text A: Sentence 26a</u> **"…After this initial elongation, the cell sustains the growth by synthesizing more wall …"**
MC-intention to reread to fix comprehension problem	*Saya baca balik…*(TAP 4A, line 275) [Translation: I (will) reread…]
LC-rereading	"After this initial elongation, err the cell sustains the growth by synthe… …by synthesizing more wall material and cytoplasm…"
MC-admitting no images formed	*Err ini …saya tak dapat gambaran …* [Translation: Err…this..I could not visualize…]
MC-acknowledging understanding	*tapi saya faham yang… yang sel ini akan terus develop dengan buat lagi banyak err komponen-komponen untuk dinding sel wall ni dengan lebih banyak buat cytoplasm…* (TAP 4A, line 278) [Translation: but I understand that…that this cell will continue to develop by generating more err…components for the cell walls…this wall by generating more cytoplasm…]

Excerpt 6 shows that Wan failed to have images of what he had read. The researcher attributes the failure to lack of prior knowledge for him to fall back on and Wan admitted that he could not visualize new information (SSRI4, p. 29). Failing that, Wan reread the problematic sentence by processing it from the bottom up to understand the idea.

Wan spoke of the mental images, which was a HC strategy, as many as 70 times when reading text A and 34 times for text B. Besides that, Wan was an efficient user of other higher cognitive strategies such as verbal summarizing (HC) and guessing meaning of sentences (HC), and he closely monitored his understanding of the text (MC). Yet, during a retrospective interview, Wan admitted that he was only aware that he utilized reading strategies such as rereading (LC), relating ideas from different sentences/paragraph (MC), drawing flow charts (HC), and taking notes (LC).

6.2.5 Respondent # 5 Riz

Riz obtained a band 2 in MUET and was thus deemed a low L2 proficiency learner. He underwent a two-semester science matriculation course prior to his undergraduate studies as did Wan and Zeti. Riz earned an average of B- for biology, a GPA of 2.67 in the first semester of his freshman year, and scored 256 for MAI which was similar to Zeti’s MAI score. Riz admitted that he was very weak at reading and writing in English (SSRI5A, pp. 2, 5, 10) yet thought that there was no way around the problem of low English proficiency but to work hard, study and struggle in order to learn in this second language.

In both of his TAP and retrospective interview for text A, Riz expressed satisfaction in his understanding of scientific text A. In contrast, he admitted that text B was difficult for him to comprehend. Nevertheless, Riz performed equally poor on both reading comprehension measures of texts A and B. He scored the lowest compared to the other four respondents on both reading tasks. Riz was another good example of a respondent who had low L2 proficiency but very high prior knowledge of ‘auxins’ (text A). He was well acquainted with the hormone ‘auxin’ yet his prior knowledge was of general in nature as opposed to scientific knowledge. As a result, this general prior knowledge failed to facilitate his comprehension of the scientific phenomenon of the hormone auxin. One of the consequences of having low L2 proficiency but too much general knowledge on a scientific phenomenon was the tendency to generalize as well as infer unknown scientific concepts. Excerpt 7 illustrates Riz's effort to associate what he read with his general prior knowledge of auxin. This excerpt establishes the fact that Riz had first hand knowledge of auxin.

Excerpt 7

	<u>Scientific Text A: Sentence 1</u> **Plant biologists have identified five major types of plant hormones; auxins, cytokinins, gibberellins, abscisic acid in bracket ABA, and ethylene.**
HC-accessing prior knowledge	*Bila ingat auxin ni mesti saya ingat abah, dia suka tanam pokok cili…sebenarnya dia ada kawan dengan Cina kat Batu Pahat tu so dia ambik dia ada ambik hormone auxin, dia ada pergi kursus dekat UM, dia ada ambik sample untuk biakkan auxin ni, dia kata emm… sekarang ni kalau dok sibuk guna baja ni je tak boleh jugak, sebab auxin ni boleh tambahkan dia punya product*. [TAP 5A] [Translation: When (I) think about auxin I think of my father, he like to plant chillis, Actually, he has befriended a Chinese man in Batu Pahat, so he took… he took the hormone auxin, he had gone for a course in UM, he took a sample to breed this auxin, he said emm…now we cannot just use (ordinary) fertilizers because auxin can increase the harvest..]

Excerpt 8 illustrates Riz's tendency to infer unknown scientific concepts based on his general prior knowledge of auxin. Riz was trying to understand the concept of elongation of root and shoot cells based on the concentration of IAA. His low L2 proficiency resulted in his failure to grasp the meaning of complex sentence and thus used his general prior knowledge of auxin to compensate for his comprehension problem. His inference to the meaning of the sentence based on his general prior knowledge led him to misunderstand the scientific concept presented by the author.

Excerpt 8

Scientific Text A: Sentence 21

On the other hand, an IAA concentration high enough to make stem cells elongate is in the concentration range that inhibits root cell elongation.

Eh.. dah lain pulak…(TAP5A, line 260)
[Translation: this is different (from the sentence before).]

On the other hand, an IAA concentration high enough, to make stem cells elongation…(TAP5A, line 261)

Dia kata tadi kat sini, bila **IAA concentration**, *kepekatan IAA* **concentration** *dia rendah,* **too low** *rendah , untuk* **to stimulate** *pucuk, menyebabkan err apa …sel…***root, root** *apa* **root***? akar jadi panjang… Lepas tu kat sini pulak dia kata, kepekatan IAA yang tinggi ni cukup untuk…Ha… faham…maknanya bila dah pokok tu yang dekat pucuk tu dah err rendah, mungkin dia bagi dekat akar kot. Apabila kat akar, jadi panjang untuk menambahkan pemanjangan...* (TAP5A, lines 262-271)

[Translation: It says here, when IAA concentration, concentration of IAA is low, **too low** low, to **to stimulate** shoot, causes err…this cell…**root, root**, what is '**root**'? ……. root becomes long… Then here it says, this high IAA concentration is enough to… Ha..(I) understand, it means that when the (auxin at the) shoot is low, may be it gives (the auxin) to the root, perhaps. When (the auxin is) at the root, (the root) becomes long for elongation.]

Excerpt 9 provides further evidence that having high general prior knowledge for a low L2 proficiency reader may not necessarily improve his or her reading comprehension of scientific texts. In fact, Riz seemed to have relied too heavily on his general prior knowledge to make sense of the text that he tended to overlook certain new information provided by the author.

Excerpt 9

	<u>Scientific Text A: Sentence 32</u> **Farmers sometimes produce tomatoes, cucumbers, and eggplants, for example, by spraying the plants with synthetic auxins and resulting in seedless fruits.**
HC-accessing PK	*Macam abah selalu (ju)gak buat, abah buat, lada tu dekat kebun dia ambik sendiri, dia extract err…biji dia, lepas tu dia tanam, …Lepas tu, err … auxin ni…macam dalam ni pun dia cakap…farmer ni…farmer spray auxin…dia tak boleh spray auxin ni, sebab auxin mahal … auxin mahal, dia kena campur dengan air sikit, kasi dia banyak…*(TAP5A, lines 470-479) [Translation: Like father always does, the chillies at the farm… he plucked them himself, he extract(ed) err…the seeds, then he planted… then… err..this auxin, like it says here, farmer spray auxin…he cannot spray this auxin because auxin is expensive…auxin is expensive, he has to mix it with some water to increase the volume …]

The above excerpt from Riz's TAP shows that Riz failed to make use of his prior knowledge on auxin to gain new information that the text had to offer. He continuously guessed and generalized new information based on his prior knowledge and repeatedly missed the points put forward by the author. However, it could not be denied that Riz was a persistent reader who employed a high number of strategies consistently in both reading tasks. Unfortunately, his strategies were predominantly of lower cognitive level like rereading and translating. Failing to move above the text level to using higher cognitive strategies, like Zeti and Di, Riz may have obtained a fragmented understanding of both scientific texts. His HC strategies, which were mainly accessing his prior knowledge, were not used effectively and thus did not help his comprehension of the scientific concepts in scientific text A.

6.3 Research Question 7: Reading strategies used by five ESL undergraduates as revealed by the Think Aloud Protocols

This section reports on the findings that address the seventh research question on the types of reading strategies employed by ESL science undergraduates when reading the two scientific texts. Reading strategies of the five respondents while they were reading the two scientific texts were identified through their think aloud protocols and later coded and categorized based on the STARS inventory used earlier for the quantitative data.

6.3.1 General strategy use to read two scientific texts

From the grand total of 2203 coded TAP units recorded in this study from five respondents while reading scientific texts A and B, 980 or 44.5% were coded as lower cognitive strategies (LC), 688 or 31.2% were coded as higher cognitive strategies (HC), and 532 or 24.1% were coded as metacognitive strategies (MC). This indicates that the five respondents used more cognitive strategies (75.7% of the total strategy use) compared to metacognitive strategies. Table 6.2 illustrates the details of the strategy use by the five respondents as revealed by their think aloud protocols while reading scientific texts A and B.

Table 6.2

Frequency and Percentage of Specific Types of Strategies Used to Read Scientific Texts A and B

No.	Specific types of Strategies	Text A		Text B	
		Freq	%	Freq	%
1.	MC-Planning	17	1.4%	19	2%
2.	MC-Monitoring	175	14 %	143	15%
3.	MC-Evaluating	44	3.5%	56	5.9%
4.	MC-Debugging	40	3.2%	41	4.3%
	Metacogntitive Strategies	**276**	**22.1%**	**259**	**27.2%**
5.	HC-Analyzing Text Content	6	0.5%	9	0.9%
6.	HC-Visualizing	100	8.0%	39	4.1%
7.	HC-Analyzing Visual Diagram	45	3.6%	59	6.2%
8.	HC-Inferring Language	15	1.2%	16	1.7%
9.	HC-Inferring Content	34	2.7%	31	3.3%
10.	HC-Accessing prior knowledge	50	4.0%	52	5.5%
11.	HC-Questioning Content	19	1.5%	38	4.0%
12.	HC-Summarizing	54	4.3%	33	3.5%
13.	HC-Reading for global understanding	40	3.2%	48	4.8%
	Higher Cognitive Strategies	**363**	**29%**	**325**	**34.1%**
14.	LC-Paraphrasing	26	2.1%	12	1.3%
15.	LC-translating	179	14.3%	117	12.3%
16.	LC-Memorizing & Taking notes	48	3.8%	4	0.4%
17.	LC-Reading for local understanding (rereading/ decoding/ reading slowly)	368	29.4%	238	25%
	Lower Cognitive Strategies	**611**	**48.9%**	**369**	**38.7%**
	Total Strategy Use	**1250**		**953**	
	GRAND TOTAL	**1250 + 953 = 2203**			

From the grand total of strategies used, 1250 of them were made while respondents were reading scientific text A and 953 were made while reading scientific text B. As Table 6.2 illustrates, while reading scientific text A, respondents utilized LC strategies the most (Freq = 611, 48.9%) followed by HC strategies (Freq = 363, 29%) and MC strategies (Freq = 276, 22.1%). Yet, while reading scientific text B, a more difficult and less familiar text, respondents tended to follow the same pattern of strategy use but at a much reduced frequency; LC strategies (Freq = 369, 38.7%), HC strategies (Freq = 325, 34.1%), and MC strategies (Freq = 259, 27.2%). In fact, respondents seemed to employ top down reading strategies on a difficult and less familiar text (text B) to compensate for their inferior language proficiency and prior knowledge.

Upon closer examination of the strategy use in Table 6.2, it was found that LC strategy of reading for local understanding (which comprised of rereading sentences and questioning meaning of words and phrases, decoding words, reading slowly, circling and underlining problematic words) was the most frequently used strategy in reading scientific texts A (29.4%) and B (25%). This was followed by the LC strategy of translating with 14.3% in text A and 12.3% in text B. MC strategy of monitoring came third as frequently used strategy with 14% of total strategy use for text A and 15% for text B. Visualizing and analyzing visual diagrams (HC strategies) came forth frequently used strategy with 11.6% in text A (visualizing: 8%; analyzing visual diagram: 3.6%) and 10.3% in text B (visualizing: 4.1%; analyzing visual diagram: 6.2%).

Surprisingly, accessing prior knowledge (HC strategy) was used only 4% of total strategy use for text A while 5.5% was utilized in text B. It was earlier expected that respondents would access their scientific prior knowledge more for text A as they had about 50% prior knowledge on the topic compared to only about 30% for text B. Yet, the data revealed that respondents accessed their prior knowledge slightly more when reading text B. This may suggest that when a text is syntactically easier and the content can be understood through the prints, prior knowledge is kept at bay and only utilized when comprehension difficulties arise. On the other hand, when meaning is at stake while reading a challenging text such as text B, whatever prior knowledge a reader possesses will be accessed in order to untangle comprehension problems.

HC-summarizing was the fifth most frequently used strategy with 4.3% of total strategy use for text A but dropped to only 3.3% in text B. MC-evaluating and debugging and HC-reading for global understanding replaced summarizing strategy in fifth place for text B with 5.9%, 4.3%, and 4.8% of total strategy use respectively. HC-analyzing (text A = 0.5%, text B= 0.9%), inferring language (text A = 1.2%, text B= 1.7%), and MC-planning (text A = 1.4%, text B = 2%) were the three least used strategies in reading both scientific texts A and B while LC memorizing & taking notes (0.4%) and paraphrasing (1.3%) were the two least used strategies for text B.

It is interesting to note that the total strategy use for MC strategy and HC strategy increased from 22.1% and 29% respectively while reading text A to 27.2%

and 34.1% for text B. This may perhaps imply that readers were aware of the difficulties they encountered while reading text B, which was a more difficult text on a less familiar topic, and thus tended to exert more metacognitive strategies to monitor understanding and repair comprehension problems. Stanovich's interactive compensatory reading model was also evident when the data revealed that respondents tended to slightly shift strategy use from bottom up strategies (LC) in text A to top down strategies (HC) in text B. The percentages of LC strategies used dropped from 48.9% to 38.7% from text A to text B respectively while HC strategies used increased from 29% to 34.1% from text A to text B.

6.3.2 Strategy shift while reading scientific text A and scientific text B

Respondents' strategies were further analyzed and thus listed according to the most to the least frequently used as illustrated in Table 6.3. LC- reading for local understanding, translating and MC monitoring were the top three most frequently used strategies by five ESL science undergraduates when reading both scientific texts. Even though the order of the strategies was shifted, they remained the most frequently used strategies by the five ESL respondents.

Table 6.3

The Most to the Least Frequently Used Strategies while Reading Scientific Texts A and B

	Scientific Text A	%	Scientific Text B	%
1.	LC-Reading for local understanding	29.4%	LC-Reading for local understanding	25%
2.	LC-Translating	14.3%	MC-Monitoring	15%
3.	MC-Monitoring	14 %	LC-Translating	12.3%
4.	HC-Visualizing	8.0%	HC-Analyzing Visual Diagram	6.2%
5.	HC-Summarizing	4.3%	MC-Evaluating	5.9%
6.	HC-Accessing prior knowledge	4.0%	HC-Accessing prior knowledge	5.5%
7.	LC-Memorizing & Taking notes	3.8%	HC-Reading for global understanding	4.8%
8.	HC-Analyzing Visual Diagram	3.6%	MC-Debugging	4.3%
9.	MC-Evaluating	3.5%	HC-Visualizing	4.1%
10.	MC-Debugging	3.2%	HC-Questioning Content	4.0%
11.	HC-Reading for global understanding	3.2%	HC-Summarizing	3.5%
12.	HC-Inferring Content	2.7%	HC-Inferring Content	3.3%
13.	LC-Paraphrasing	2.1%	MC-Planning	2%
14.	HC-Questioning Content	1.5%	HC-Inferring Language	1.7%
15.	MC-Planning	1.4%	LC-Paraphrasing	1.3%
16.	HC-Inferring Language	1.2%	HC-Analyzing text content	0.9%
17.	HC-Analyzing text content	0.5%	LC-Memorizing & Taking notes	0.4%

The only common strategy utilized for texts A and B in the second top three strategies was HC accessing prior knowledge. While HC visualizing and summarizing came fourth and fifth most used strategies for text A, HC analyzing visual diagram and MC evaluating were the fourth and fifth strategies for text B. This may suggest that for text A, having more prior knowledge of the topic *Auxins* and the text being syntactically less difficult, the five respondents in this study were more able to mentally visualize the description of the text and summarize the main points. However, with a more difficult text on a less familiar topic, visualizing and summarizing the content of text B appeared to be tougher. Thus, the readers resorted to analyzing the visual diagram provided to understand the text and evaluated their understanding more rigorously.

For text A, LC memorizing and taking notes was seventh most used strategies, yet these two strategies dropped to number 17 and thus the least used strategy for text B. HC strategies of analyzing, inferring language and content, LC strategy of paraphrasing, and MC strategy of planning remain at the bottom quarter of scientific reading strategy use.

In general, there was a moderate shift in the overall strategy use from reading text A (which was less difficult and familiar) to text B (difficult and less familiar) by the five undergraduates. The main difference lies in the extent of the use of strategies like MC evaluating, HC visualizing, summarizing, analyzing visual diagrams, reading for global understanding, questioning content, and LC memorizing and taking notes.

6.3.3 Reading strategies used by five ESL science undergraduates

To get a better understanding on the use of reading strategies by the five ESL undergraduates while reading scientific texts A and B, their strategies are tabulated in Table 6.4 . This Table displays the frequency of each specific type of strategies used by them collectively.

