Co- and self-regulation in a computer supported collaborative learning environment among Key Stage Three students

Thesis

Co- and Self-Regulation in a Computer Supported Collaborative Learning Environment among Key Stage 3 Students

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Abstract

The current understanding of students' co- and self-regulated learning behaviours during group learning is limited. Research on social cognitive models of self-regulated learning (SRL) focused primarily on understanding the processes that students use to self-regulate their learning and the subsequent benefits of SRL on learning and academic performance. Recently, sociocultural models have begun to argue that SRL is fostered, developed, and maintained within social contexts and as a result of interactions with teachers and peers. This research employs both social cognitive and sociocultural theories to investigate students' co- regulatory behaviours in a computer supported collaborative learning (CSCL) environment. The students worked in a computer based science simulation learning environment in which either self-regulatory prompts or co- and self- regulatory prompts were given. A longitudinal design methodology incorporating four studies was adopted.

The first study engaged two hundred and fourteen year 7 and 8 (11-13 year olds) students to pilot the developed co-regulated strategies for learning questionnaire (CRSLQ) in a high school at Bedfordshire County in the United Kingdom. The remaining three studies engaged forty year 7 students (11-12 year olds) from the same school who were randomly assigned to either the experimental or the control group to work collaboratively on various science topics. Both quantitative and qualitative data analyses were used to examine the strategies that students used to co- regulate their learning processes over time. Results from the quantitative analysis revealed a statistically significant difference between the experimental and the control groups in the students' demonstration of co-regulated learning (CRL) behaviours over time. However, the results from the knowledge tests, although they suggested that learning had taken place, did not reach statistical significance. Findings from the qualitative analysis suggested between group and within group differences in the nature of co-regulatory processes that groups used to co-regulate their learning behaviour over the course of the three studies.

Theoretically, this research extends individual models of SRL to include social forms of regulation arguing that students acquire, refine, and use different forms of regulatory processes to regulate their learning behaviours during collaborative learning. Finally, given the emphasis on SRL throughout the national curriculum this research supports the use of collaborative tasks in a technology-rich learning environment as an instructional method to increase students' regulatory processes. Some recommendations for future work are then made.

Dedication

This thesis is dedicated to:

- My Lord and Saviour, Jesus Christ. I would not have done this without His grace, mercy, courage and strength.

- My lovely parents, (Deacon and Mrs J.A Oyebanji), for being my lifelong prayer warriors!

- My dear and special angels, my children, Olaifekristi and Ayoifekrist who have been a very strong source of inspiration and have given me the will to grow stronger each day of my life.

- My unconditionally loving husband, Eyitayo, who believed in me and encouraged me with love and support... I love you so much!!!

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My parents Deacon and Mrs Oyebanji and my siblings (Mr and Mrs Oluwafemi Oyebanji, Mr and Mrs Ade Familusi, Eng Kayode Oyebanji and Mr and Mrs Kolapo Adigun) who have supported and encouraged me by whatever means necessary throughout the three years. Thanks very much for your moral and spiritual encouragement. May God bless you all tremendously. To my in-laws, the Olakanmis, thanks for your prayers and may the good Lord bless you all.

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Last but not least, to God be the glory, honour and majesty. He is the Great I am, provider and creator of all living things. Nothing is too difficult for Him. He has provided me with physical, mental, emotional, social and spiritual needs during these three challenging years while pursuing my doctoral degree. He has also given me the assurance through His Word, 'With God all things are possible' (Mark 9:23). I give praise and glory to Him for all my accomplishments. Thank You

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List of Abbreviations

A	The number of agreements between two coders
BERA	British Educational Research Association
CRL	Co-Regulated Learning
CRSLQ	Co-Regulated Strategies Learning Questionnaire
CSCL	Computer Supported Collaborative Learning
D	The number of disagreements between two coders
HPMEC	Human Participants and Materials Ethics Committee
n_1 *and* n_2	The numbers of units coded by coders 1 and 2 respectively.
PA_O	Proportion of agreement observed
PA_E	Proportion agreement expected by chance.
SRL	Self-Regulated Learning
SRSLQ	Self-Regulated Strategies Learning Questionnaire
κ	Cohen's Kappa

CHAPTER ONE: Background to the Study

1.1: Introduction

This thesis examines co- and self-regulated learning strategies that students use when working collaboratively in a technology-rich science classroom. Specifically, a computer supported collaborative learning (CSCL) environment which involves computer based science simulations to support collaborative learning of various science topics was employed to investigate co- and self-regulated learning processes that students demonstrated during science learning.

Self-regulated learning (SRL) is an active and constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behaviour as well as the contextual features of the learning environment (Pintrich, 2000). Over the last twenty years, self-regulated learning (SRL) researchers have focused primarily on understanding the processes learners use to self-regulate and the subsequent benefits that self-regulated learning has on learning and performance (Boekaerts & Niemivirta, 2000; Zimmerman, 2000: Corno & Mandinach, 2004; Wolters *et al.,* 2005). Research has also shown that students may fail to use self-regulatory behaviours for many reasons: for example, students may not have prior knowledge or know when to apply certain regulatory strategies during learning processes in order to meet their set goals. Students may also not engage in planning their learning through goal setting as well as monitoring their progress toward the set goals within the learning context. Students may not even know when to seek help from a peer or teacher and finally they may not be motivated about their learning tasks (Azevedo *et al.*, 2003; Narciss *et al.*, 2007). The context of the learning situation within the classroom plays an important role in how students self-regulate their learning behaviours, when they use technology-rich learning environments such as a computer supported collaborative learning (CSCL) environment.

The majority of these studies have examined students' self-regulated learning (SRL) processes in isolation from individual students (Lajoie *et al.* 2001), it is therefore critical that researchers and educators understand how students working collaboratively regulate their learning behaviours. It is also important for the teachers to know how they can facilitate students' co-and self-regulated learning processes by using different instructional approaches in technology-rich science classrooms. To that end, the research in this thesis adopts and extends social cognitive and sociocultural models of SRL to investigate co- and self-regulated learning processes during collaborative science learning among Key Stage 3 students learning in a computer supported collaborative learning environment.

This chapter begins by discussing the research background and the rationale for this research. Thereafter, the research aims and objectives as well as the research questions are highlighted. In the last section of this chapter, I have presented the outline of this thesis.

1.2: Background and Rationale for the study

Based on social cognitive theory, self-regulated learners are familiar with various cognitive and metacognitive strategies, and have the ability to plan, monitor, and regulate their learning strategies (Wolters *et al.*, 2003). While the social cognitive literature has certainly added to knowledge of the types of strategies individuals use to self-regulate, these models primarily focus on SRL as an individual activity, with the individual as the regulator of his or her behaviour. Although these models have recognized the influence of the social context through modeling and feedback, they treat interpersonal, social, and/or cultural influences as separate factors and investigate how these factors affect students' SRL. As such, in the social cognitive framework a conceptualisation of the social origins of self-regulation processes is limited (Martin, 2006).

Several researchers (such as Corno & Mandinach, 2004; Järvela & Järvenoja, 2007; Järvelä *et al.*, 2010; Hadwin & Oshige, 2007) have begun to consider self-regulated learning processes at the social level with reference to concepts such as social regulation, shared regulation, and co-regulation. Instead of treating interpersonal, social, and/or cultural influences as separate variables that affect regulatory processes, sociocultural researchers argue that SRL is fostered, developed, and maintained (1) within social contexts and (2) as a result of interactions among teachers and peers. Therefore, the development of self-regulated learning is conceptualised as a social as well as individual process (Järvelä *et al.*, 2010). This approach is critical for understanding productive engagement and participation in real-life social learning environments.

Sociocultural theories of SRL however, offer a new lens with which to examine how students potentially develop and refine SRL strategies and how such theories can be used to improve classroom practice. In a sociocultural approach to SRL, researchers investigate how learners acquire SRL processes by interacting with other students or teachers on a joint task. This process occurs as a more able student/teacher co-regulates other students' cognition, motivation, and behaviour (Hadwin & Oshige, 2007). Co-regulated learning (CRL) involves two or more students or students and teachers engaging in aspects of planning, monitoring, evaluating and reflecting on the learners' cognition, motivation behaviour, and context as they work towards investigating a problem (Volet *et al.,* 2009). In CRL, according to McCaslin (2004), social environments support individual participation and learning. With respect to the present research, CRL entails students working in groups of five, mutually searching for understanding, solutions, or meanings, on the given science tasks. CRL encourages active student participation in the learning process because it is based on the idea that learning is a naturally social act in which the participants talk among themselves and involve one another in the learning process (Smith & MacGregor 1992, Dillenbourg 1999). Therefore, this thesis is based on the assumption that in collaborative learning, individual group members represent interdependent self-regulating agents who at the same time constitute a social entity that creates affordances and constraints for group and individual engagement during collaborative learning using computer based science simulations.