Table 6.4

Specific Strategies Employed by Five ESL Undergraduates When Reading Scientific Texts A and B

		SCIENTIFIC TEXT A (AUXINS)					**SCIENTIFIC TEXT B (SIGNAL TRANSDUCTION)**				
		Az	**Zeti**	**Di**	**Wan**	**Riz**	**Az**	**Zeti**	**Di**	**Wan**	**Riz**
1.	MC-Planning	4	2	1	7	3	7	4	3	4	1
2.	MC-Monitoring	69	38	29	28	11	34	35	27	26	21
3.	MC-Evaluating	11	6	13	5	9	19	13	7	6	11
4.	MC-Debugging	17	8	1	11	3	10	11	8	12	
	Metacogntitive Strategies	**101 (36.9%)**	**54 (20%)**	**44 (15%)**	**51 (28.8%)**	**26 (10.9%)**	**70 (32.7%)**	**63 (28.4%)**	**45 (27%)**	**48 (40%)**	**33 (14%)**
5.	HC-Analyzing	1	3		2		6				3
6.	HC-Visualizing	4	16	7	73		1	2	2	34	
7.	HC-Analyzing Visual Diagram	1	18	11	8	7	23	11	8	5	12
8.	HC-Inferring Language		3	7	1	4		9	2		5
9.	HC-Inferring Content	5	5	9	5	10	6	3	13	2	7

Table continues…

Table 6.4 (Continued)

		SCIENTIFIC TEXT A (AUXINS)					SCIENTIFIC TEXT B (SIGNAL TRANSDUCTION)				
		Az	**Zeti**	**Di**	**Wan**	**Riz**	**Az**	**Zeti**	**Di**	**Wan**	**Riz**
10.	HC-Accessing prior knowledge	12	15	1	4	18	4	17	10	6	15
11.	HC-Questioning Content	2	3	7	2	5	12	11			15
12.	HC-Summarizing	4	13	29	4	4	8	10	3	9	3
13.	HC-Reading for global understanding	24	12	3		1	29		16		3
	Higher Cognitive Strategies	**53 (19.3%)**	**88 (32.6%)**	**74 (25%)**	**99 (55.9%)**	**49 (20.7%)**	**89 (41.6%)**	**63 (28.4%)**	**54 (32.9%)**	**56 (47%)**	**63 (26.9%)**
14.	LC-Paraphrasing	5		7	2	12	4	1		1	6
15.	LC-translating	9	55	60	3	52	5	38	24	2	48
16.	LC-Memorizing & Taking notes	11	20	16		1		4			
17.	LC-Reading for local understanding	95	53	91	22	91	46	53	41	12	84
	Lower Cognitive Strategies	**120 (43.8%)**	**128 (47.4%)**	**174 (59.6%)**	**27 (15.2%)**	**162 (68.3%)**	**55 (25.7%)**	**96 (43.2%)**	**65 (39.6%)**	**15 (12.6%)**	**138 (58.9%)**
	TOTAL STRATEGY	**274**	**270**	**292**	**177**	**237**	**214**	**222**	**164**	**119**	**234**

As displayed in Table 6.4, Az used the highest number of metacognitive strategies while reading text A (Freq=101; 36.9%) with MC- monitoring made up 63% (F=69) of her total metacognitive strategy use. Az also utilized LC- reading for global understanding (F=24) like reading faster than her normal reading speed and read two to three sentences at once. She admitted in her interview that she preferred to get a holistic idea of the concept in the text before going for detailed understanding (SSRI 1A, pg. 8). Since she had come across and learned about the topic auxins prior to the study, she accessed her prior knowledge quite frequently (F=12). As mentioned in section 6.1, Az seldom translated the English sentences into her L1 but more inclined to read for local understanding (F=95) which includes rereading, reading slowly, and decoding and breaking up problematic words and phrases. Evidently, Az spent more time on lower cognitive strategies and metacognitive strategies to process scientific text A than she did on higher cognitive strategies.

When reading scientific text B, Az considerably reduced her lower cognitive strategies to only 55 (25.7%) and metacognitive strategies to 70 (32.7%) but increased her higher cognitive strategies to 89 (41.6%). This time, she spent more time analyzing the visual diagrams (F=23) yet continued to read for global understanding (F=29) as well as for local understanding (F=46). Az also summarized more (F=8) while reading text B compared to text A and questioning the content of the text (F=12). One puzzling issue here is that Az accessed her scientific prior knowledge of signal transduction (Text B) only 4 times when the other respondents except Riz increased that specific type of strategy for text B. So the question that arose from this puzzle was whether she had enough scientific prior knowledge of signal transduction to access. The analysis of her interview protocol revealed that Az had plenty of scientific prior knowledge on text B. She admitted that she had learnt about human hormones (SSRI 1A, pg. 7) and *serpentine receptor* (SSRI1A, pg. 8) in form six. She also informed the researcher that her prior knowledge on scientific concepts *enzyme cascade* (line 24) and *second messenger* (line 22) had actually emerged/ surfaced while she was still reading at line 13 (SSRI 1A, pg. 15). So the fact that she did not access or did not verbally mention her mental association between her prior knowledge and the text may imply that she did not encounter comprehension difficulty that required her to do so while reading text B. This may suggest that a reader may not access their prior knowledge even though they had a lot of them when there is no need for it.

While reading scientific text A, Zeti spent more time on lower cognitive (F=128; 47.5%) and higher cognitive strategies (F=88; 32.6%) and the least on metacognitive strategies (F=54; 20%). Unlike Az, Zeti monitored her understanding half of the time than Az did for text A, most probably because she understood the text straightaway since she did a lot of translating (F=55) and summarizing (F=13). Besides that, unlike Az, Zeti closely analyzed the visual diagrams provided in text A (F=18) which she later summarized in her own words. In addition, Zeti also visualized (F=16) the content of her text which includes having mental images and drawing concept maps, diagrams and direction arrows in the text. Zeti accessed her scientific prior knowledge 14 times and only once relied on her general prior knowledge to untangle her reading confusion. Besides that, Zeti also read for local understanding (F=53) and took notes (F=20).

Reading a more difficult text on a less familiar topic (text B), Zeti used more metacognitive strategies (F=63; 28.4%) and reduced her higher cognitive (F = 63; 28.4%) and lower cognitive strategies (F = 96; 43.2%). Her use of MC strategy of monitoring (F=34), HC strategy of accessing prior knowledge (F=17) and summarizing (F = 10), and LC strategy of reading for local understanding (F = 53) remained fairly consistent for text B as she did for text A. Surprisingly, Zeti reduced her use of LC strategy of translating to only 38, HC strategy of analyzing visual diagrams to 11 and visualizing to only 2. Text B was quite difficult for a limited English user like her and reading the text was very taxing because it was long (TAP 2B, line 414). However, in the interview she admitted that although the language of the text was difficult and she had limited prior knowledge on *signal transduction*, she was still able to understand it (SSRI 2B, pg. 1). Unlike Az who admitted having a lot of prior knowledge on *signal transduction* but only accessed her prior knowledge 4 times, Zeti having ‘limited’ prior knowledge on the topic accessed it 17 times. This finding again provides support for readers’ tendency to access their prior knowledge rigorously only when comprehension difficulties arise which usually occur when one is reading a text on a less familiar topic.

Di used only 44 metacognitive strategies (15%), 74 higher cognitive strategies (25%) and 174 lower cognitive strategies (59.6%) while reading text A. She relied on her LC-translating (F=60) a lot even though she was a high L2 proficiency learner. Like Az and Zeti, Di too read text A for local understanding (F = 91) as well as memorizing and taking notes (F= 16). She appeared to understand text A very well and was able to summarize the content (F= 29) effectively. If the earlier assumption about frequent access of prior knowledge occurs only when comprehension breaks down could be applied here, the assumption may prove correct. This is because, Di accessed her prior knowledge only once compared to her summarizing strategy 29 times. Di acknowledged that text A was not very difficult (SSRI 3B, pg. 1) and her translating and summarizing strategies proved to be a good combination in an effort to process the sentences of the text. Even though the text was not difficult, Di did not go for global reading (F=3). She took time to analyze and understand the visual diagrams (F = 11) but inferred the meaning of words and content a lot (F = 16).

When reading text B, Di increased her metacognitive strategies to 45 (27%) but reduced her higher cognitive strategies to 54 (32.9%) and her lower cognitive strategies to 65 (39.6%). Di also greatly reduced her LC strategy of translating (F = 24) and her LC strategy of reading for local understanding (F = 41). However, scientific text B was too difficult for her and she admitted that there were many long sentences (SSRI 3B, pp. 1& 3; TAP 3B, lines 10, 23, 43, 75, 252). Her strategy choices essentially reflected her comprehension problem of text B. This is because unlike reading text A where she summarized 29 times, Di did not manage to summarize (F=3) some concepts discussed in text B. She also resorted to HC strategy of inferring content (F=13) and reading for global understanding (F = 16). Even though her MC strategy of monitoring (F = 27) remained consistent as in text

A, half of the time this MC strategy was on acknowledging the fact that she failed to understand what she had read (F=13; TAP 3B). In addition, Di did not memorize points or take notes when reading text B which was a contrast to her reading tactics of text A. She resembled a reader who gave up trying to understand the text because there were many new concepts in addition to the difficult language structure of text B.

Wan, on the other hand, employed 99 higher cognitive strategies (55.9%) and 51 metacognitive strategies (28.8%) and only 27 lower cognitive strategies (15.2%) while reading text A. As a HP learner, Wan understood each piece of information presented and translated them by visualizing (F=73) or through mental images that he described quite vividly. Thus, he only summarized 4 times throughout the reading process but did not resort to HC strategy of reading for global understanding or LC-memorizing and taking notes. Even though he had a high prior knowledge on the topic *Auxins*, Wan did not have to access them frequently (F=4).

While reading text B, Wan employed 48 MC strategies (40%), 56 HC strategies (47%) and only 15 LC strategies (12.6%). Wan maintained similar frequency of MC monitoring (F=26) for this text as he did for text A but employed only 34 HC strategy of visualizing and 5 HC strategy of analyzing visual diagrams. He also summarized (F=9) and accessed a little more prior knowledge (F=6) for this text compared to text A. The total number of strategies employed by Wan was only 119, which was the least amount of strategies compared to the other readers for both reading texts. However, since Wan read text B before text A, it could also be assumed that he was hesitant to spend too much of the researcher's time on his reading and figuring out the meaning. This notion could perhaps be the source of his lower reading comprehension score for text B (see Table 6.5).

Riz was the only respondent who maintained a consistent total number of strategies for texts A and B. For text A, Riz used only 26 MC strategies (10.9%), 49 HC strategies (20.7%), and 162 LC strategies (68.3%). Like Zeti and Di, he translated the text rigorously (F = 52) and like Az, he intensely read for local understanding (F = 91). As mentioned in section 6.2.5, Riz possessed first hand knowledge on the use of *auxins*. He accessed his prior knowledge on a*uxins* the most (F=18) compared to the other four respondents but half of the time it was general prior knowledge as opposed to scientific prior knowledge. He also inferred the content (F =10) more than the other respondents and this may be attributed to his abundance of general prior knowledge on the subject *auxins*.

For text B, Riz increased his use of MC strategies to 33 (14%) and HC strategies to 63 (26.9%) but reduced his LC strategies to 138 (58.9%). Since the text was more difficult, it could be assumed that Riz tried to use top down strategies to get around problematic sentence structures. Yet, closer inspection of his LC strategies revealed that he translated (F=48) and read for local understanding (F = 84) about as much as he did for text A. It was found that he analyzed visual diagrams (F = 12) more for this text compared to only 7 in text A and questioned the content (F = 15), of which only one that he could answer. Like Di, Riz repeatedly mentioned that the text was very difficult to understand (SSRI 5B, pg. 1 , TAP 5B, lines 171, 315, 447, 454, 474) and his limited knowledge on the topic also did not help much even though his think aloud protocol revealed that he tried to access his prior knowledge (F = 15). Even though Riz's MC strategy of monitoring increased to 21 while reading text B, 17 of them were on acknowledging the fact that he did not understand the sentences that he was reading.

In general, respondents tended to decrease their frequency of strategy use when reading text B. At the same time, they increased the percentage of MC and HC strategies and reduced LC strategies. In addition, respondents appeared to access their prior knowledge only when they encountered comprehension problems such as Di and Wan while reading text B and Az while reading text A. However, Zeti and Riz continued to access their prior knowledge while reading both texts which may suggest that their comprehension problems mainly originated from their own limited L2 proficiency.

6.3.4 The interactions of L2 proficiency, reading strategies and reading comprehension of the five ESL undergraduates

Table 6.5 below shows the reading comprehension (RC, hereafter) scores of texts A and B obtained by the five respondents as well as the summary of strategies utilized by them while reading both scientific texts.

Table 6.5

Reading Comprehension Scores and Summary of Strategies Used by Five ESL Undergraduates

RC scores & strategies	**SCIENTIFIC TEXT A (AUXINS)**				
	Az	**Zeti**	**Di**	**Wan**	**Riz**
RC score	23	30	28	31	19
(%)	(35%)	(45%)	(42%)	(47%)	(29%)
MC Strategies	101	54	44	51	26
HC Strategies	53	88	74	99	49
LC Strategies	120	128	174	27	162
Total Strategies	**274**	**270**	**292**	**177**	**237**
	SCIENTIFIC TEXT B (SIGNAL TRANSDUCTION)				
RC score	29	27	20	24	20
(%)	(46%)	(43%)	(32%)	(38%)	(32%)
MC Strategies	70	63	45	48	33
HC Strategies	89	63	54	56	63
LC Strategies	55	96	65	15	138
Total Strategies	**214**	**222**	**164**	**119**	**234**

(*a*) *L2 proficiency and reading comprehension scores*

Wan, Zeti and Di obtained the top three highest RC scores for text A while Az, Zeti and Wan were the top three achievers for text B. While it was expected that Wan and Di would do well on the RC of both texts due to their proficiency in the English language, the findings of this study revealed a slightly different story. As anticipated, Wan scored the highest RC marks for text A but did not do very well for text B. Di did reasonably well in text A but poorly in text B. In contrast, Az with modest English proficiency, did not do very well in text A but scored the highest marks for text B. Zeti, the least proficient respondent in this study besides Riz, was a unique case. With limited English language proficiency, she came in second for both texts, outperformed Di on both texts, and did better than Wan for text B.

In order to identify good and poor readers among the five respondents, similar measures to divide good and poor readers in the quantitative study was used (see section 5.8, pg. 281). As mentioned in Section 5.8, those scoring below the means (RCA: M = 27.52; RCB: M = 23.04) were considered poor readers and those scoring above the means were good readers. Using this measure, Zeti, Di and Wan could be categorized as good readers for text A whereas Az and Riz poor readers. On the other hand, Az, Zeti and Wan were good readers for text B while Di and Riz poor readers. On the whole, Zeti and Wan were consistently good readers and Riz poor reader while Az and Di performance tended to fluctuate between the two reading tasks.

The findings of this study also indicate that the five readers used less metacognitive strategies than cognitive strategies for both texts A and B. Riz utilized the least number of metacognitive strategies (26) and obtained the lowest RC marks for text A. Az, Zeti and Wan were the top users of metacognitives strategies for text A but only Zeti and Wan obtained good RC scores. Az utilized the highest number of metacognitive strategies (101) but failed to score above 40% in the RC of text A. Di, on the other hand, employed the least number of metacognitive strategies among the three but managed to score above 40% in RC of text A. So, if Bonner and Holliday's (2006) claim is taken into account, why did Az who demonstrated more metacognitive awareness fail to score in RC of text A and yet Di who showed less awareness did better? This issue will be taken up again in part (d) of this section.

(b) Metacognitive strategies and reading comprehension scores

Zeti, Di and Riz increased their use of metacognitive strategies on text B which is consistent with the Koda's (2005) claim that as the text becomes more challenging, readers tend to strategize and pay closer attention to their reading processes. Az and Wan, on the other hand decreased their use of metacognitive strategies in text B. Eventually, it was found that Di, Wan and Riz's frequency of metacognitive strategy use was much lower than that of Az and Zeti, the top scorers for text B. If less number of metacognitive strategies implies less awareness of their reading processes and less reflection on what they could and could not do, Wan, Di and Riz's RC scores of text B certainly reflect this shortcoming. Wan obtained 38% while both Di and Riz obtained 32% which was the lowest in the group. Az and Zeti utilized higher number of metacognitive strategies than the three other respondents and both obtained the highest marks, 46% and 43% respectively in the RC of text B.

Even though the above finding lends further support to the claim regarding metacognitive awareness and increased reading comprehension (Bonner & Holliday, 2006), there were a few puzzling and contradictory outcomes which require further explanation. For example, Az managed to obtain the highest marks in RC of text B with less number of metacognitive strategies. Does this mean less reflection is good to succeed in reading processes or that too much reflection renders the strategy ineffective? Again, this issue will be examined further in part (d) of this section.

(c) Cognitive strategies and reading comprehension scores

The result of the analysis also indicates that good readers for text A (Zeti, Di and Wan) utilized much higher number of HC strategies compared poor readers (Az and Riz). This finding is consistent with previous reading strategy research (Block, 1986; Carrell, 1989; Chamot & O'Malley, 1994) in that HC strategies are good strategies which can lead to successful reading comprehension. However, the same studies also noted that LC strategies inhibit global comprehension and are thus unsuccessful strategies (Block, 1986; Carrell, 1989; Davis & Bistodeau, 1993; Horiba, 1990; Hosenfeld, 1977). Yet, the data in Table 6.5 show that a high frequency of LC strategies utilized by Zeti (F = 128) and Di (F = 174) did not hinder their comprehension of scientific text A and thus obtained a reading comprehension score of 45% and 42% respectively.

Further inspection of the strategies used to read scientific text B revealed that two high scorers (Az and Zeti) used a high frequency of HC strategies which were 89 and 63 respectively. However, Zeti's frequency of LC strategies was still high (F = 96) whereas Az had reduced her LC strategies by almost half the amount she used for text A (F = 55). While it is tempting to confirm the earlier assumption about HC strategies being ‘good’ strategies that promote comprehension, a look at Riz’s high frequency of HC strategies (F = 63) requires further examination.