Given this, both social cognitive and sociocultural theories are used to conceptualise regulation in this thesis, in order to understand how co- and self-regulation processes are demonstrated by the students learning science in a CSCL environment. While the literature has placed a different emphasis on the role the social context played in the development of students' regulatory processes, the current research uses both theories to analyse a computer supported collaborative learning environment (CSCL) in which co- and self-regulation were present. However, Chapter two of this thesis differentiates between social cognitive and sociocultural theories and offers a premise for their use in conceptualising the regulation of learning processes.

The need to offer tools that provide a more effective medium for classroom discussion than the traditional classroom setting and that may promote participation and social interaction among students has also resulted in the emergence of the field of computer-supported collaborative learning (CSCL) which deals with issues concerning collaboration, learning processes, and the use of computer-mediated communication (CMC) (Lipponen *et al.*, 2003). In order to promote the emergence of productive interactions and improve the quality of learning, different pedagogical models and technology-based regulation tools have been developed to support collaboration between participants (Mayer & Moreno, 2002; Kimmerle & Cress, 2008; Volet *et al.*, 2009; Gress & Hadwin, 2010). Collaborative technologies offer a range of new ways of supporting learning by enabling learners to share and exchange their learning experiences with one another (Wang & Lin, 2007; Gress & Hadwin, 2010). However, CSCL environments have not always fulfilled expectations as researchers and educational practitioners have failed to provide the support that groups of learners need to succeed (Kreijns *et al.* 2004)·

We may expect to see students develop and use both co- and self-regulated learning processes in collaborative learning context. Despite the large amount of literature on collaborative learning, little research has used this context to examine the development and use of co- and self-regulatory processes simultaneously. Co- and self-regulatory processes in a CSCL environment are indicated by the ability of students to propose, discuss, and negotiate the planning process of the given task; to quote peer contributions, summarise ideas, ask questions, and check understanding; to assess group learning and comment on group achievement; and to discuss and share expectations (Dettori & Persico 2008). While collaborative learning environments may be appropriate environments to examine students' co- and self-regulated learning processes (Järvela & Järvenoja, 2007), collaborative learning techniques are not always appropriate and not all groups are always productive when learning in such an environment (O'Donnell & O'Kelly, 1994, Summers & Volet, 2010). Students face a lot of difficulties such as the inability to regulate their own learning in a variety of learning contexts, including CSCL environments (Kimmerle & Cress, 2008; Volet *et al.,* 2009). It is worth noting that the crucial pre-requisite to successful learning in a CSCL setting is the willingness of the participating learners to share their knowledge and ideas with others (Kimmerle & Cress, 2008). In order to engage in collaborative activities for effective learning in a CSCL situation, it is important that students are able to control their own pace of learning. CSCL is considered a highly learner-centred and co- and self- regulated learning environment where students must take responsibility for what and how to learn due to the nature of the setting (Mayer & Moreno, 2002). High demand for co- and self-regulated learning is required in technology learning environments (Mayer & Moreno, 2002) and learners are required to independently manage their own learning in accordance with their goals.

Furthermore, in order to encourage active collaboration among students, research has shown that it is necessary to impose external structures including individual accountability and positive interdependence. These structures ensure that each student knows that he or she is responsible for his/her own learning within a group and that he or she is also responsible for the learning of others (Abrami, 2010). Therefore, the ability to combine computer support and collaborative learning in order to successfully enhance the learning of scientific concepts remains a challenge which CSCL environments are designed to address. Consistent with the position of Kozma *et al.* (2000), students encounter difficulties in gaining in-depth understanding of the complexity of scientific concepts in a CSCL environment because they face the challenge of employing multiple representations such as text, diagrams, and animations to attain a fundamental understanding and use the representations to make inferences during the learning process. Therefore, this requires that science educators employ CSCL environments as tools for enhancing students' understandings of scientific concepts in order to solve real-world problems (Chi *et al.*, 1994; Chi, 2000; and Azevedo *et al.*, 2001). Since the students' competence in CRL and SRL is paramount to their academic pursuit, it is therefore imperative that attempts are made to enable individual students improve on his or her CRL and SRL competence in CSCL environments through active participation while learning science. In this present research, the CSCL environment consisted of computer based science simulations and a means of communication either face to face in group or using an online tool called *InterLoc.* This is a communication tool which consists of either CRL and SRL or SRL-only instructions to guide the students when working on various science topics. It enabled the students to collaborate with one another by expressing their ideas via typing on the computer screen. The science simulations consisted of texts, animation, and diagrams to promote the understanding of scientific concepts.

This present research aims to address some of the difficulties that students face when learning in these environments by introducing co- and self-regulated learning (CRL and SRL) prompts into a CSCL environment with a view to assisting science learners to improve their social learning processes by involving active knowledge construction over a period of time. This research is designed to explore the possibility of whether collaborative learning can be enriched by providing technological tools (a combination of the *InterLoc* tool and a science simulation) with some prompts to help students regulate their learning in order that they may better manage and evaluate their learning processes in CSCL. *Interloc* was adapted for use in this research because it enabled a synchronous discussion during the lesson. The longer term aim is to enhance the process of collaboration and to integrate individual and group-level perspectives of learning.

As such, drawing on the available literature, this research is designed so that participants worked collaboratively in groups of five on three science tasks. The choice of these science tasks was largely based on my teaching experience across the UK and Nigeria through which I discovered that students encountered problems in understanding the concepts underlying these tasks. Learning to co- and self-regulate their learning processes is important for the participants in this research (11–12 year old high-school students, also known as Key Stage 3 students in the UK) for several reasons. First of all, it is the stage where strong foundations are laid for acquiring sound scientific knowledge and the development of inquiry skills and independent critical thinking in preparation for their General Certificate of Secondary Education (GCSE) exams. Students need to be very active during their learning processes and to adjust to the new technologies that are used in the classroom. Students can also benefit from improving their self-efficacy, which is an important component of SRL (Moos & Azevedo, 2008). The science tasks used in this research were based on the science curriculum, and therefore were assumed to be relevant to the development of the skills in scientific inquiry which students are expected to cultivate at this stage of their learning process. Given that the tasks were authentic, complex, and enabled collaborative participation, co- and self-regulatory processes were expected to develop as students learned science over the course of time during the research.

Co- and self-regulated learning strategies are internal processes and consequently researchers must draw inferences about cognitive operations that they cannot directly observe (Webb, Nemer, Chizhik, & Sugrue, 1995). As a result, researchers have primarily relied on questionnaires (self-report measures) as measures of students' regulatory processes. Although questionnaire data have added significant knowledge about students' perceptions of their CRL and SRL to the literature, a complete reliance on questionnaire data raises validity issues as to the extent to which students' perceptions reflect their actual performance (Perry & Winne, 2006). For example, Winne & Jamieson-Noel (2002) found a low calibration between students' trace measures (objective behavioural measures) of SRL and their self-reported regulatory processes. Because questionnaire measures can be considered one indication of students' self-monitoring skills, more research is needed to differentiate the relationship between students' actual and self-reported SRL (Zimmerman, 2008). This present research included qualitative analyses of group interactions with quantitative measures of students' CRL reports to triangulate data about their co-regulation processes.

After reviewing the available literature, the development of instruments to measure co-regulated learning emerges as an urgent task if a meaningful contribution is to be made to the development of a greater understanding of CRL behaviours among young science learners. In other words, the lack of an instrument limits the development of more empirical research on this important topic, and would explain why so little is known about CRL behaviours among students, even though research on self-regulation has been carried out for many decades. As a result a co-regulated strategy for learning questionnaire (CRSLQ) was developed and tested in this study using Key Stage 3 students. Finally, while sample sizes in the qualitative analysis were relatively small to make any reliable generalizations, it is hoped that the research findings will encourage further investigation into the consistency between the use of questionnaires and observed CRL.

1.3: Aims and Objective of the Study

The objectives of this study are as follows:

1. To develop the Co-regulated Strategies for Learning Questionnaire (CRSLQ) fit for the purpose of this research.
2. To determine the effect of a CSCL environment incorporated with CRL and SRL prompts on students' CRL strategies.
3. To determine the effect CSCL environment incorporated with CRL and SRL prompts on the students' academic performance in a real-world classroom setting.
4. To determine the effect of a CSCL environment incorporated with CRL and SRL prompts on students' CRL strategies over time.
5. To determine the nature of co-regulated learning behaviours that students use when they learn science collaboratively in a CSCL environment incorporated with either CRL and SRL prompts or SRL-prompts only?