Riz employed the same number of HC strategies as Zeti but scored low on the RCB. Closer inspection of Riz’s strategies for text B (see Table 6.4) indicated that his HC strategies were inferring content (F = 7), questioning content (F = 15), of which only one was answered, and reading for global understanding (F = 3). In addition, his other HC strategies were accessing scientific knowledge (F=12), seven of which were accessed while he was still reading paragraph one, and summarizing (F=3). Based on the examination of the types of HC strategies used by Riz, it could be concluded that these strategies were not particularly helpful to a reader to comprehend scientific text B. Thus, even though the final count of Riz’s HC strategies was high, the specific HC strategies used such as inferring, questioning without getting the answers, global reading, and accessing scientific prior knowledge to match paragraph one were not helping the reader to build a propositional model of the whole text content.

Zeti, on the other hand, inferred the content (HC) only 3 times, accessed scientific prior knowledge (HC) 16 times throughout the text, questioning content 11(HC), of which 3 were answered, and verbally summarized content pieces 10 (HC) times. Thus, it can be concluded that (i) efficient HC strategies like summarizing and accessing prior knowledge must be carried out frequently throughout the text to be effective, and (ii) certain HC strategies may not work with scientific text like inferring content and questioning content without having the questions answered.

(d) Synthesis on the interplay of all strategies and the effects on reading comprehension scores

The frequent employment of metacognitive strategies indicates the presence of metacognitive awareness, which has been claimed to enhance the reading comprehension of scientific texts (Bonner & Holliday, 2006). This is evident in the reading of text A by Wan and Zeti. Both of them utilized a lot of metacognitive strategies and they obtained the highest and second highest marks respectively in the RC of text A.

Yet, this study also provides evidence that a large number of metacognitive strategies does not necessarily lead to enhanced comprehension of the text read. Az who utilized the most number of metacognitive strategies and ought to be more metacognitively aware obtained second lowest marks among the five respondents. The difference in the reading processes of text A between Az and the two top readers lies in the LC and HC strategies they utilized. Wan was focused on getting the total understanding of the text, a complete picture, and thus employed numerous HC strategies, mainly visualizing. Zeti, on the other hand, might have realized that her limited L2 proficiency required her to work on the text at lower level first and so she did but did not remain there for long. Once she had figured out the meaning of the sentences through repeated reading and translation, she rose above the text level and began to build a propositional model of the text by employing HC strategies such as summarizing, analyzing visual diagram, and visualizing such as having mental images and drawing mind/concept maps. Az, on the other hand, kept on working at the text level (LC strategies) and rarely move up to higher cognitive level. Working at the text level and utilizing LC strategies gave Az fragmented pictures of the whole text. So, even though she was highly aware of her reading process, she failed to choose the best cognitive strategies to assist her in getting a complete picture of the text.

Another support for the contention that reading comprehension of scientific text is not only enhanced by metacognitive awareness but also by efficient HC strategies is provided by the reading processes of Az and Zeti while reading text B. For the second text, Az remained the most metacogntively aware reader among the five respondents and scored the highest marks in the RC of text B. Most of the time while reading text B, Az complemented her LC strategies, which gave her fragmented ideas with HC strategies. This reading tactic enabled Az to get an overall comprehension of the text instead of disjointed ideas in the previous reading. Another support for the above claim was Zeti's reading process of text B. Zeti was a consistent and persistent reader. She actively monitored her reading comprehension and knew her own strengths and weaknesses. Zeti matched her LC strategies with substantial number of HC strategies to get a holistic understanding of both texts.

The notion that a low usage of metacognitive strategies most often leads to poor reading comprehension of scientific text is clearly demonstrated in the reading processes of Riz and Di. Riz who utilized the least number of metacognitive strategies obtained the lowest marks in RC of texts A and B. Riz continued to employ unsuccessful strategies and remained working at text level during most of his reading time. Di too employed a small number of metacognitive strategies in reading text B and thus obtained the lowest marks too. However, when Di was reading text A, she did employ less metacognitive strategies but managed to obtain 42% in the RC. One explanation is her high utilization of HC strategies, mainly summarizing, which might have enabled her to get a rather complete picture of the text content.

(e) Common HC strategies frequently used by good and poor readers of scientific texts A and B

All respondents utilized between five to nine types of HC strategies while reading texts A and B. A closer look at the HC strategies utilized by good readers of both texts reveals some commonalities of HC strategies that may have contributed to enhanced comprehension of both scientific texts. Listed in table 6.6 below are four to five most frequently used HC strategies, from the most to the least usage. As illustrated in Table 6.6, good readers of text A were Wan, Zeti and Di and poor readers were Az and Riz. For text B, good readers were Az, Zeti and Wan while Di and Riz were poor readers.

Table 6.6

Frequently Used HC Strategies to Read Texts A and B by Good and Poor ESL Readers

SCIENTIFIC TEXT A				
Good Readers			Poor Readers	
Wan	Zeti	Di	Az	Riz
HC-**Visualizing (73)** HC-**Analyzing Visual Diagram (8)** HC-Inferring Content (5) HC-**Accessing PK* (4)** HC-**Summarizing (4)**	HC-**Analyzing Visual Diagram (18)** HC-**Visualizing (16)** HC-**Accessing PK (15)** HC-**Summarizing (13)** HC-Reading for global understanding (12)	HC-**Summarizing (29)** HC-**Analyzing Visual Diagram (11)** HC-Inferring Content (9) HC-**Visualizing (7)**	HC-Reading for global understanding (24) HC-**Accessing PK (12)** HC-Inferring Content (5) HC-**Visualizing (4)**	HC-**Accessing PK (18)** HC-Inferring Content (10) HC-**Analyzing Visual Diagram (7)** HC-Questioning Content (5)
SCIENTIFIC TEXT B				
Az	Zeti	Wan	Di	Riz
HC-Reading for global understanding (29) HC-**Analyzing Visual Diagram (23)** HC-Questioning Content (12) HC-**Summarizing (8)** HC-**Accessing PK (4)**	HC-**Accessing PK (17)** HC-**Analyzing Visual Diagram (11)** HC-Questioning Content (11) HC-**Summarizing (10)**	HC-**Visualizing (34)** HC-**Summarizing (9)** HC-**Accessing PK (6)** HC-**Analyzing Visual Diagram (5)**	HC-Reading for global understanding (16) HC-Inferring Content(13) HC-**Accessing PK (10)** HC-**Analyzing Visual Diagram (8)**	HC-**Accessing PK (15)** HC-Questioning Content (15) HC-**Analyzing Visual Diagram (12)** HC-Inferring Content (7)

* PK-Prior Knowledge

Common HC strategies used by good readers to read text A were visualizing, analyzing visual diagrams, accessing prior knowledge, and summarizing. For text B, analyzing visual diagrams, summarizing, and accessing prior knowledge were again the common strategies used by good readers while visualizing was utilized to a lesser degree (Zeti: visualizing- 2) and did not make the list of most frequently used HC strategies. The findings of this study suggest that at least two HC strategies, namely analyzing visual diagrams and summarizing, could be considered as the most efficient combination of HC strategies frequently used by successful readers of both scientific texts. Successful readers tended to verbally summarize the text or portions of the text as well as analyze the diagram(s) given in order to get a better understanding of the texts read. In addition to that, visualizing the content in the form of mental images or concept/mind maps was also effective in making the abstract scientific concepts more concrete.

However, the contribution of HC strategy of accessing prior knowledge to successful comprehension is more intricate than it was initially assumed but could be summarized into three key points. First, it was found that only scientific as opposed to general prior knowledge could successfully contribute to comprehension of scientific text, as in the case of Zeti and Riz. Second, scientific prior knowledge may only be accessed when a reader encounters comprehension problem and not because s/he possesses an abundant of knowledge on a familiar topic. This is because, having a lot of prior knowledge on the topic being read may make reading and comprehension smooth and easy but would not necessarily trigger the need to consciously access that knowledge, whereas reading confusion would. As in the case of Az, she encountered reading difficulty in text A and thus accessed her prior knowledge rigorously but she did not access her prior knowledge as rigorously while reading text B because she admitted to having a lot of prior knowledge on the topic *Signal Transduction* (SSRI 1B, pp. 7, 7, 15). However, for limited L2 proficiency readers like Zeti and Riz, reading second language scientific texts always posed a comprehension problem and therefore accessing prior knowledge was done rigorously to aid understanding. Third, at times, the strategy of accessing prior knowledge overlaps with the strategy visualizing, as in the case of Wan and Zeti. Wan's mental images of shapes and colours of molecules and hormones resembled diagrams which he had seen in biology textbooks (SSRI 4A, pg.17). So, even though while reading text A Wan did not consciously access his prior knowledge, the images forming in his mind that he verbally reported were, in fact, based on his prior knowledge of diagrams previously seen and learnt.

The data also suggest that inferior HC strategy which may not contribute to successful comprehension of both scientific texts was inferring content. This is because, all poor readers of texts A and B tended to make use of the strategy inferring content. However, Wan and Di too used this HC strategy while reading text A and they succeeded. One explanation could be due to the L2 proficiency of the reader who infers. High proficiency readers may be able to infer the meaning of content more accurately (Wan and Di in text A) compared to low L2 proficiency readers (Riz and Az in text B).

Two HC strategies which neither contribute nor inhibit reading comprehension of scientific texts as suggested by the data were reading for global understanding and questioning content. Reading for global understanding includes reading to get an overall understanding of sentences or paragraph, reading fast, and reading more that one sentence at once. Questioning content is a strategy when readers questioned the information given in the text and wanted to know information outside the scope of the text. Using these two HC strategies may not cause the readers to misinterpret the content of text or hinder detailed comprehension. This is because, reading speed and reading more than one sentence at once are the result of good comprehension of the text which the reader can adjust when confusion occurs. In addition, questioning content may perhaps show that the reader wants more familiar information which they can use to understand the text better. Based on the findings, these two strategies may not interfere with the comprehension and if used with efficient HC strategies such as those mentioned before, these two HC strategies may prove to be fruitful.

In summary, the analyses on the strategies used by the five ESL undergraduates reveal the following findings:

(1) As a group, these ESL undergraduates used more LC strategies to read both scientific texts A and B, followed by HC and MC strategies. Nevertheless, when respondents were reading text B (difficult/ less familiar), the percentage of LC strategies usage tended to decrease as much as 10% while HC and MC strategies increased about 5% each.

(2) LC strategy of reading for local understanding, which includes rereading, decoding words and sentences, and reading slowly, made up the biggest percentage (up to and beyond 25%) of the overall strategy use. The

second top strategy use was shared by MC monitoring and LC translating at 14%. These three strategies were the most frequently utilized strategies by the five ESL respondents while reading both scientific texts.

(3) It was found that having a lot of prior knowledge on a certain topic does not necessarily prompt a reader to access it. Respondents tended to access their prior knowledge only when they encountered comprehension problems. Comprehension problems in this study mostly originated from new information and syntactic difficulty of the texts as well as limited L2 proficiency of the readers.

(4) The use of LC strategies could lead to successful comprehension if they were complemented with HC and MC strategies, in particular HC analyzing visual diagrams and summarizing as well as MC monitoring and debugging. Yet, a high frequency of MC strategy usage does not guarantee comprehension of scientific texts if crucial HC strategies are not utilized.

6.4 Research Question 8: Difficulties and problems faced by the five ESL readers while reading the two scientific texts

This section addresses the eighth research question, “What are the difficulties they (ESL science undergraduates) encountered while reading the two scientific texts and how did they overcome the problems?” Respondents’ think aloud and interview protocols were examined to determine comprehension difficulties and reading challenges that they had to cope with and the steps taken to untangle their confusions.

6.4.1 Problematic general English words and familiar scientific terminology

To identify words that caused comprehension problems to the five ESL readers, the researcher requested that the respondents circle the problematic words using a green pen. Besides that, problematic words were also identified through respondents' think aloud as well as interview protocols. Sometimes, respondents thought that they understood certain words, for example 'inhibit' and 'dominance' thus did not circle these words in green when requested to do so. However, triangulation process with think aloud protocols revealed that the respondent had inaccurately guessed the meaning of the words. Therefore, it was decided that words not identified personally by the respondents but were discovered to pose comprehension problems through think aloud protocols were also included in the list of easy and difficult words in texts A and B, as shown in Table 6.7.

Table 6.7

Reported Easy and Difficult Words/Phrases in Scientific Texts A and B

SCIENTIFIC TEXT A		SCIENTIFIC TEXT B	
Difficult	Easy	Difficult	Easy
(act in) concert*	Counters the effects	Activated (protein)*	Catalyze
Commercial preparations*	Diffuse	Active ingredient*	Diffuse
Derivatives	Synthesis	Alter	Secreted
Distribution	Synthetic auxins	Amplified	-----------------------
Dominance*	---------------------	Anchoring*	Adrenal cortex
Dormant	Active transport	Conversely*	Cell receptor
Eggplant*	Apical meristem	Elicit*	protein
Horticulturist*	Apical tip	Exterior	Cytoplasm
Inability	Cell wall	Extracellular	Endocrine gland
Induce	Cross-linking cellulose molecules	Interact	First messenger
Lateral branching*	Cytokinin	Intracellular	G protein
Minute (amount)	Cytoplasm	Mediator*	Glucagons
Profound	H ion activates enzyme	Magnitude	Gonad
Pruning*	Meristem	Off switch	Hydrogen bonds
Reinforce*	Nervous system	Organize	Hydrophobic interactions
Resist	Osmosis	Penetrate	Metabolic regulation
Seedless	Plasma membrane	Recognition	Noncovalent interactions
Suppressive	Proton	Relays	Plasma membrane
Sustain*	Target cells	Reversibly	Polar/non polar hormones
Swell*	Unspecialized cells	Scaffolding*	Receptor enzyme
Tendency	Vascular cambium	Span	Second messenger
Trigger		Stretches*	Signaling molecules
Ulterior*		Trigger*	van der Waals forces
Uniform (flowering)*		------------------------------	
----------------------		Atrial natriuretic factor*	
Apical dominance*		Enzyme cascade*	
Depressing		Epinephrine*	
Plant organization		Serpentine*	
		Signal transduction*	
		Transmembrane	

* at least 4 out of 5 readers identified as difficult; dotted lines separate general English words from scientific words/ phrases

Table 6.7 presents easy and difficult words encountered by the five respondents while reading texts A and B. In each column of difficult and easy words in scientific texts A and B, those above the dotted lines were general English words and those below the dotted lines were scientific words. Another feature of the table is the words in asterisks which were words identified by at least four respondents as difficult.

As shown in the above Table, a total of 57 words/phrases were identified as difficult to ESL science undergraduates while reading scientific texts A and B. Of the 57 words/phrases, 48 were general English words and 9 were scientific words. On the other hand, 20 words/phrases which the researcher assumed to be difficult for the ESL readers were easy and thus perfectly understood. In fact, the five ESL readers did not spend much time figuring the meaning of the 20 words/phrases. Most respondents admitted that they did not have problems with the scientific terminology as they were used to reading them (SSRI 1A, pg.2; SSRI 2B, pg. 26; SSRI 3B, pg. 3). In addition, during the retrospective interviews, two respondents commented that when they encountered scientific terminology in a sentence, that terminology acted like a window that provided them with a wealth of other information that helped them to understand the particular sentence more than what was stated in it.

Respondents had at least five different strategies at their disposal when they encountered with difficult words. The strategies to solve comprehension problems with regards to problematic words are illustrated in Excerpts 10 to 14. All problematic words in the excerpts are underlined.

The first and most frequently used strategy was to translate the words directly into Malay (L1) as illustrated in Excerpt 10. This strategy sometimes resulted in accurate translation and sometimes it was not. In example (2), even though *dominance* can also mean *'a lot'*, this translation was not accurate in the context of the sentence below.

Excerpt 10: L2-L1 translation

Accurate translation

(1) **…vascular tissues and induce cell division in the vascular cambium…**

… induce… *saya … maksudnya galakan…*

(TAP 2B, lines 472-473)

[Translation: …induce.. I….means encourage…]

Inaccurate translation

(2) **An important principle of plant organization based upon auxin distribution is apical dominance…**

Dominance- *banyak…*

(TAP 2A, lines 335-336)

[Translation: Dominance – a lot]

The second strategy was to relate the words to their prior knowledge to arrive at the closest translation. Excerpt 11 illustrates this strategy. Again, inaccurate translation/guess may occur especially among low L2 proficiency readers.

Excerpt 11: Relating to prior knowledge

Accurate guess

(1) **<u>Penetrating</u> the Plasma Membrane**

Err.. <u>Penetrating</u> *saya tak tahu tapi saya rasa* <u>penetrating</u> *tu dia nak masuk dalam membrane plasma, sebab saya terbayang masa saya belajar kat matrik dulu, err saya bayang err sperm nak masuk dalam ovam tu, dia kena pene..* <u>penetrate</u> plasma membrane *ovari.., ovem tu nak masuk…*
(TAP 2B, lines 52-55)

[Translation: Penetrating…I don't know but I think penetrating (is)…it is entering inside the plasma membrane, because I remember when I was in matriculation centre, err I remember err the sperm is going inside the ovam, it has to pene… penetrate the plasma membrane of the ovari…, (because) the ovem has to get in…]

Inaccurate guess

(2) **and the scaffolding proteins are thought to <u>organize</u>,**

scaffolding protein *akan* ***organize****, akan…****organize*** *apa ni?*
organize *err* ***organize organize***
organize *mengenalpasti*
Saya …balik ayat ni.
Saya tak ingat apa **organize**
Apa yang saya bayang, Saya telah dapat kad dulu, kad dulu… ada budak ni saya tak kenal dia cakap seseorang yang saya kenal – **organize**
(TAP 2B, lines 333-349)

[Translation: **Scaffolding protein** will **organize**, will ….what is **organize**?
I…go back to this sentence.
I don't remember what **organize** is
What I comes to my head, I got a card sometimes ago, a card sometimes ago…there was this person, I did not know him, he said (from) someone that I know-**organize**]

Excerpt 12 shows the third strategy, which was breaking up the suffix and prefix of the unknown words.