1.4: Research Questions

In order to achieve the aims of the research, there are four research questions guiding the research. They are as follows:

1. *Is the Co-regulated Strategies for Learning Questionnaire (CRSLQ) developed as part of this research fit for purpose of measuring the CRL behaviours of Key Stage 3 science students?*

The first research question aims to investigate the validity and the reliability of the Co-regulated Strategies for Learning Questionnaire (CRSLQ). The development of the instrument was based on models of the SRL theoretical framework (Zimmerman, 1989a, 2000). The instrument is expected to capture the complexity of the topic, be able to distinguish different dimensions of co-regulated learning, to emphasise the behaviours that are carried out by students as they learn science collaboratively in their groups as well as having good psychometric properties. The second research question was:

2. *a). Does the computer based science simulation learning environment with both co- and self-regulated learning prompts support Key Stage 3 students to regulate their learning behaviour more effectively than using self-regulated learning prompts only?*

   b). Does the computer based science simulation learning environment with both co- and self-regulated learning prompts result in a greater improvement in Key Stage 3 students' academic performance when learning scientific concepts than when using self-regulated learning prompts only?

This second research question investigates the effect of a CSCL environment with CRL and SRL prompts on students' co-regulatory behaviours as measured by the CRSLQ. Previous studies revealed that students with well-developed learning strategies have the tendency to develop interest in group activities. Therefore it is hypothesised that a CSCL environment with co- and self-regulated learning prompts would be associated with a statistically significant level of CRL behaviours as compared to a computer collaborative learning environment with SRL prompts only. This present research also considered it necessary to investigate co-regulated learning behaviour over time in order to determine if continuous exposure of students to a CSCL environment incorporated with CRL and SRL prompts would lead to continuous improvement in their usage of CRL behaviours. Therefore the third research question was:

3. *Does the incorporation of CRL and SRL prompts into a computer based science simulation learning environment improve co-regulated learning behaviours of Key Stage 3 students over time (from Studies 2, 3 and 4)?*

This research question investigates further if there will be enhanced improvement in the students' co-and self-regulation overtime when prompted with CRL and SRL during science learning in a CSCL environment. This research question is addressed in Chapter six (comprising studies 2, 3 and 4) and was answered by analysing the result of the Co-regulated Strategies for Learning Questionnaire (CRSLQ) and the Self-Regulated Strategies for Learning Questionnaire (SRSLQ) administered to students over studies 2, 3 and 4.

The last research question investigates the nature of co-regulatory behaviours demonstrated by students learning science in a CSCL environment. The question was:

4. *What co-regulated learning behaviours do Key Stage 3 students use when they learn science collaboratively in a computer based science simulation learning environment incorporated with either CRL and SRL prompts or SRL-prompts only?*

This research question used qualitative data to examine the students' attempts to co- and self-regulate over the Studies that took place in the classroom. The present research extended previous studies that collected qualitative data rather than self-reports (Dweck & Leggett, 1988; Pintrich, 2000) by examining co- and self-regulatory processes over a relatively long time period in which students worked on various science tasks.

1.5: Thesis Outline

This thesis consists of eight chapters. The first chapter presents the background and rationale for the research. The research aims and objectives as well as the questions that the research is set out to answer are presented in the same chapter. Chapter Two discusses the relevant literature and theoretical background for this study. This includes a discussion of social cognitive theories and sociocultural theories and a proposed integrated approach as the theoretical basis of this research. Also in Chapter Two, the research on co- and self-regulated learning strategies, and the role of computer-supported learning environments in promoting co- and self-regulated learning in the teaching and learning of science were reviewed.

Chapter Three gives a description of the research methodology. This includes the rationale for the choice of methodology, instruments used for data collection and explain the research design implemented. Ethical issues for the participants are also discussed here. Chapter Four presents the procedure for the development and validation of CRSLQ as well as the outcome of its validation. Chapter Five describes the effect of a computer supported collaborative learning (CSCL) environment with co- and self-regulated learning (CRL and SRL) prompts on students' co- and self-regulated learning behaviours and academic performance as compared to a CSCL environment with SRL prompts only, while the Sixth chapter considers these effects over a period of three term time (Spring, Summer, and Winter terms of 2010).