Excerpt 12: Breaking up word

Accurate guess

(1) **These mediators of cell function have a wide range of structures that include amino acid <u>derivatives</u>, small peptides, proteins, and steroids**.

Oh…mungkin…maksud perkataan these mediators of cell functions*…ni dia refer pada hormone yang mengandungai* amino acid… derivatives..
Derivatives *ni* …derive
Derive *maknanya huraian*
Oh..terdiri daripada amino acids
Huraian-huraian amino acid
(TAP 5B, lines 35-40)

[Translation: Oh perhaps…the meaning of 'these mediators of cell functions' it refers to hormone that contains amino acid…derivatives..
This 'derivatives' …. Derive
Derive means constituents
Oh…it is made up of amino acids
the constituents of amino acids]

Inaccurate guess

(2) **These effects of IAA on cell elongation <u>reinforce</u> two points:**

Effect IAA elongation *ni meng*-reinforce
Force…. *Paksa*
memaksa lagi sekali
two points
(TAP 5A, lines 281-285)

[Translation: This 'effect(of) IAA elongation …to reinforce
Force …force
to force one more time
two points]

The fourth strategy was guessing meaning by translating the words surrounding the problematic word as shown in Excerpt 13.

Excerpt 13: Translating surrounding words

Accurate guess

(1) **The cell then <u>swells</u> with water and elongates because its weakened….**
because its weakened wall no longer resists the cell's tendency to take up water osmotically.
*Err…*the cell *akan* swell *dengan air dan mula memanjang sebab* wall *tu dinding tu jadi lemah dan dia tak dapat* resist *err* resist*, lepas tu dia akan take up water…dia akan ambik air…*
(TAP 2A, lines 441-447)

[Translation: Err…the cell will 'swell' with water and starts to elongate because the wall, the wall becomes weak and it cannot resist err resist, after that it will 'take up water'…it will take water]

Inaccurate guess

(2) **..of magnitude by enzyme <u>cascades</u>.**
Cascade ni apa ni…?
An enzyme molecule that is activated catalyzes the activation of several molecules of another enzyme…… that, in turn, activate many molecules of another enzyme, and so on.
Ha… maknanya enzim yang daripada luar ni tadi…
Messenger…second messenger ni, enzim ni err… dia akan menghasilkan…
Order… orders of magnitude…… enzyme cascade...
nama enzim kot…
(TAP 5B, lines 345-351)

[Translation: What is 'cascade'?
Ha..it means the enzyme from the outside…
Messenger…this second messenger, this enzyme…err it will catalyzes…
Order…orders of magnitude…enzyme cascade….
Perhaps a name of an enzyme…]

Finally, the fifth strategy was to look for clues in other parts of the text or skip the unknown word altogether and samples TAP are shown in Excerpt 14.

Excerpt 14: Looking for clues or skipping the word

(1) **Penetrating the plasma membrane**.
Penetrating *ni, first belek2 tadi pun dah focus kat sini, apa penetrating tu?*
Tapi okay tak pe, saya akan baca next supaya saya akan faham apa yang dimaksudkan dengan penetrating the plasma membrane.
(TAP 1A, lines 18-21)

[Translation: This (word) 'penetrating', when (I) first flipped through (the text) just now (I) had started to focus on this, what is this 'penetrating'?
But it is okay, I will read the next (sentence/paragraph) so that I will understand what is meant by 'penetrating the plasma membrane'.]

(2) Transmembrane *protein ni apa?*
Transmembrane
Trans…pindah
Membrane protein…
Ahh.. tengok dulu
(TAP 2B, lines 160-164)

[Translation: What is this 'transmembrane protein'?
Transmembrane
Trans- move
Membrane protein…
Ahh…(we'll wait and) see later…]

(3) **It is a process by which an extracellular chemical message is transmitted through a cell membrane in order to elicit an intracellular change.**
Ada banyak iskk… perkataan yang saya tak faham contohnya macam elicit, lepas tu saya tak dapat kaitkan ayat dia dengan ayat yang sebelum ni
So saya terus sambung dengan ayat lain
(TAP 4B, lines 73-77)

[Translation: There are many iskk…words that I do not understand for example like 'elicit', and then I cannot make a connection between this sentence and the sentence before this…
So..I will straightaway continue with the next sentence]

All strategies in dealing with unknown words usually resulted in both accurate and inaccurate translations and guesses. Most of the time, respondents were not aware of the wrong translations/guesses of the problematic words thus leading them to incorrect or mistaken conclusion of the piece of scientific information. However, most respondents claimed that when they come across unknown words while reading independently (as opposed to reading for this study) they would look up words in a biology dictionary (SSRI 2B, pg. 2; SSRI 4A, pg. 3), refer to online dictionary (SSRI 5B, pg. 6), consult friends (SSRI 1A, pg.6, SSRI 5B, pg. 7), and refer to other books (SSRI 4A, pg. 3). This is because Zeti and Di insisted that it was important to know every word (SSRI 2B, pg.3; SSRI 3A, pg. 3) and Az had to know every detail (SSRI 1A, pg. 3) while Wan maintained that one cannot translate scientific terminology at one's will (SSRI 4B, pg). In contrast, Riz admitted that even while reading on his own, he would skip unknown words (SSRI 5A, pg. 14) because it was too burdensome to translate all words.

6.4.2 Long and complex general and scientific English sentences

Sentences in scientific texts A and B that were found difficult by the five respondents were identified through two means: (a) respondents were asked to underline in green ink sentences they thought were difficult, (b) respondents' expressions regarding certain sentences in the think aloud protocols such as "this sentence is too long", "I really do not understand this sentence", "I don't know what this sentence is trying to say", and "I understand each word in the sentence but could not figure out the meaning". Based on the sentences identified by the respondents as well as those picked out from the think out protocols, it was found that there were 5 problematic sentences in text A and 16 in text B. Closer inspection of the data revealed that respondents had problems with two to four sentences in text A and five to eleven sentences in text B. For analysis purposes, only difficult sentences identified by three or more respondents are included in Table 6.8 as shown below.

Based on the sentences in Table 6.8, it could be summarized that there seemed to be three distinct features that characterized a sentence as difficult to process by the five ESL respondents. One is that the sentence is made up of complex English sentence structure. Two, the sentence contains unknown general English words or unfamiliar scientific terminology. Three, the sentence is long and comprises more than 25 words. Listed in Table 6.8 are a few sample sentences that contain at least two of the features mentioned above. (Please refer to appendix C for texts A and B)

Table 6.8

Difficult Sentences in Scientific Texts A and B Identified by Five ESL Respondents

	Scientific Text A
1.	Sentence 14 An important principle of plant organization based upon auxin distribution is apical dominance, which means that the auxin produced by the apical bud (or growing tip) diffuses downwards and inhibits the development of ulterior lateral bud, which would otherwise compete with the apical tip for light and nutrients. (48 words)

Table continues…

Table 6.8 (Continued)

2.	Sentence 15 Removing the apical tip and its suppressive hormone allows the lower dormant lateral buds to develop, and the buds between the leaf stalk and stem produce new shoots which compete to become the lead growth. (35 words)
3.	Sentence 22 These effects of IAA on cell elongation reinforce two points: (1) the same chemical messenger may have different effects at different concentrations in one target cell, and (2) a given concentration of the hormone may have different effects on different target cells. (42 words)
	Scientific Text B
1.	Sentence 12 The detailed step-by-step process of signal transduction varies greatly from one hormone and organism to another, but a general chain of events involving several common elements has been identified. (29 words)
2.	Sentence 27 The off switch is usually an enzyme that chemically modifies an activated protein or one that catalytically destroys a second messenger. (21 words)
3.	Sentence 30 Cell surfaces have many different types of receptors, and the scaffolding proteins are thought to organize and enhance the signal transduction process by holding all necessary extracellular and intracellular molecular components together in a single network. (36 words)

Sentence14 (text A) is a typical scientific text written in English which is very complex, packed with details and long. However, the problem in unpacking the meaning of this sentence mainly lies in the inability of the readers to focus on the two relative pronouns ‘which’ used in the sentence that act as modifying clauses to describe the scientific terminology of ‘apical dominance’ and ‘ulterior lateral bud’. This can be attributed to the poor grasp of the general English grammar. Besides not knowing the scientific terminology of ‘apical dominance’, the ESL readers were also deterred by the unfamiliar phrase ‘ulterior lateral’. Similarly, sentence 30 (text B) is long and complex and contains one unknown word, ‘scaffolding’. Adding to the difficulty is the inability of the respondents to accurately comprehend sentence 29 as shown below:

> Scaffolding and anchoring proteins hold groups of receptor proteins together to form networks for accurate transmission of information.

Most respondents were not very sure of the word ‘scaffolding’ and ‘anchoring’. This led one respondent to guess that these were names of proteins (TAP 3B, line 232) while others were satisfied with their translation of ‘anchor’ to mean ‘something like a hook or a gadget used to keep a ship stationary’ and thus skipped the word ‘scaffolding’ (TAP 5B, line 388; TAP 2B, line 340). Assuming they understood sentence 29, they moved on to sentence 30 and the word ‘scaffolding’ reappeared. In addition, Zeti also had problem with another general English word in the same sentence which was ‘organize’ and she thought it meant ‘recognize’.

Sentences that were found difficult because of unknown general English words are sentence 15 of text A (suppressive, dormant, lateral) and sentences 2 and 9 of text B (mediators and elicit respectively). For sentence 2 of text B, the poor grasp of general English grammar had caused the respondents to overlook the determiner ‘these’ which actually refers to ‘hormones’ in sentence 1. For sentence 9, most respondents did not look at this sentence a second time when they failed to understand the word 'elicit' (TAP 2A, line 89; TAP 3A, line 75; TAP 4A, line 70; TAP 5A, line 160).

Sentences 22 (text A) and 12 (text B) were reread as many as seven to 13 times and three to four times respectively by the respondents. In the retrospective interviews with the researcher, some of the respondents reported that there were no key words (scientific concept) which they could hold on to help them understand the ideas conveyed. For sentence 22 (text A), a few students had problem with the word 'reinforce' which they translated as 'force again' and at least two students did not know that 'chemical messenger' refers to IAA or auxin. Again, the respondents failed to notice the clue 'the same' as in "(1) the same chemical messenger…" provided in the same sentence. As for sentence 12 (text B), respondents admitted that they understood each word in the sentence yet they could not get the meaning of the sentence as a whole (SSRI 2B, pg. 21; SSRI 4B, pg. 2; SSRI 5B, pg. 3). Wan and Zeti claimed that the sentence was too general and lacked scientific terminology which they could focus on in their attempt to comprehend it (SSRI 4B, pg. 3).

The difficulty to unpack the above sentences resulted in at least four consequences. First, the ESL reader may miss the important point that the author tried to put forward. After rereading and translating sentence 14 of text A, Zeti only managed to understand that 'auxin is produced at the apical bud and the presence of auxin in large quantity causes the cells at the tip to divide and grow'. Yet, the focus of the sentence was on 'apical dominance' which inhibits the growth of ulterior buds. Second, ESL reader tended to generalize the meaning, which again would fail to attend to the significant scientific phenomenon being discussed. For example, Az read and reread sentence 15 of text A and ended up with an understanding that when shoots were cut, more new shoots would grow and make the plant bushy (SSRI 1A, pg. 13). In contrast, the focus of the sentence was on auxin, whereby when the shoot is cut, apical dominance would disappear on the main stem and thus allow new buds and shoots located further down on the stem to branch out, and compete for apical dominance. Third, failing to process the difficult sentence, an ESL reader would usually skip the sentence altogether. Almost all respondents had skipped at least two difficult sentences at one point or another while reading both texts. Fourth, the ESL reader may not realize that s/he had managed to unpack the difficult sentence correctly. Riz read sentence 27 of text B and in his TAP he translated and summarized the phrase 'off switch' as 'a type of enzyme that would destroy the second messenger'. His translation was very accurate, yet he was not convinced that his understanding was correct (TAP 5B, line 380).

Analyses of the TAP units showed that before the respondents guessed, generalized or skipped a problematic sentence, they would first employ a number of strategies to work out the meaning. They reread problematic sentences, split the sentences into shorter clauses and translated each piece one at the time, accessed their scientific prior knowledge to shade more light on the information on hand, and even made general assumptions or guesses about the sentence, at times missing important details. In addition, they also put the sentence on hold and continued with the sentence that follows for clues and if the sentence seemed too difficult, they ignored it altogether. The above strategies to untangle problematic sentences are best illustrated in Excerpt 15 which shows TAP units by Zeti, a limited English user but good reader of scientific texts A and B when she read to understand sentence 14 of text A.

Excerpt 15

Strategy	Sentence 14 (text A)
	(TAP 2A, Lines 114-134) **An important principle of plant organization based upon auxin distribution is apical dominance, which means that the auxin produced by the apical bud (or growing tip) diffuses downwards and inhibits the development of ulterior lateral bud, which would otherwise compete with the apical tip for light and nutrients. (48 words)**
MD-rereading	*Ayat ni panjang, saya nak ulang balik* [Translation: this sentence is long, I want to reread]
Rereading	**An important principle…an important principle….important principle…**
Translating	*Satu prinsip yang penting pada… pada* **plant organization** [Translation: one principle which is important to …to **plant organization…**]
Splitting sentence	*berdasarkan auxin err…pembentukan auxin* **pada apical dominance…** [Translation: based on auxin err…the formation of auxin on **apical dominance**] *Ini bermaksud auxin dihasilkan daripada* **apical bud or growing tip***…errr…* [Translation: This means auxin is produced from **apical bud or grouing tip.**.err..]
Referring to self-sketched diagram	*(VCD: Pointed at self drawn sketch of apical meristem)*
Splitting sentence	**Diffuses downwards and inhibits the development…**

Splitting sentence and translating	**Downwards and inhibits**...*dan merencat* [Translation: …and hamper]
Translating	**The development**, *pembesaran* [Translation: growth] [TAP 2A, lines 325-345]
Rereading the whole sentence 14 the second time	**An important principle ....development**
Relating sentence 14 to scientific prior knowledge	*Nak stop kat sini kejap.* *Err…Saya teringat yang belajar 'bio orga'…kat sini…* *Err…hydra akan buat ' budding'…'budding' macam nak bertunas…* [Translation: (I) want to stop here for a moment. Err…I (suddenly) remember that (I) studied bio orga…here. Err…hydra will make 'budding'… 'budding' is like it is going to bloom/open out]
Summarizing	*Mungkin dia jadi macam…pokok tu bila auxin banyak kat sini…dia akan menyebabkan sel tu divide, so akan ada benda bonjolan, bonjolan, dia akan panjang…so dia akan adalah pucuk baru, apical bud…* [Translation: Perhaps it becomes like…the plant…when auxin (accumulates) in large (quantity) here…it will cause the cell to divide, so there will a lump/swell/ bulge, lump/swell/bulge, it will elongate…so it will generate new shoot, apical bud…]

It is also worth mentioning that the examinations of the respondents' think aloud protocols revealed that successful comprehension occurred when readers summarized the content after their piece meal translations and guesses. However, when piece meal translations were not accompanied by summarization, comprehension tended to fail. Excerpts 16 (Di's TAP) and 17 (Riz's TAP) illustrate this point.

Excerpt 16

Strategy	Sentence 15
	Removing the apical tip and its suppressive hormone allows the lower dormant lateral buds to develop, and the buds between the leaf stalk and stem produce new shoots which compete to become the lead growth.
Splitting sentence & Rereading	**Removing the apical tip…** **removing the apical tip…**
Translating	**emm… remove…** *alihan* [Translation: remove….move/move from its place]
Rereading	**apical tip and its suppressive hormone, and its suppressive hormone allows the lower dormant lateral buds to develop**
Translating	*Oh… apabila* **apical tips** *ini dipindah err…* **apical tips** *dan hormon dipindah, akan membenarkan err…* [Translation: Oh…when this apical tips is moved away err… apical tips and hormone is moved away, (it) will allow err….]
Rereading	**lower dormant lateral buds**…
Repeating problematic word Translating	**buds buds buds** *emm…***buds…***mungkin* **buds emm… buds buds** *kuntum ah?* [Translation: buds buds buds emm buds…may be buds emm…buds buds.. .. Blossom..ah?]
Translating	Err…**dormant,** *yang tidak bergerak dibawah akan membesar* [Translation: Er…dormant, which (is) not moving downwards will grow]
Rereading	**and the buds between the leaf stalk and stem produce new shoots which compete to become the lead growth.**

Summarizing idea	*Oh… apabila* **apical tip** *dipindah dan hormon dialihkan, dor…err bahagian bawah…***buds** *-kuntum yang* **dormant** *akan membesar dan membesar, okay*. [Translation: Oh… when apical tip is moved away and hormones are displaced, dor…err…the lower part…buds- buds which are dormant will grow and grow, okay.] [TAP 3A, lines 150- 162]

Excerpt 16 shows Di's attempt to understand sentence 15 of text A. Di had read the whole sentence once and may perhaps find that she did not understand it. She then split the sentence into three parts; (a) Removing the apical tip, and (b) its suppressive hormones allow the lower dormant lateral bud to develop, and (c) and the buds between the leaf stalk and stem produce new shoot which compete to become the lead growth. She reread the first part and translated the word 'remove' before reading the second part of the sentence. She, then, translated and read the first and second part together. She then translated a few words in the second part of the sentence and reread the third part of the sentence. Finally, she summarized in Malay the whole sentence. Even though she mistook 'suppressive' for 'move', she still managed to draw out the gist of the sentence without leaving out important details except for 'suppressive hormone'.

Excerpt 17 illustrates Riz's attempt to figure out sentences 29 and 30.

Excerpt 17

Strategy	Sentence 29
	Scaffolding and anchoring proteins hold groups of receptor proteins together to form networks for accurate transmission of information.

Splitting sentence	***Scaffolding anchoring protein…***
Translating	Oh… ni protein…kira macam…iskk… *scaffolding protein*… mele… benda yang melekatkan… [Translation: Oh..this is protein…it is like…iskk… Scaffolding protein…something that fastens…] ***groups…hold groups of proteins together to form*** Oh maknanya… [Translation: Oh that means…]
Translating	***hold groups of proteins together…*** ***Receptor protein*** yang banyak-banyak ni dikaitkan dan dihubungkan oleh… [Translation: The many receptor proteins are related and connected by…]
Translating	***scaffolding and anchoring protein***...maknanya Oh maknanya…penghubunglah…kiranya untuk menghasilkan… [Translation: Oh that means….a connector…its like to produce…]
Translating	***networks for accurate transmission of information*** untuk menghasilkan cetusan informasi… [Translation:…to produce informational sparks]

Strategy	Sentence 30
	Cell surfaces have many different types of receptors, and the scaffolding proteins are thought to organize and enhance the signal transduction process by holding all necessary extracellular and intracellular molecular components together in a single network.
Splitting sentence	***Cell surfaces have many different types of receptors…***
Translating	Permukaaan sel ada banyak sel… jenis sel ***receptor*** ***and the scaffolding proteins…*** yang tadi tu… [Translation: the surface of cells has many cells….types of cells receptor and the scaffolding proteins…]

Splitting sentence	***are thought to organize and enhance the signal transduction…***
Rereading	***signal transduction process by holding all necessary extracellular and intracellular molecular components together in a single…in a signal…in a signal network.***
Rereading	***Scaffolding protein are thought to organize… and enhance the signal transduction process****…err err…*
Translating	Maknanya dia bukan setakat… *scaffolding protein* ni bukan setakat mengabungkan *receptor-receptor,* tapi dia … emm…mengabungkan extracellular dan intracellular molekul component ni dalam satu network. [Translation: This means it does not only ….this 'scaffolding proteins' not only combine the receptors, but it…emm…combines these extracellular and intracellular molecule components in one network.] [TAP 5B, lines 395 – 416]

Excerpt 17 shows how Riz read and translated sentences 29 and 30. Protocol for sentence 29 reveals that Riz had successfully unpacked and translated this sentence. Unfortunately, Riz continued to read sentence 30 without summarizing sentence 29 as a whole first, thus leaving him with fragmented ideas of this sentence. When reading sentence 30, Riz started of by splitting the sentence into a few shorter clauses and then translating and rereading each one. His translation for sentence 30 was quite accurate but towards the end of the protocol he still claimed that he did not understand the sentence. The problem may lie in the very last part of his problem solving strategies. This means that after reading problematic sentences at lower cognitive level (rereading, translating, splitting long sentences) he should move up to higher cognitive level by employing summarizing strategy on the whole sentence. In this way he may be able to get the overall understanding and picture of the whole sentence, like Di did.

6.4.3 Unfamiliar scientific concepts

Unfamiliar scientific concepts in texts A and B had been anticipated by the researcher before the start of the study and was aimed to investigate how ESL readers negotiate them with some and limited scientific prior knowledge. The two scientific concepts introduced in texts A and B were ‘apical dominance’ and ‘signal transduction’ respectively and the sentences that described these concepts are shown in Excerpt 18.

Excerpt 18

Text A

An important principle of plant organization based upon auxin distribution is apical dominance, which means that the auxin produced by the apical bud (or growing tip) diffuses downwards and inhibits the development of ulterior lateral bud, which would otherwise compete with the apical tip for light and nutrients

Text B

Conversely, other hormones which are relatively polar and/or ionic undergo a signal transduction process to modify activities inside the cell. It is a process by which an extracellular chemical message is transmitted through a cell membrane in order to elicit an intracellular change. Signal transductions often involve the binding of small extracellular signaling molecules to receptors that face outwards from the plasma membrane and trigger events inside the cell.

The first scientific concept ‘apical dominance’ is presented in one long sentence. In addition to being long, the sentence also contains a few unknown words to the respondents like ‘dominance’, ‘ulterior’, and ‘lateral’. Two multiple choice questions to assess comprehension of the concept 'apical dominance' are shown in excerpt 19 below and asterisks on options mark the correct answers.

Excerpt 19

3. Apical dominance means the presence of auxin at high concentration level______________

   A. in the apical bud which inhibits the elongation of the stem.
   B. in the apical bud which promotes the growth of lateral buds.
   C.* in the stem which inhibits the development of lateral buds.
   D. in the stem which elongates all buds to receive enough light and nutrients.

4. Which of the statements below is TRUE?

   A.* Cutting off the shoot of a rose plant will decrease the auxin level in the stem.
   B. Cutting off the stem of a rose plant will increase the production of ethylene.
   C. Ethylene will be produced in the stem where auxin level is low.
   D. The lateral bud will compete with apical bud for light and nutrient.

Zeti managed to get correct answers for both questions above which may suggest her understanding of the concept. Wan, on the other hand, chose the wrong answers for both questions. Meanwhile, both Az and Di answered question 3 wrongly by choosing options A and D respectively but got it right for question 4. However, the reverse was true for Riz who answered question 3 correctly but chose option D for question 4. The analysis of answers given by the respondents on the two questions above reveals that Az, Di, Wan and even Riz did not understand what apical dominance is. This is because they failed to understand the scientific phenomenon that apical dominance 'inhibits' the growth of other buds. Even though Riz answered question 3 correctly, his wrong answer in question 4 revealed his lack of understanding of the scientific concept apical dominance. Riz's answer for question 3 may purely be accidental because his think aloud protocol reveals that he misunderstood the word 'inhibit' as 'encourage'. Thus, the option C in question 3 may be read by Riz as "…in the stem which 'encourage' the development of lateral buds", hence his choice. This was probably the reason why he chose option D for question 4.

In general, respondents did not capture the meaning of 'apical dominance'. This failure may be attributed to their anxiety when they encountered a long sentence which at the same time consisted of a few unknown words (TAPs 1A, 2A, 3A, 4A, 5A). The analysis also indicates that even though the respondents utilized LC strategies like splitting sentence, translating and rereading to unpack the sentence, some of them still ended up with fragmented understanding of the sentence when they failed to employ HC summarizing to get a holistic understanding of the concept or relate the sentence to their scientific prior knowledge on auxins. Of the five respondents, only Zeti accessed her prior knowledge on 'budding' (TAP 2A, lines 329-333) which might have contributed to her comprehension of the concept. Another reason for the failure was the complete overlook of the second clause as a modifier which was marked by 'which means'. This can be attributed to their somewhat weak grasp of the English grammar or even reading skills.

The second scientific concept was 'signal transduction' introduced in text B. Unlike 'apical dominance' which was described in one long sentence, the scientific concept 'signal transduction' was explained in three separate sentences (sentences 8, 9 and 10). In all the three sentences, there were only two words which the respondents identified as difficult (elicit and trigger) besides the phrase 'signal transduction' itself. 'Signal transduction' is also described in detail as a biochemical process throughout the text. The analysis of the respondents' response to multiple true and false (MTF) statements indicated that they had a good if not complete understanding of the concept. The following excerpt is on the MTF statements on 'signal transduction' and asterisk indicates correct response for each statement.

Excerpt 20

D. Signal transduction is a process_______________

23.	whereby a cell membrane becomes a mediator between extracellular signaling molecules and intracellular chemical exchanges inside the plasma membrane.	T	F*
24.	that involves the binding of hormone molecules on the surface of the plasma membrane which causes chemical changes inside the cytoplasm.	T*	F
25.	of modifying cell activities outside the plasma membrane through internal chemical stimulation in the cytoplasm.	T	F*
26.	whereby a polar hormone diffuses itself through the plasma membrane to elicit chemical changes inside the cell.	T	F*
27.	by which a cell converts one kind of stimulus into another, most often involving ordered sequences of biochemcial reactions inside the cell.	T*	F
28.	involving the binding of extracellular signaling molecules to receptors that face outwards from the membrane and trigger events inside the cells.	T*	F

Out of the six statements, Wan and Riz obtained four while Di, Zeti and Az obtained 3 correct answers. Interestingly, all respondents responded correctly for statements 24 and 28 which were the gist of sentences 8, 9 and 10. Everyone except Wan answered correctly on statement 27. In general, respondents managed to understand that ‘signal transduction’ is about transmitting signal from outside to the inside of cells. Details such as it was ‘cell membrane’ (statement 23) or ‘polar’ hormones (statement 26) were overlooked which could also be attributed to a lapse in memory.

Unlike ‘apical dominance’, which was described in one long sentence, the scientific concept ‘signal transduction’ was described in detail that covers three full pages or the whole of text B as it is a biochemical process. Naturally, even if respondents were not able to process the meaning of this concept while reading sentences 8, 9 and 10, this process was explained at great length starting from sentence 13 onwards and with the aid of three diagrams. Hence, the better understanding of ‘signal transduction’ compared to ‘apical dominance’.

Therefore, in response to the final research question on the difficulties and problems faced by the five ESL readers and how they overcame the problems, the analyses of qualitative data reveal five findings:

(1) One of the obstacles faced by the five ESL respondents was comprehending general English words as 84.2% of words they found difficult were general English words and only 15.8% scientific words. Most scientific terminology did not pose a big comprehension problem

to the five respondents as they had often encountered the terminology in biology and chemistry texts, thus were familiar with them.

(2) Respondents utilized several LC and HC strategies to work out the meaning of unknown words such as translating to their native language, guessing by associating the words to their scientific or non-scientific prior knowledge, breaking up the problematic word and translating each part, translating words surrounding the problematic ones, putting off to look for contextual clues in succeeding sentences, and even skipping the unknown words. All these strategies resulted in accurate and inaccurate translations and guesses. However, a comforting notion is that the respondents claimed that they regularly looked up meaning of unknown words in the dictionary or other sources when reading independently.

(3) Another obstacle encountered by these five ESL undergraduates was long and complex general and scientific English sentences. A sentence is perceived as difficult to process when it is made up of complex English sentence structure, contains unknown words, and has more than 25 words. A combination of these three features would consequently result in either missing important point(s) that the author was trying to put forward, generalizing the meaning of the scientific sentence and thus failing to notice significant details, skipping the sentence altogether, or even not knowing that s/he had in fact deciphered the sentence correctly.

(4) Respondents employed at least three LC strategies on a single difficult sentence, namely rereading, splitting the sentence into smaller lexical items and then translating each of them. However, it was found that meaning became apparent when the reader, after employing the three LC strategies, summarized the whole sentence in either his/her L1 or L2. Thus, the earlier fragmented ideas were synthesized into a complete picture.

(5) The third obstacle was to comprehend unfamiliar scientific concepts in their second language. It was found that new scientific concepts explained in one long sentence and not repeated elsewhere in the text is destined to be misread, misunderstood, and ignored by ESL readers. Yet, if these unfamiliar scientific concepts are explained and reemerged in succeeding portions of the text, ESL readers at tertiary level would be able to comprehend the phenomenon, if only at a very general level initially.

6.5 Chapter Summary

This chapter describes the data analyses and findings of five case studies involving five ESL science undergraduates. The aim was to triangulate the findings with those of the quantitative findings. Qualitative data analyzed were think aloud protocols of two scientific texts, semi structured retrospective interview protocols, video observations of readers while reading, and notes made by respondents on the texts. The qualitative analyses of all the data provided by the five ESL respondents showed individual differences in strategy use triggered not only by L2 proficiency of the reader but also text difficulty, topic familiarity, and prior knowledge possessed by each respondent.

CHAPTER SEVEN

DISCUSSION AND CONCLUSION

7.1 Overview

This chapter presents a discussion and some conclusions based on the findings on chapters five and six. It first summarizes the research design, discusses and synthesizes the findings as well as links them back to the literature. This is then followed by highlights on the significance and pedagogical implications of the findings. The final section of this chapter discusses the limitations of the study, suggestions for future research, and a summary conclusion.

7.2 Summary of research design

Local research have repeatedly found that Malaysian ESL undergraduates were struggling to cope with reading tertiary-level academic texts in English (Cooper, 1984; Goh, 2004; Jamaliah & Faridah Noor, 2001; Lee, 1994; Lim, 1992; Nik Suriana, 2001; Noor Fadhillah, 1999; Ponniah,1993; Ramaiah, 1997; Ruhaizan, Mohd Jasmy, Norlena, & Rosadah., 2001; Sargunan and Nambiar, 1994; Teoh, 1996). Findings of these studies indicated that these undergraduates were having serious problems in reading English academic texts as well as lacking in reading practice, skills and perseverance to tackle tertiary-level academic reading requirements.

The problem concerning Malaysian ESL undergraduates' reading difficulties was revisited in this study. In particular, this study took a closer look at how they read two scientific texts with different degree of text difficulty and topic familiarity. Reading scientific texts was the focus of this study since it seems to be the major obstacle faced by ESL readers (Fang, 2006; Flick & Anderson, 1980) as scientific texts are often syntactically complex and linguistically and conceptually domain-specific (Atkinson, 2001; Conrad, 2001; Halliday, 1998). In addition, while studies on how ESL learners read non-scientific texts have been widely researched, how ESL learners read scientific texts has not been thoroughly understood.

This study drew on theories closely associated with the reading comprehension processes namely the reading theory, schema theory, and metacognition theory. Studies have found that successful comprehension of L2 texts is affected not only by the reader's L2 proficiency level but also the prior knowledge s/he utilizes (Chen & Donin, 1997; Lee, 1986a; Tan, 1986), the metacognitive awareness s/he possesses (Bonner & Holliday, 2006; Carrell, 1989; Cassanave, 1988; DiGisi & Yore, 1992; Mokhtari & Reichard, 2004), and the types and intensity of reading strategies s/he opts for (Anderson, 1991; Block, 1986; Carrell, 1989; Pritchards, 1990).

The central focus of this study has been to find out and understand how Malaysian ESL science undergraduates read scientific texts by identifying the types of cognitive and metacognitive strategies utilized by these undergraduates while reading to comprehend the scientific contents. In addition, this study was designed to determine the extent of L2 proficiency, metacognition, and scientific prior knowledge contributions on the strategy choices as well as on reading comprehension of the scientific texts read. Data collection involved both quantitative survey method and qualitative data collection techniques, in particular case studies. The first made use of instruments to assess reading strategies, metacognitive awareness, scientific prior knowledge, and reading comprehension performance. The latter drew on data from respondents' think aloud protocols, retrospective interview protocols, and observations.

7.3 Discussion of research findings

This section reviews, synthesizes and discusses the research findings from quantitative and qualitative data. Six major discussions based on the research questions are presented in this section. They include (a) the role of metacognitive awareness in strategy use and comprehension, (b) the contribution of scientific prior knowledge in strategy use and comprehension, (c) the contribution of L2 proficiency in strategy use and comprehension, (d) variables that predict L2 reading comprehension of scientific texts, (e) characteristics of good ESL readers, and (f) difficulties and strategies to overcome comprehension problems.

7.3.1 The role of metacognitive awareness in strategy use and reading comprehension of scientific texts

The first research question was formulated to find out the metacognitive awareness level of Malaysian ESL science undergraduates and how this awareness contributed to their strategy use and choices as well as to their reading comprehension of the two scientific texts.

The findings reveal that Malaysian ESL science undergraduates possess a very high level of metacognitive awareness. The collective group of Malaysian ESL undergraduates from the quantitative study (n=334) obtained a mean score of 255 for metacognitive awareness (MAI, hereafter) (Schraw & Dennison, 1994) while three (Zeti, Wan and Riz) of the five respondents from the case studies obtained 242, 256 and 258 respectively. These MAI scores match the MAI scores of undergraduates in the studies by Coutinho (2007) and Coutinho & Neuman (2008) but exceed those in Bendixen & Hartley (2003), Kleitman & Stankov (2007), Magno (2008), and Young & Fry (2008).

In addition, the findings of this study indicate that MAI significantly correlated to all 18 metacognitive strategies (MC, hereafter), higher cognitive strategies (HC, hereafter), and lower cognitive strategies (LC, hereafter) used by high proficiency (HP, hereafter) and low proficiency (LP, hereafter) learners and the strength of the correlations ranged from modest to strong. It is also found that the correlations between MAI and strategy use increased in strength from text A (less difficult/familiar) to text B (difficult/less familiar). Yet, correlations between MAI and reading comprehension scores of text A (RCA, hereafter) and text B (RCB, hereafter) were generally not significant with a few exceptions. In LP and HP learners with high scientific prior knowledge (SPK, hereafter), the correlations between MAI and RCA and RCB tended to be negative yet significant. This implies that the higher the metacognitive awareness, the lower is the reading comprehension scores. In contrast, correlations between MAI and RCA and RCB in LP learners with low SPK were positive and significant but weak. In this group of learners, the correlation indicates that as the metacognitive awareness level increases, the scores of RCA and RCB also increase. Nevertheless, the findings from qualitative data indicated that respondents with a high level of MAI scores did not necessarily succeed in their comprehension of the two scientific texts.