Chapter Seven highlights the contrasts and the similarities in the demonstration of CRL behaviours by students working in a CSCL environment with co- and self-regulated learning (CRL and SRL) prompts in comparison to a CSCL environment with SRL prompts only over time, and the factors that promoted the co-regulatory behaviours demonstrated by the experimental and the control groups. Chapter Eight presents the conclusions and implications of this research as well as recommendations for further studies.

CHAPTER TWO: Literature review

2.1: Introduction

This chapter reviews research into self-regulated learning (SRL), co-regulated learning (CRL) and collaborative learning in a computer supported collaborative learning environment (CSCL). It locates the research described in this thesis in the context of the previous studies, gaps in the literature are identified and theoretical frameworks for the data analysis are also reviewed.

Self-regulation refers to individuals' capacity to be cognitively, motivationally, and behaviourally active participants in their own learning behaviours (Zimmerman, 1989a). Traditionally, researchers have examined self-regulated learning (SRL) processes from a social cognitive perspective emphasising the active role individuals assume in regulating their own cognition, motivation, and behaviour (Zimmerman, 1989b; Boekaerts *et al.*, 2000). This research has focused on how individual characteristics of the learner affect SRL processes, and how learners use various strategies to regulate their cognition, motivation, and behaviour. Self-regulated learning (SRL) models recognise the influence of the social context through modeling and feedback, accounting for interpersonal, social, and/or cultural influences as separate factors that possibly affect students' SRL (Martin, 2006). Socio-cultural theories argue that SRL is fostered, developed, and maintained within social contexts and as a result of interactions with teachers and peers (McCaslin & Hickey, 2001; Schunk, 2001). Originally based on Vygotsky's work (1978), socio-cultural theories investigate SRL by examining how individuals learn and refine SRL strategies by working with an individual with high SRL on shared tasks through the process of co-regulation. Expanding socio-cultural theories to a collaborative group context, co-regulation can take on many forms including (1) a single more capable group member co-regulating others in the group (2) each group member taking on the role of regulating others in the group depending on the strengths of that particular learner, or (3) several group members sharing together in regulating the groups' activities.

Social cognitive and socio-cultural theories seem appropriate for this present research as the key elements under investigation are how students develop, use, and refine their co- and self-regulatory processes within a collaborative learning context that is supported by technology: that is, a computer supported collaborative learning (CSCL) environment. The aim of this literature review is to discuss social cognitive and socio-cultural theories of SRL and then offer a combined approach to investigating co-and self-regulatory processes in a CSCL environment as the theoretical basis of this research. Subsequent sections in this chapter will review co- and self-regulated learning in a CSCL as well as the benefits of adopting CRL and SRL prompts in a CSCL environment. Finally, a detailed discussion of measurement of co- and self-regulation will conclude the literature review.

2.2: Social Cognitive Models of Self-Regulation Processes

2.2.1: Zimmerman's Model of SRL

Figure 2.1 depicts Zimmerman's (1989a) model in which SRL sub-processes of forethought, performance control, and self-reflection associated with regulating cognitive processes involved in learning interact reciprocally to constitute SRL. The forethought phase describes the planning processes that learners employ to engage in goal setting and modelling and it occurs prior to the time a learner takes any action toward achieving his or her goals. Zimmerman (2002) pointed out that the forethought phase involves a number of motives to self-regulate such as self-efficacy beliefs, outcome expectations, task interest or value, and goal orientation as well as two key self-regulatory processes: goal setting and strategic planning. Moreover, the performance control phase involves processes such as the use of social comparisons, feedback, or various learning strategies that learners initiate during learning and which affect attention and action toward meeting his or her goals. During self-reflection, learners evaluate his or her goal progress and strategies.