The positive and strong correlations between the three measures of metacognition (knowledge of cognition, regulation of cognition and MAI) and strategy use adds support to the contention that readers who are highly aware of their own cognition have the knowledge and procedural ability to meet the reading demands of the texts by taking the necessary steps and strategies to circumnavigate their reading problems (Baker & Brown, 1984; Carrell, 1989; Cassanave, 1988; Kleitman & Stankov, 2007; Koda, 2005; Schraw & Dennison, 1994). Yet, the high metacognition of ESL science undergraduates in this study fail to correlate to the reading comprehension of scientific texts A and B. This finding was not anticipated but certainly not an exception because many previous studies have also found that metacognition did not correlate to single achievement measure or course grade (Bendixen & Hartley, 2003; Cubukcu, 2009; Young & Fry, 2008) or correlated only very weakly to achievement or academic performance measures such as GPA (Coutinho, 2007; Coutinho & Neuman, 2008; Sperling, Howard, Staley, & DuBois, 2004).

The lack of correlation between metacognition and reading comprehension measures may be attributed to three factors. First, metacognitive awareness assessed using an inventory was based on respondents' perceived metacognition and it may be different from their actual metacognition (Coutinho, 2007) as evidenced by one of the case study respondents named Di. Her reported MAI was at 317 but her RCB put her in a poor reader's category. This implies that some respondents may have inflated their responses to the items in the MAI in order to give 'the right answers' to please the researcher.

Second, the relationship between perceived metacognition and the processing of L2 texts, scientific L2 texts in this case, is not straightforward. Perceived metacognitive awareness is stymied by the L2 proficiency of the ESL readers, the language structure of the texts, and the prior knowledge of the readers. In other words, having the knowledge, the awareness, and the control of one's own learning may not necessarily guarantee that a reader would make the right and strategic decision to comprehend a particular text during the actual reading task (Cao & Nietfeld, 2007; Cubukcu, 2009). This notion was demonstrated by Az (one of the case study respondents) whose MAI was 287. Having less prior knowledge on the topic *auxins*, failure to comprehend a few key scientific points embedded in the complex sentences in text A, and inaccurate choices of cognitive strategies resulted in a low RCA score and thus placed her in a poor reader's category. In contrast, when reading text B, even though the text was endorsed to be syntactically more difficult, Az managed to navigate through it successfully and scored the highest in RCB. Successful comprehension of text B by Az could be accredited to her having more prior knowledge on hormones as well as her choices to utilize more of certain cognitive strategies over the others. In summary of the second point, the presence of metacognitive awareness alone may not be enough to direct a reader in making the right cognitive moves in a given reading situation.

Third, metacognition is a measure of learners' ability to reflect, understand and control their learning (Flavell, 1979; Koda, 2005; Schraw & Dennison, 1994). The phrase 'control their learning' suggests that learners possess self-regulation learning behaviours and are able to learn and read independently. So, the reason as to why this variable failed to correlate to reading comprehension of scientific texts among Malaysian ESL undergraduates may be because the majority of the respondents in this study were not used to self-regulated learning and may lack independent reading practices (Cooper, 1984; Noor Fadhillah, 1999; Saragunana & Nambiar, 1994) which the design of this study may have called for.

With the three factors put forward to rationalize the lack of correlation between metacognition and reading comprehension of scientific texts, it could just be assumed that the weak but positive correlation between MAI and RCB in the LP group with low SPK implies that they may have already acquired some independent reading practices. Meanwhile, the groups which showed a negative correlation between MAI and RCA and RCB may be due to the inflated scores of MAI or due to their high L2 proficiency as well as high scientific prior knowledge which enabled them to understand the texts with less strategic planning and monitoring.

7.3.2 The contribution of scientific prior knowledge on strategy use and reading comprehension of scientific texts

The research design of this study was also guided by the schema theory that accounts for the role of prior knowledge in reading comprehension of texts (Bazerman, 1985; Bernhardt, 1984; Carrell & Eisterhold, 1983; Coady, 1979; Nassaji, 2002; 2007; Rumelhart, 1980; Urquhart & Weir, 1998). Hence, two scientific texts with varying degree of topic familiarity were used to determine the relationships between prior knowledge and strategy use as well as reading comprehension scores (Alexander, Jetton, & Kulikowich, 1995; Hammadou, 1991).

Using an 80 item scientific prior knowledge (SPK) inventory to measure prior knowledge, three general patterns of correlations between SPK and reading strategies emerged. First, there was a lack of correlation between SPK and reading strategies in both reading tasks in HP learners in all three university groupings except for those HP learners with low SPK (Univ PQ/HP learners) but only to MC strategies. Second, there were significant correlations but weak to modest between SPK (*auxins & hormones*) and the three types of strategies in LP learners with mediocre SPK (Univ S/LP learners) but correlations were stronger to reading strategies for text B. In addition, only HC strategies correlated to SPK in LP learners with high SPK (Univ R/LP learners). Third, there was no correlation between SPK and reading strategies in both reading tasks in LP learners with low SPK (Univ PQ/LP learners).

The first and third research findings suggest that learners with high L2 proficiency may not have relied heavily on their prior knowledge in their strategy use to comprehend the two scientific texts while low L2 proficiency readers may have failed in their attempt to access their limited prior knowledge (Krekeler, 2006; Hammadou, 1991, Baker and Brown, 1984). Researchers (Carrell, 1983; Clapham, 2000; Hammadou, 1991; Krekeler, 2006) argued that high L2 proficiency learners relied more on the language elements as opposed to their prior knowledge of topic to understand a given text. Similarly, Chen and Donin (1997) found that having high or low prior knowledge had no significant effect when readers were reading in their L1, a language that they were proficient in. This suggests that when a reader is proficient in the language of the text, s/he is able to build a propositional model of the content through the incoming data or bottom up processing (Carrell, 1984; Carrell & Eisterhold, 1983; Eskey, 1988).

The finding of this study also indicates that the HP learners above also possessed high prior knowledge on the two texts. This could also explain for the lack of correlation between SPK and strategy use. The high scientific prior knowledge that they possessed did not require them to strategize in order to understand the text. The prior knowledge was already internalized and the new information they read from both texts may have unconsciously been blended in with the old information in their possession.

In contrast, low L2 proficiency among some ESL learners may have been insufficient to activate their content schemata (Carrell & Eisterhold, 1983) which resulted in less inferencing and top down processing which would otherwise be triggered by successful bottom up processing (Chen & Donin, 1997). Pang (2006) reported that ESL readers could only be successful in using top-down strategies (such as activating prior knowledge) when their bottom up processing is successful. Another explanation is that very limited L2 proficiency readers tended to process the texts at word and sentence levels and thus left very little cognitive resources to attend to higher order text features and prior knowledge (Carrell, 1984; Clapham, 2000).

The second research finding was a significant yet weak correlation between prior knowledge and strategy use in Univ S/LP learners and Univ R/LP learners. As the data indicated, Univ S/LP and Univ R/LP learners possessed higher scientific prior knowledge (see Table 5.17, pg. 213; Table 5.34, pg. 250) compared to Univ PQ/LP learners. Therefore, even though the L2 proficiency of Univ PQ/LP and Univ S/LP learners were at par, Univ S/LP learners may have tried to access their scientific prior knowledge when they were visualizing, analyzing, summarizing and even paraphrasing and decoding (see Table 5.21, pg. 224) the text contents to compensate for their inadequate linguistic knowledge (Chen & Donin, 1997; Hammadou, 1991). This phenomenon is consistent with Stanovich's interactive compensatory reading model (1980; 2000) where readers were putting a heavier reliance on one knowledge resource, that was their prior knowledge, to compensate for a deficiency in another knowledge resource, which was their L2 competency. Thus, these LP learners were perhaps utilizing top down strategies in their attempt to make sense of the scientific texts.

Correlations between SPK and strategy use were also observed to be stronger in text B (difficult/ less familiar) than in text A (less difficult/ familiar). This finding confirms the notion that when readers encountered reading difficulties (Block, 1992; Brown and Baker, 1984; Li and Munby, 1992; Young & Oxford, 1997), they tended to employ more rigorous problem solving strategies. Thus, the more difficult the text, the more rigorous the LP learners with ample SPK would strategize in order to comprehend the texts and one of their problem solving strategies was accessing their scientific prior knowledge.

When SPK was correlated to reading comprehension measures of the scientific texts, three interesting outcomes were observed. First, SPK A (*auxins*) did not correlate to any comprehension measures in any group. Second, significant correlation between SPK B (*hormones*) and reading comprehension text B was observed in learners with low SPK (Univ PQ learners). Third, significant but weak correlation was found between SPK scientific terminology and reading comprehension in HP learners with high SPK (Univ R learners). In addition, stepwise regression analysis revealed that scientific prior knowledge contributed only 1.5 per cent to reading comprehension of text A and 1.9 per cent to RCB in the collective group (n=336) and up to 2.2 per cent in respondents with low SPK (those in Univ PQ).

The findings above are not consistent with many previous studies (Alexander et al., 1995; Brantmeier, 2005; Chen & Donin, 1997; Keshavarz, Atai, & Ahmadi, 2007; Krekeler, 2006; Ozuru, Dempsey, & McNamara, 2009; Pritchard, 1990) which usually found a strong effect of prior knowledge on reading comprehension. One very obvious explanation was that the respondents were all biology majors who generally possessed similar fundamental scientific prior knowledge. For example, the qualitative analyses indicated that all respondents had a good understanding of scientific concepts such as ‘plasma membrane’, ‘cytoplasm’, ‘polar and non polar hormones’, and ‘receptor enzyme’. On the other hand, respondents in previous studies usually consisted of two very contrasting groups of students, for example engineering and administration/finance students (Alderson & Urquhart, 1988), engineering versus biology majors (Chen & Donin, 1997), American and Palauan learners (Pritchard, 1990) reading about funeral rites in each other’s cultures, psychology and biology learners (Ozuru et al., 2009), and pre medical and educational psychology graduates (Alexander et al., 1995). With a very big gap in prior knowledge between the two participating groups, previous studies successfully showed that prior knowledge played a big and significant role in reading comprehension.

Yet, the most interesting thing about the findings of this study is that prior knowledge is only rigorously accessed when the readers encountered comprehension problems through bottom up processing. The evidence from this study showed that ESL readers who possessed a lot of prior knowledge on the content of a text, for example the topic *auxin* in text A, did not constantly access that prior knowledge in order to understand the text. For one, text A was syntactically less difficult, thus readers may not have encountered a lot of reading problems. This in turn did not require them to strategize (Baker & Brown, 1984) as found in the lack of correlation between SPK of text A and reading comprehension measures in all groups.

Another reason may perhaps be because the knowledge is constantly present in the reader's working memory during reading and when it matches the bottom up processing (Carrell & Eisterhold, 1983), it tends to be blended in with the new information. Alternatively, the prior knowledge may remain at bay of the active memory when it is not immediately required. Interestingly, in both situations the reader does not have to put a lot of effort to access it since it is already present in the working memory for utilization. However, conscious effort in accessing one's prior knowledge will only occur when a reader encounters comprehension difficulties. Comprehension difficulties may stem from the inability to process certain scientific concepts from the text due to insufficient linguistic competence, a mismatch between the data understood from the bottom up processing and the conceptual expectation based on readers' prior knowledge, or a mere unfamiliarity of the topic. Insights from the qualitative data found that at least two respondents (Az and Di) very clearly demonstrated the tendency to access their scientific prior knowledge more frequently while reading a text on the topic which they had less prior knowledge. Az accessed her prior knowledge on *auxin* 12 times while reading text A (which she had problem reading stemming from lack of knowledge on *auxin*) and only six times while reading text B (which she admitted to having a lot of knowledge on *hormones and signal transduction*). Di, on the other hand, accessed her prior knowledge only once while reading text A but 13 times while reading text B. Two other qualitative respondents showed similar pattern of increased frequency of accessing prior knowledge on less familiar topic, but the difference was very small.

The second finding on the relationship between prior knowledge and reading comprehension scores indicated that even though the correlation of SPK B and reading comprehension of text B in the learners with low SPK (Univ PQ) was significant, it was weak. This finding evidently shows that with a difficult text such as text B, there is an added advantage for a learner who has more prior knowledge on the topic as well as has the ability to strategize by relating the content of the text to his/her prior knowledge (Carrell & Eisterhold, 1983).

Apparently, Univ PQ learners were an intriguing group of learners. As found in Chapter 5 (pg. 250), their L2 proficiency was inferior to those in Univ R but at par with those in Univ S. In addition, their SPK mean score was the lowest among the three groups. Yet, their reading comprehension scores of the two texts were either similar to or superior than those in Univ R and consistently better than those in Univ S. These learners resembled respondents in Cluster 2 in the second experiment of Alexander, Jetton and Kulikowich's (1995) study. As noted by Alexander et al. (1995), this group of learners "….are quite effective at learning from text…..the strategic processing abilities of these students, as evidenced in their recall performance, may be quite strong…" (p. 570).

Indeed, the finding regarding Univ PQ learners on the significant correlation between SPK and reading comprehension seemed to reinforce the earlier finding on significant but weak correlation between SPK and metacognitive strategies in the same group of learners (Univ PQ/HP learners). Univ PQ learners may have consisted of 'medium L2 proficiency learners' as described by Clapman (2000). He argued that while lower L2 proficiency learners could not take advantage of their prior knowledge and high L2 proficiency learners did not have to rely on their prior knowledge, "…medium proficiency learners were affected by their background knowledge" (p. 515-516). In other words, both scientific texts used in this study matched the L2 proficiency as well as the current prior knowledge possessed by these learners (in Univ PQ) which were perhaps dynamic or ideal conditions to trigger efficient and successful strategizing.

The final finding, which was unexpected yet very fascinating, was on the nature of prior knowledge that contributes to successful comprehension of scientific texts. Prior knowledge which facilitates reading comprehension of scientific texts would be one which is topic-specific (Hanmadou, 1991; Ozuru et al., 2009) and scientific in concepts. Qualitative insights indicated that Riz who had first hand experience and knowledge about *auxins* came last among the five respondents on the comprehension measure of text A. A closer study on his prior knowledge of *auxins* and its function revealed that it was general or layman's knowledge. In addition to that, his L2 proficiency level was low, which did not help him to completely comprehend the text. Instead of functioning as an added advantage for an LP learner like Riz, his high prior knowledge on *auxins* failed to facilitate his reading comprehension but instead it may have led him to over generalize and over infer certain scientific concepts which he failed to figure out and unpack due to his low L2 proficiency. The consequences of Riz's tendency to generalize scientific concepts based on his high prior knowledge of auxin were many. Among others were that he overlooked important details (Lee, 2009), misunderstood concepts, and did not learn new information provided in the text (Ozuru, Best, Bell, Witherspoon, McNamara, 2007; Ozuru et al., 2009).

7.3.3 The contribution of L2 proficiency on strategy use and reading comprehension of scientific texts

This study examined cognitive and metacognitive strategies used by Malaysian ESL science students while reading two scientific texts that were of different syntactic difficulty and topic familiarity. From the quantitative portion of the study, the findings of the study indicated that HP and LP first year ESL science undergraduates did not differ in their choices, use and intensity of MC and HC strategies while reading both scientific texts. As anticipated, compared to HP learners, LP learners were found to exert slightly more LC strategy of translating. Yet, when reading a more difficult text on a less familiar topic (Text B), both HP and LP groups of learners tended to struggle and the findings showed that HP learners exerted a little more MC strategies and used translating as an LC strategy to unpack comprehension problems.

The first part of the above findings was not consistent to previous reading strategy research (Block, 1992; Carrell, 1989; Horiba, 1990; Pang, 2006; Phakiti, 2003; Young & Oxford, 1997; Zhang & Wu, 2009). Most other studies found that HP learners tended to use ‘global’ or HC strategies more while LP learners were generally involved in ‘local’ or LC strategies like decoding and translating (ibid; Crain Thorenson, Lippman, & McClendon-Magnuson, 1997; Koda, 2005; Hosenfeld, 1997; Sariq, 1987). However, similar trend of strategy use as found in the above mentioned studies was not evident in this study. Other than LC strategy of translating, HP and LP learners especially in Univ PQ were found to utilize a number of similar MC, HC and LC strategies, which significantly correlated to reading comprehension of scientific texts.

One point of information which is very significant to be included in this discussion is the lack of correlations between strategies used and reading comprehension scores of both texts among learners in Univ R and Univ S. The finding on strategy use by learners in Univ R again confirmed previous findings (Carrell, 1983; Clapham, 2000; Hammadou, 1991; Krekeler, 2006) that high L2 proficiency and high prior knowledge readers did not have to strategize since the language and topic of the scientific texts matched their own English proficiency and scientific prior knowledge. Thus, comprehension was automatic.

Since there was a lack of correlation between strategies used to read the two texts and reading comprehension scores in HP and LP learners in Univ R and Univ S, the subsequent discussions on the correlations between strategy use and reading comprehension scores will only be based on the findings obtained in the HP and LP learners in Univ PQ.

Among the strategies which were utilized by both HP and LP learners and which correlated to reading comprehension scores were MC strategies of evaluating, debugging, monitoring, as well as HC strategies of visualizing, analyzing visual diagrams, analyzing text, accessing prior knowledge, summarizing, questioning content, and LC strategies of memorizing and taking notes, and reading for local understanding. Insights from the qualitative data too revealed that, besides LC strategy of translating which was used extensively by two LP and one HP learners, MC strategies of monitoring and evaluating, as well as HC strategies of visualizing, analyzing visual diagram, inferring content, accessing prior knowledge, questioning content, summarizing, and LC strategy of reading for local understanding were used with high intensity by both HP and LP learners.

The second part of the findings above indicated that the strength of MC strategies was observed to be higher in HP compared to LP learners when reading text B adds support to the notion that MC strategies only emerged when readers encountered reading difficulties (Brown & Baker, 1984). This finding is also consistent with those reported in previous studies (Block, 1992; Carrell, 1989; Pang, 2008; Zhang & Wu, 2009) in that L2 proficiency dictates the use of MC strategies and that skilled readers are more able to reflect and monitor their reading processes (Block, 1992; Sheorey & Mokhtari, 2001).

Another finding regarding strategy use among HP and LP learners was that even though both groups were found to utilize similar strategies, the strength of correlations between these strategies and reading comprehension scores of both texts were different in each group. First, the correlations between strategies used and comprehension scores were stronger to RCB than to RCA in the HP learners, while in the LP group, the strength of correlations remained the same. Second, the strategies utilized by HP learners had stronger correlations to their RCA and RCB compared to the strength of correlations in the LP learners.

The differences in the strength of correlations between strategies and comprehension scores in the HP learners compared to the LP learners may imply three points. First, while reading text A (less difficult/familiar) readers might not be facing reading problems, thus less effort in strategizing (Brown & Baker, 1984). Hence the low correlation coefficients between strategies and RCA in HP group as well as in the LP group. In effect, the HP readers were relying heavily on their language proficiency and only utilized a few reading strategies to comprehend the text. Meanwhile, LP learners too were relying on their L2 proficiency as well as the use of at least five HC strategies.

Second, it may also be that HP learners were able to get more advantage out of the strategies they utilized when reading a challenging text (text B) compared to their LP counterparts (Anderson, 1991; Phakiti, 2004). In other words, extra effort in the strategies utilized by the HP group had a facilitative effect and went a long way towards reading comprehension. The attempts made by the HP group to use their linguistic knowledge (by utilizing LC strategies) to unpack problematic sentences had also contributed to their comprehension of text B. This finding is consistent to Johnson & Ngor's (1996, cited in Sharp, 2004) claim that readers tended to use LC strategies to cope with difficult texts. Earlier analysis also revealed a significant increase in the MC strategies in the HP group while reading text B. Thus, it is safe to assume that these HP readers recognized their reading problems and made attempts to solve them (Baker & Brown, 1984) by employing bottom up strategies which were evidently effective in this case.

Third, the strategies undertaken by the LP group while reading text B were hampered by their low L2 proficiency and thus short circuited (Clarke, 1980) efficient strategies which would otherwise be facilitative. In fact, attempts made by the LP group in using their limited linguistic knowledge (LC strategies) failed to contribute to their comprehension of text B. Another noteworthy observation is that the correlations between strategies and reading comprehension became stronger and the number of strategies that correlated to RC increased from text A (less difficult/familiar) to text B (difficult/ less familiar) in both HP and LP groups. This suggests that as the text increased in language and topic difficulty, readers may have experienced reading difficulties which demanded rigorous problem solving strategies (Brown & Baker, 1984; Block, 1992).

Another yet very significant finding is regarding the specific types of strategies which contribute and did not contribute to reading comprehension of scientific texts as revealed by the quantitative and qualitative data. Findings from both research approaches indicated that while a combination of a variety of strategies contributed to successful reading comprehension, there were at least five specific strategies which were recurring and being utilized among these ESL science undergraduates. Cognitive strategies that often correlated to reading comprehension (RC, hereafter) in quantitative data and frequently used by qualitative respondents include HC strategies of visualizing, analyzing visual diagrams, accessing prior knowledge, summarizing, and LC strategies of translating, memorizing and taking notes, and reading for local understanding.

Alternatively, cognitive strategies which failed to contribute to RC scores of scientific texts include HC strategies of reading for global understanding (guessing unknown words, skipping unknown words and reading for overall meaning of text) and LC strategy of decoding. HC strategy of inferring for content, on the other hand, has small facilitative effect on comprehension of text B among LP learners but did not contribute to comprehension in the HP group. However, insights from the qualitative data revealed that HC strategy of inferring content was not frequently utilized by good ESL readers of scientific texts. In addition, MC strategies of monitoring and debugging almost always correlated to RC scores and frequently used by good ESL readers of scientific texts.

The most significant finding from these data suggests that there are some differences between the types of strategies that contribute to successful comprehension of scientific L2 texts from those strategies for non scientific L2 texts. LC strategies such as focusing to understand each word and sentence, rereading, memorizing important points and taking notes correlated significantly to reading comprehension of both scientific texts yet they were considered ‘poor’ strategies for reading non scientific L2 texts (Block, 1986; Carrell, 1989; Chamot & O’Malley, 1994; Kern, 1989; Koda, 2005; Sariq, 1987). In addition, HC strategies such as analyzing visual diagrams, visualizing text content and drawing concept/mind maps are very significant to reading comprehension of scientific texts and are typical strategies in reading biology as endorsed by science education researchers (Amer, 1994; Bonner & Holliday, 2004; Cook, 2006; Derbentseva, Safayeni, & Cañas, 2007; DiGisi & Yore, 1992; Koch, 2001). In contrast, HC strategies like skipping unknown words and reading to get the overall meaning of text as well as inferring for content which are ‘good’ strategies for non scientific L2 texts are not significant in reading scientific texts. However, MC strategies like monitoring and debugging are universal strategies which are successful for reading both scientific (Anderson & Nashon, 2006; Dhieb-Henia, 2003; Koch, 2001) and non scientific texts (Baker & Brown, 1984; Block, 1992; Carrell, 1989; Koda, 2005; Li & Munby, 1996; McCormic, 2003; Pang, 2008; Phakiti, 2004; Tang & Moore, 1992; Yang, 2002; Zhang & Wu, 2009; Zicheng, 1992).

This finding seems to indicate that when reading scientific texts, science students tend to use strategies that are crucial in that field (i.e biology) like analyzing diagrams, visualizing and reading for details plus other common strategies at their disposal to get to the crux of the text, be it lower or higher cognitive strategies. As noted by Anderson (1991), besides L2 proficiency level, strategy choices may be attributed to the reader's prior knowledge in the text content, interest and motivation in the field, and learning styles of the specific domain area. Learning styles mentioned by Anderson could also mean strategies for reading in a particular discipline such as science. Therefore, a set of successful strategies for one domain area may not be so successful in another (Koch, 2001). Reading strategy instructors and L2 students alike need to work out which set of strategies work best for reading in their specific domain area such as biology, chemistry or even psychology and political science.

7.3.4 Variables that predict L2 reading comprehension of scientific texts

As has often been found in previous studies, L2 proficiency is the key factor to efficient reading comprehension of texts in the second language (Bernhardt & Kamil 1995; Brantmeier, 2005; Brisbois, 1995; Carrell, 1984; 1991; Keshavarz, Atai, & Ahmadi, 2007; Koda, 2005; Tan, 1986). Similar result was also found in the present study which was on the L2 reading comprehension of scientific texts. However, unlike the findings in previous studies which reported that L2 proficiency contributes 30%-

38% (Bernhardt, 2005; Bernhardt & Kamil, 1995; Bossers, 1991; Brisbois, 1995) of the variance in L2 reading comprehension, the finding obtained in this study indicates that the effect of L2 proficiency tended to fluctuate from 5.2% to 24.3% in ESL science undergraduates reading scientific texts.

It was found that the more syntactically difficult the text, the higher is the contribution of L2 proficiency in the reading comprehension of the L2 text. For example, in high L2 proficiency learners (Univ R), L2 proficiency contributed 22.3% and 24.3% of the variance to RC of scientific texts A and B respectively whereas in intermediate L2 proficiency learners (Univ PQ), L2 proficiency contributed 5.2% and 7.9% of the variance to the RC of the same texts respectively. This finding reinforces the fact that as the text gets syntactically more difficult (as in text B), these ESL readers were *holding in the bottom* (Eskey, 1988) or processing the text more closely at the lower cognitive level such as unpacking problematic sentence structure and decoding words. Hence, there was an increase in the percentage of L2 proficiency in reading text B.

Surprisingly, stepwise multiple regression analysis indicated that scientific prior knowledge did not contribute to the reading comprehension of both texts in all groups but SPK on scientific terminology did contribute 2.2% to RCB in L2 learners of Univ PQ. Compared to the L2 learners in Univ R and Univ S, those in Univ PQ possessed significantly less overall SPK score. This finding points to the role of prior knowledge in reading comprehension which remains at bay in the working memory for easy reference during the reading process. The integration of prior knowledge and the new information from the text is perhaps automatic and smooth until comprehension is disrupted due to syntactic difficulty (Brantmeier, 2005) or unfamiliarity of terminology. Overt access of prior knowledge will only then take place to resolve the reading problems which naturally would occur in learners with low L2 proficiency and low SPK.

The variable metacognitive awareness did not contribute to the reading comprehension of both texts in L2 learners of Univ PQ and Univ S. However, metacognitive awareness contributed 3.1% of the variance to RCB in L2 learners of Univ R (of higher L2 proficiency and high SPK). This finding was not anticipated as the variable metacognitive awareness did not correlate to reading comprehension of both texts in L2 learners of Univ R as it had correlated for Univ PQ/LP learners (discussed previously in section 7.3.1). Yet, using the stepwise multiple regression analysis, the contribution of metacognitive awareness came through for learners in Univ R but not for those in Univ PQ. What this may perhaps imply is that no matter how highly aware one is about his metacognition, his inferior command of the language of the texts or language of the reading comprehension assessments could in fact stymie his ability to take charge of his own cognition. Sternberg (1998) has argued on this point when he stressed that metacognition converges with other attributes of the individuals that are linked to the abilities necessary for academic success. In this study, academic success refers to the marks obtained for RCA and RCB. One of the attributes necessary for that success is a good command of English vocabulary and syntax to comprehend the texts (Fitzgerald, 1995). Thus, with inferior L2 proficiency, metacognitive awareness possessed by a learner may fail to work to his/her advantage in reading comprehension of the two scientific texts and vice verse for those with high L2 proficiency.

While reading strategies did not contribute any variance to reading comprehension of scientific texts amongst the high proficiency and high prior knowledge L2 learners (Univ R), MC strategies contributed 5.1% to RCA and HC strategies contributed 11.2% to RCB in L2 learners of Univ PQ (with intermediate L2 proficiency and low SPK). This finding adds to Bernhardt's (2000; 2005, p. 140) compensatory model of L2 reading. In her model, 30% of the variance was attributed to L2 language knowledge, 20% L1 literacy, and 50% was unaccounted for and was assumed to be contributed by, among others, comprehension strategies and domain knowledge. Hence, this study has successfully shown that at least 5% to 11% of the unexplained variance in Bernhardt's model could be explained by comprehension strategies. However, Bernhardt's model was rather rigid in that it failed to account for the varying contribution of L2 proficiency as this study had managed to uncover. The contribution of L2 knowledge in reality fluctuates according to the syntactic and topic difficulty of the L2 texts as well as the L2 proficiency of the readers.

In sum, the answer to the question on which variable (L2 proficiency, metacognition, science prior knowledge, or reading strategies) influences L2 reading comprehension of the scientific texts the most would likely be L2 proficiency, which almost all L2 reading studies have found thus far. However, other knowledge sources are equally crucial and working 'synchronically, interactively, and synergistically'

(Bernhardt, 2005, p. 140) together in assisting the inadequacies of knowledge sources of each individual through efficient strategizing on the part of the L2 readers.

7.3.5 The characteristics of good ESL readers of scientific texts

The attempt to study the characteristics of good ESL readers of scientific texts in this study revealed that the interaction of a number of variables contributed to a good reading behaviour which in turn resulted in successful reading comprehension of scientific texts.

It was found that there are four distinct features that separate good ESL readers from poor ESL readers when reading scientific texts. The key variable is L2 proficiency. This is followed by the familiarity or the scientific prior knowledge on the topic possessed by the readers, deliberate use of cognitive strategies as well as the control of these cognitive strategies while reading to comprehend the texts, and the employment of metacognitive monitoring. Finally, perseverance in an ESL reader is vital to ensure that s/he reads the text to the end with sustained effort and concentration. These findings are similar to the findings of good readers of non scientific texts by Carrell (1989, p. 128).

First, good ESL readers of scientific texts possess a certain level of L2 proficiency or at least a modest proficiency to make sense of the scientific texts. Qualitative evidence revealed that Az (modest L2) and Zeti (limited L2) managed to emerged as good readers with their current level of L2 proficiency. Zeti's reading behaviour demonstrated the fact that possessing modest or limited L2 proficiency does not necessarily signify poorer processing skills or limiting the readers from taking advantage of their prior knowledge to make sense of the texts. Quantitative findings too indicate that L2 proficiency is a pre requisite for a good reading behaviour but it is not the ultimate predictor of a good reader. Certainly with regards to Univ R learners, they possessed higher L2 proficiency compared to Univ PQ and Univ S learners which enabled them to comprehend both scientific texts successfully, even without the significant contribution of reading strategies. Thus, reading to comprehend among the majority of Univ R learners became automatic and smooth. Yet, it was also found that there were ESL learners with lower L2 proficiency who could comprehend both scientific texts as good as or better than high L2 proficiency learners. Zeti's reading processes and some findings from the quantitative data have, to a certain extent, challenged the 'short circuit' hypothesis (Clarke, 1980). Clarke maintained that limited L2 proficiency of the reader will 'short circuit' or inhibit his good L1 reading system from being transferred to and utilized in the L2 reading task, consequently, causing him to employ poor reading tactics which would mainly be processing the text at word level. Since the findings in this study showed otherwise, the problem of the 'short circuit' hypothesis may perhaps lie in (i) the definition of 'limited' L2 proficiency, (ii) whether or not the L2 reader has a good L1 reading system to begin with, or (iii) his exposure or lack of exposure to good reading tactics.

Second, good ESL readers of scientific texts were also found to possess some scientific prior knowledge on the topic as well as the ability to use that knowledge to unlock reading comprehension difficulties. Scientific texts are known to be very domain-specific (Atkinson, 2001; Conrad, 2001; Halliday, 1998) which require the readers to have not only the knowledge of general English but also the language, rhetoric and terminology of science to understand the text (Halliday, 1993; Ozuru, Dempsey, & McNamara, 2009; Swales, 1990; Tarantino, 1991). Even though Stanovich (1980; 2000) argued that readers with limited linguistic knowledge tended to compensate their L2 deficiency with other knowledge sources, it is important to note that the mere use of any knowledge sources may not be enough for successful comprehension. In fact, the data point to the ability of the ESL readers who could extract only relevant or pertinent science prior knowledge for the purpose of comprehending the text in hand to be successful. In other words, having more knowledge on a topic does not necessarily result in successful comprehension. Thus, that was why Riz (limited L2) who possessed a first hand experience and prior knowledge on the plant hormone *auxins* failed to compensate his limited L2 proficiency with his top down strategies even though he accessed his prior knowledge repeatedly. On the other hand, good but low L2 proficiency readers like Az and Zeti were found to choose only scientific details from their prior knowledge to assist them in the meaning making processes of both texts. Findings from quantitative data showed that LP good readers possessed either similar to or inferior scientific prior knowledge than HP poor readers. Yet they managed to outperform the HP poor readers in both reading tasks. It was not evident from the data if LP good readers had, in fact, chose specific or relevant scientific as opposed to general prior knowledge to assist in their reading comprehension. Nevertheless, the mean scores of their top down or HC strategies were found to be much higher and significantly different from those of HP poor readers. It may imply successful use of compensation strategies in these low L2 proficiency learners.

Third, good ESL readers of scientific texts deliberately chose certain cognitive strategies that could enhance their comprehension of the scientific texts and exerted greater intensity on each chosen strategy compared to poor ESL readers. This finding is consistent to Anderson's (1991) who found that successful comprehension also depends on the intensity of each strategy used. Findings from both qualitative and quantitative data of this study indicated that the choice of MC and HC strategies and the intensity of the usage differentiated good from poor ESL readers. The mean scores of HC strategies like visualizing, analyzing visual diagram, inferring language, and summarizing were higher in good ESL readers compared to poor ESL readers. The data from case studies confirmed this finding when good ESL readers were observed to use with high frequency the above mentioned HC strategies except for HC inferring language. The evidence from qualitative data also indicated that good ESL readers were more inclined to question content while poor ESL reading tended to employ HC strategy of inferring content. Yet, this latter finding and assumption require further qualitative investigation with bigger samples that comprise of both high and low L2 proficiency science learners.

While it is common to find HP learners perform well in reading comprehension tasks and are labeled good readers, it is of great pedagogical implication to understand the processing strategies undertaken by LP good readers which enabled them to comprehend the scientific texts as good as if not better than HP learners. Insights from the qualitative data revealed that due to their limited or modest L2 proficiency, some LP good readers resorted to lower cognitive strategies like translating, paraphrasing and rereading to make sense of the texts, in Eskey's (1988) words, they were *holding in the bottom.* Besides that, good ESL readers of lower L2 proficiency were also found to take notes and constructing mind maps. Yet, unlike poor ESL readers who continued to read the texts at lower level, LP good readers promptly applied HC strategies like verbal summarizing, visualizing, and analyzing visual diagrams provided in order to get a complete understanding of the text content. Thus, the significant contribution of LC strategies like translating and rereading to L2 reading comprehension must not be underrated. They are in fact a necessity to LP learners. However, these LC strategies are found to be effective only when they are complemented with efficient HC strategies such as summarizing and synthesizing.

Fourth, good ESL readers of scientific texts possessed comprehension monitoring competence that enables them to select and carry out not only effective cognitive strategies (Pang, 2008; Yang, 2002) but also problem solving strategies in their attempt to comprehend the specific text in hand. The most outstanding MC strategies observed in good ESL readers while reading the two scientific texts were MC monitoring and debugging. Even though there was no significant difference found in the level of metacognitive awareness between good and poor ESL readers, significant difference were found in the mean scores of MC strategies of monitoring and debugging. Data from qualitative study substantiated this finding with one exception. In the case of Az, too much monitoring hampered her comprehension of text A (Sternberg, 1998). Sternberg argued that excessive deliberations and reflections are uncalled for because they tend to be superficial and get in the way of true or deeper monitoring. Instead, learners need to be trained to automatize certain metacognitive activities.

It is also noteworthy to include perseverance (Carrell, 1989, p. 128) as perhaps the last determining characteristic of a good ESL reader of scientific texts. This is because both quantitative and qualitative data indicated that good ESL readers usually sustained or increased the intensity of their strategy use in order to stride through the complexities of the texts in order to get to the core message with correct interpretation.

7.3.6 Reading comprehension difficulties and strategies employed to overcome comprehension problems

While scientific terminology was not found to be a major problem in reading comprehension of L2 scientific texts among ESL science undergraduates, the obstacles faced by these learners that this study managed to uncover were those related to proficiency in L2, in particular vocabulary and complex sentence structure of the general English language. Similar finding was obtained by Malcom (2009) who studied reading strategy awareness among Arabic-speaking medical students. These students had less problem reading medical books compared to reading English newspapers. It is also consistent to the study by Parkinson, Jackson, Kirkwood and Padayachee (2007) that L2 students usually struggle with general academic and ‘everyday’ English words. Evidence from the qualitative data indicated that respondents employed a number of fix-up strategies which resembled those in reading non-scientific texts like translating (Clarke, 1980; Hosenfeld, 1977), associating to their prior knowledge, breaking up problematic words, guessing, and skipping the unknown word (Chamot & O'Malley, 1994; Crain Thorenson, Lippman, & McClendon-Magnuson, 1997; Koda, 2005).

Having a high metacognitive awareness, these ESL respondents were able to plan for 'fix-up' strategies to cope with comprehension difficulties and failures (Baker & Brown, 1984; Block, 1986; Carrell, 1998; Stanovich, 1980; 2000). Figuring out the meaning of unknown words involved one or more fix-up strategies. Respondents' initial attempt would be to translate the problematic word. If this initial attempt failed to make sense to the L2 readers, another fix-up strategy would follow. In this process, they linked the new unknown word in the text with their prior knowledge or experience. All the while, they would monitor their comprehension and reread the sentence if the translation they did made sense.

Another approach would be to break up the word and again translate or guess the meaning of each piece. If that attempt failed, some respondents would then try to figure out the meaning from context by reading sentences surrounding the word. Even though guessing unknown words from contextual clues was known as a 'good' strategy (Chamot & O'Malley, 1994; Chen & Donin, 1997; Kern, 2000), this strategy was not high on the priority list when guessing unknown words among ESL respondents in this study. Skipping unknown words was observed to be used by two proficient respondents but it was not a very popular strategy among the less proficient (Hosenfeld, 1977)

The findings also revealed that the strategies to figure out the meaning of unknown words worked only half of the times and failed the rest of the times. The design of this study, however, did not allow the respondents to refer to the dictionary.

This was done on purpose because previous studies showed that metacognitive strategies would only emerge when readers were faced with reading comprehension difficulties (Brown & Baker, 1984; Koda, 2005) and cognitive strategies would follow suit to solve the problems. Therefore, without a dictionary to help the respondents, misunderstanding of sentence statements occurred especially when they made inaccurate translations and guesses. This in turn led to miscomprehension of the scientific contents. Fortunately, unlike the design of this research, daily reading assignments given to the respondents do not prohibit them from using a dictionary. Therefore, inaccurate guesses and translation could be corrected if they were in doubt while reading independently for class or life long learning.

Even though most of the scientific terminology used in the two scientific texts was understood by the respondents, there were a few which were new and unfamiliar (Graesser, Leon, & Otero, 2002; Ozuru et al, 2009). In addition, the sentences that described these unfamiliar scientific concepts were sometimes long and complex and not repeated elsewhere in the text. The author of the scientific text has probably assumed that the ESL readers of the text are in fact equipped with the specialist vocabulary (Walsh, 1982) used. Hence, only a brief definition on the scientific terminology was given which was aimed at triggering the readers' specific prior knowledge on the subject before the author delves deeper into the abstract scientific concepts. However, ESL readers with low and high L2 proficiency did not attempt to guess or infer the meaning of unfamiliar scientific terminology without the backing of ample prior knowledge on the topic. Thus, unlike reading non scientific text where inference strategy was a key factor in differentiating good from poor L2 readers

(Hosenfeld, 1997; Kern, 2000), inference strategy when reading a scientific text may not be the best option.

In addition, another stumbling block for ESL learners when reading scientific texts was the long and complex sentence structure. When encountered with such sentences, most respondents would look for and focus on familiar scientific terminology to provide them with a window to the meaning of the complex sentence. However, it was found that sentences containing only general English words became very challenging to these ESL respondents as also found by Parkinson, Jackson, Kirkwood, & Padayachee (2007). To unpack long and complex sentences, a sequence of fix-up strategies was employed beginning with breaking up the sentence into short clauses, rereading each clause and translating one piece at the time. Good ESL readers would normally summarize the whole idea to get a holistic understanding of the sentence resulting in successful comprehension. Similar to Ou's (2006) findings, less proficient ESL learners who employed summarizing strategy after the initial translating process showed positive outcomes in their reading comprehension tasks. On the other hand, poor ESL readers continued to plough through the text at lower cognitive level. Hence, they ended up with disjointed understanding of the scientific concepts, failed to notice details which were crucial to scientific reading (Koch, 2001), and were satisfied with a general understanding (Ozuru et. al, 2009) or a false understanding (McNamara, Kintsch, Songer, Kintsch, 1996) of the complex scientific concepts.

It was not surprising that scientific terminology did not pose much problem to the ESL science undergraduates in this study for three reasons. First, the respondents chosen were science majors who were required to possess a minimum of a B grade in biology and chemistry at SPM (*Malaysian Certificate of Education*) taken in Form Five and also at matriculation level to enroll in biology related degree programmes. This means that respondents were familiar with freshmen level scientific terminology. Second, scientific terminology learnt in secondary school was in the respondents' L1 or the national language. Thus, the abstract concepts of certain scientific terminology learnt before were well understood. Third, the scientific text books from where the two texts came from were meant for freshmen level (text A) and the text book for text B was specially written for Asian students. Thus, the complex scientific language and rhetoric may have perhaps been minimized.

Unlike 'authentic' scientific journal articles and research papers written for scientists and experts in the field, the two texts used in this study were written for freshmen level science course. Thus, the language of the texts tended to be descriptive in nature to make it easy for the science learners to comprehend the foundations of the scientific concepts being discussed. In other words, the texts which were used in this study were primarily written in general English syntax and vocabulary. Yet, they were still considered a big hurdle for ESL learners especially those with low L2 proficiency (Walsh, 1982). What this means is that, ESL learners with low and intermediate L2 proficiency in this study were already found to be struggling with the general English syntax, let alone be confronted with authentic scientific texts written for advanced level readings when they move on to their second and third year undergraduate study.

7.4 Significance and implications

7.4.1 Theoretical significance

This study has extended the scope of two important lines of research related to reading; strategy use in second language reading and reading in science education. First, it identified key strategies used by ESL undergraduates while reading two scientific texts of different level of syntactic difficulty and topic familiarity. The findings contribute to the present body of knowledge on cognitive and metacognitive strategies in second language reading as well as in L2 reading of scientific texts. This study confirms and also challenges earlier assumptions on strategy use among proficient and less proficient ESL learners. For example, lower cognitive strategies were regarded 'poor' or 'unsuccessful' strategies utilized by less proficient readers (Block, 1986; 1992; Carrell, 1989; Clarke, 1980; Davis & Bistodeau, 1993; Horiba, 1990; Hosenfeld, 1977; Koda, 2005). Yet, it was found in this study that lower cognitive strategies were pre requisites for higher cognitive processing in less proficient readers and utilized by both proficient and less proficient readers when syntactic difficulty of the reading text increases. Another example was regarding the claim by previous reading researchers that a high usage of metacognitive strategies improves L2 reading comprehension (Brown & Baker, 1984; Block, 1992; Carrell, 1998; Koda, 2005; Smith & Dauer, 1984; Yang, 2002). Contrary to previous assumptions but consistent to Sternberg's (1998) claim on MC strategies, this study found that too much monitoring and deliberation leads to less reading comprehension.

Second, this study also investigated the role and contribution of metacognitive awareness, scientific prior knowledge, and L2 proficiency on strategy use as well as on reading comprehension of scientific texts. The findings of the study successfully provide evidence for the compensatory use of LC and HC strategies in L2 readers with different levels of L2 proficiency and scientific prior knowledge. In addition, this is so far the only study that examined the contribution of prior knowledge among respondents from the same discipline that was biology. It extends previous findings on prior knowledge and reading (Carrell, 1984; Johnson, 1981; Ozuru et al, 2009; Pritchard, 1990) in that L2 readers tended to access their prior knowledge more while reading a text which they had little knowledge of and accessed them less when reading a very familiar text.

The data in this study also successfully provides yet another empirical evidence of the significant but not absolute role of L2 proficiency in reading comprehension of domain specific texts. However, it is noteworthy to mention that the low predictive validity of metacognitive awareness inventory (MAI) on L2 reading of scientific texts signals the need to develop a more robust instrument to measure metacognitive awareness of science L2 learners in future studies. Finally, the findings also indicate that the significant roles of all independent variables in the theoretical framework of this study may have a high predictive validity in identifying independent or self-regulated L2 readers of scientific texts.

7.4.2 Pedagogical implications

The aim of the study was to discover cognitive and metacognitive strategies utilized by first year ESL undergraduates while reading two scientific texts. Even though there was no instructional intervention involved in this study, some general pedagogical implications can be drawn from the findings.

First, the findings from the qualitative portion of this study suggest that the most prominent obstacle facing less proficient ESL undergraduates is general English proficiency, which includes general vocabulary and syntax. Thus, the implication is that English classes in Malaysia at primary and secondary levels of education must step up in their effort to develop students' general English proficiency through efficient reading programme. Carefully designed and highly supervised extensive reading programme (Bernhardt, 2000; Krashen; 1989; 2004; Lee, 2004; Mason & Krashen, 1997; Schmidt, 2007) at primary and secondary school levels is a launch pad for the development of general English language proficiency. In addition, there is an urgent need for academic preparatory programmes (Carrell & Carson, 1997, p. 48; Li and Munby, 1997) at secondary and post secondary levels that focus on developing L2 academic literacy skills for tertiary level reading and learning.

Second, from the qualitative interview protocols too it was found that some lecturers in first year undergraduate courses provided their students with their lecture notes and even power point slides to help their students to understand the lecture materials (Saragunan & Nambiar, 1994). While this gesture is commendable as the intent was to assist ESL students in their first year of tertiary education, it may not be a good decision after all for long term outcomes. Thus, to mold these science students into independent and self regulated readers for lifelong learning (Desjardins, 2003; Cornford, 2002; Koch, 2001; Vanderstoep, Pintrich & Fagerlin, 1996), they need to be given efficient reading tools such as reading strategies and ample independent reading practice. Successful attempts at independent reading practice would not only motivate them further but also improve their self-esteem and self-efficacy which would in turn boost their performance level.

Third, the findings imply that the use of efficient strategies while reading scientific texts help L2 learners to comprehend the text better than the high proficiency L2 learners. Such strategies include MC strategies of monitoring and debugging, HC strategies of summarizing, analyzing visual diagrams, visualizing, and accessing prior knowledge, and LC strategies of taking notes, and reading for local understanding. HC strategy of visualizing s includes drawing concept maps and mental visualizing while LC strategy of reading for local understanding incorporates rereading and reading for details. In addition, the crucial and explicit use of scientific versus general prior knowledge as a top down strategy while reading scientific texts must be elucidated to L2 learners so that this strategy can be used efficiently. However, it is important to note that teaching L2 readers to utilize only the above mentioned strategies in a repeated and rigid manner is delimiting the potential value of other strategies like planning, inferring language, and questioning content. Hence, it is crucial to impart to ESL learners that it is not enough to know which strategy to use but they must also know how to use all the available strategies successfully (Anderson, 1991, p. 19).

Fourth, it is a good idea to inform less proficient L2 learners that it is not wrong to utilize strategies such as translating and decoding to unpack difficult sentences. However, this practice is to be carried out on the condition that these LC strategies are complemented with high level strategies like summarizing and/or visualizing to get the whole understanding of the scientific concept infused in those difficult sentences. The findings of this study also suggest that HC strategy of reading for global understanding which includes skipping unknown words and getting the overall meaning of the text to be used minimally when reading scientific texts.

Fifth, reading is the most needed skill in the pursuit of higher academic studies (Flowerdew & Peacock, 2001) in specific domain area. Thus, a reading strategy training programme is strongly recommended to all college-bound L2 learners in Malaysia. Such programme should pay particular attention to the specific academic discipline endeavour of the students. The programme would emphasize on three most important elements of successful L2 reading. First, students should be allowed to discover their own reading strategies (Auerbach and Paxton, 1977). This first step would bring in the metacognitive awareness into the reading class. Second, the training should emphasize to teach students when, how and why they should apply the strategies that they already know and strategies which are found to be efficient in their specific domain area, such as biology. This would be beneficial in assisting students to evaluate the strengths and weaknesses (Carrell, 1998) of their own strategies and the strategies suggested in the training programme. Third, to become independent and self regulated L2 readers, the training must accentuate the importance of the compensatory use of all the reader's variables (awareness, language proficiency, prior knowledge, and strategic reading) while reading academic texts on their own.

Finally, the qualitative respondents using think aloud technique while reading the scientific texts indicated their reservation as well as interest in this method of reading. While some felt that their thinking processes were slowed down by having to report aloud, others admitted feeling at ease with the technique. Reading out loud and speaking their minds while reading may prove to be an efficient reading tool which ought to be taught to L2 learners. This is because teaching L2 learners to think aloud while reading could contribute to their awareness of their own reading ability and strategy choices. Having learnt the technique, the choice of adopting it into their every day academic reading routine would be left entirely for the L2 learners themselves to make. If nothing else, this technique would provide the L2 learners with an alternative route from reading on 'automatic pilot' (Carrell, 1998; p. 8) to reading by the 'ear' to detect inconsistencies in understanding or confusions.

7.5 Limitations, suggestions, and conclusion

7.5.1 Limitations of the study

There were a few limitations in this study that were present in both quantitative survey as well as qualitative techniques.

The first limitation concerns the mental fatigue which many respondents might have experienced during the quantitative survey. To examine the various variables that were pertinent in L2 reading strategy research and reading of scientific texts, eleven instruments had to be administered to each respondent. The Vetting Committee advised that the study to be conducted on two different days to avoid mental fatigue among the respondents. However, as the research progressed, it was extremely difficult, if not impossible, to get the same respondents to sit for the study on the second day. This resulted in incomplete data for the first badge of 30 respondents which had to be discarded. In addition, the administrators of two public universities requested that the study be conducted only once in order not to interfere with the science students' already very packed class schedule and long laboratory hours.

Second, to conduct a quantitative study among university students was extremely difficult, unlike captive audience like those in schools. Undergraduates may not want to waste their time on study such as this since there will be no gain in store for them (Tan, 1994). Therefore, to prevent setback during data collection and problems with incomplete information and fractional data for analysis, a common practice in many research done on in depth study such as this is to engage paid volunteers amongst the students (Crain-Thorenson, Lippman, & McClendon-Magnuson, 1997; Rupp, Ferne, & Choi, 2006; Davis & Bistodeau, 1993). The nominal token of appreciation which was RM10 (Malaysian currency) had motivated the respondents to be more committed and cooperative during the data collection procedures.

Third, the sample size for the case studies or qualitative study was only five people and was considered small with only one Chinese respondent and none from the Indian ethnic group. In addition, there was no respondent who could be considered highly proficient in English or obtained MUET band 5. Having highly proficient

English respondent might have provided more insights from think aloud techniques and retrospective interview on the types of strategies s/he would utilize and the reasons and conditions for his/her choices. However, this situation could not be avoided since five students from the ten pre determined respondents for this qualitative study pulled out one at the time as the study progressed. Most students gave tight laboratory schedule and preparing for assignments as the excuses for not wanting to participate in the study.

7.5.2 Suggestions for future research

Based on the results of this study, three suggestions for future research are put forward. First, research that employs qualitative research design is required to explore more deeply on how ESL undergraduates read scientific texts. Future researchers may want to get a bigger sample of respondents which would present more learner variability. A bigger sample size also would enable the researcher to use more advanced statistical tests for a qualitative study. It would also be feasible if the qualitative respondents could be selected from various universities. In this way, the findings could be generalized to the larger population of the ESL science readers.

Second, research on L2 reading is also needed in other science fields such as Physics and Chemistry. There is an urgent need to understand how L2 readers negotiate scientific texts at tertiary and advanced levels. Findings of such studies would inform strategy training team to design a domain-specific training module that is custom made for cohorts of each field. In addition, such studies would also inform curriculum designers for a more effective ESP course.

Third, it is also recommended that future research investigate and compare how L2 learners read scientific texts from science textbook and science journal. The strategies employed by L2 learners in negotiating the language and rhetorical structures of both science textbook and journal articles would inform ESP curriculum designers in preparing L2 learners for a more advanced reading endeavour at the university as well as for life long learning.

7.6 Chapter Summary

The purpose of this study was to investigate the cognitive and metacognitive strategies used by ESL undergraduates while reading two scientific texts and how these strategies contributed to their reading comprehension. In addition to that, the study examined the contributions of metacognitive awareness, scientific prior knowledge and L2 proficiency on strategy use and reading comprehension. The findings reveal that in general, there are some differences in the types of strategies used by L2 learners in reading scientific from non-scientific texts. Both proficient and less proficient L2 learners tend to utilize more lower cognitive strategies or try to *hold in the bottom* when reading a more difficult text before higher cognitive strategies are employed. L2 proficiency is a significant but not the ultimate predictor of successful reading comprehension of scientific texts. The roles played by scientific prior knowledge and HC strategies are as crucial as the one played by L2 linguistic knowledge. The findings have theoretical significance as well as pedagogical implications which successfully extend the current research on L2 reading in science education and help inform for a better ESP curriculum design.