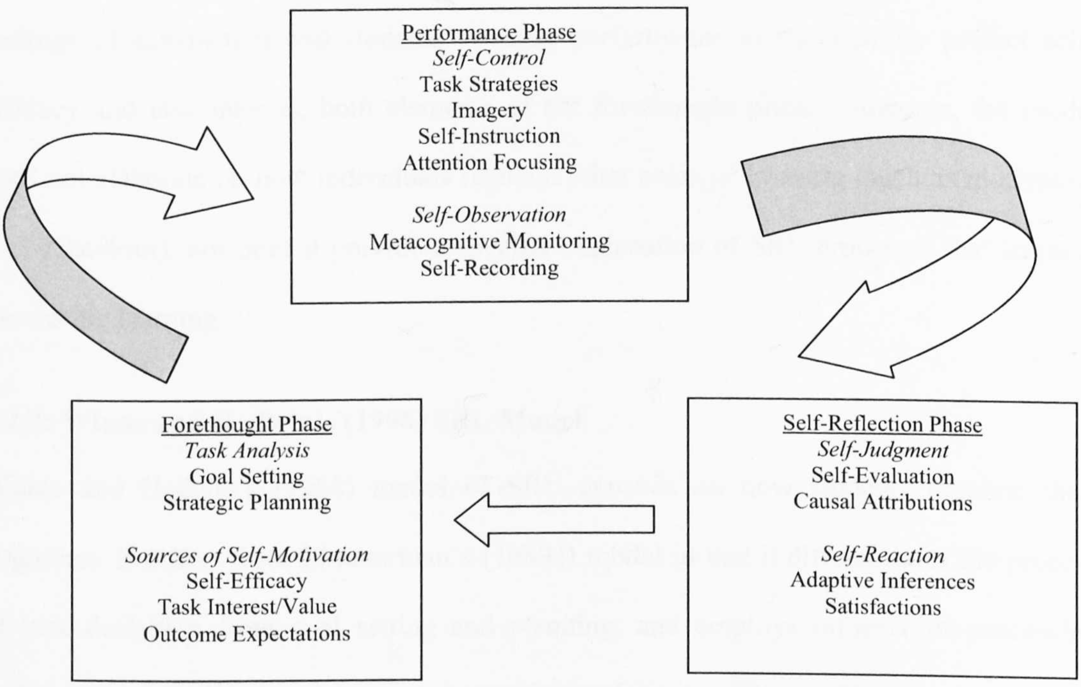


Figure 2.1: Zimmerman's (1989a) Model of Self-Regulation Processes: A cyclical model of self-regulated learning.

Moreover, Zimmerman's (1989a) model elucidates how learner's motivational orientations are engaged in promoting SRL strategies by acknowledging their influence on the cognitive SRL processes. According to Zimmerman (2002), learners with high self-efficacy orientations set more challenging and realistic goals, and are better at monitoring their strategy use. These sub-processes of SRL are reciprocally related, in that forethought processes affect performance, self-recording control processes, which in turn affect self-reflection processes, which in turn affect forethought and performance control processes. Some studies which have affirmed this model are presented in the next paragraph.

SRL researchers have found a positive relationship between, on the one hand, outcome attributions and self-reported outcomes in the performance phase and, on the other hand, feelings of satisfaction and outcome attributions in the self-reflection phase. For example, Zimmerman and Bandura (1994) found a positive relationship between students' self-efficacy perceptions and students' final grades, while Zimmerman (2008) also established a positive relationship between students' self-efficacy and the performance goals students set for themselves. Zimmerman and Kitsantas (1999) employed students' self-reflection feelings of satisfaction and students' writing performance to successfully predict self-efficacy and task interest, both elements of the forethought phase. However, the model does not elaborate on how individuals regulate other areas of learning (such as motivation and behaviour), nor does it provide a specific explanation of SRL processes that learners use during learning.

2.2.2: Winne and Hadwin's (1998) SRL Model

Winne and Hadwin's (1998) model of SRL expands on how students regulate their cognition. It differs from Zimmerman's (1989a) model in that it differentiates the process of task definition from goal setting and planning, and employs information-processing techniques to explain regulatory processes during learning. Winne (2001) suggested that learners engage in SRL processes of planning, monitoring, control, and evaluating to regulate their interactions on individual basis via conditions, operations, products, evaluations, and standards as they define the tasks, establish goals and plans, utilise study tactics, and engage in metacognitive adaptation. These roles are elucidated below.

2.2.2.1: Conditions

These include learners' cognitive and motivational attributes (e.g. high self-efficacy, positive attributions) which are used for learning purposes and the task conditions that promote or hinder learning. According to Winne (2001), cognitive conditions (which include beliefs and dispositions, motivational factors and orientation, domain-specific knowledge, knowledge of task, and knowledge of study tactics and strategies) are characteristics inherent to the learner or acquired from prior experiences. Winne and Hadwin's (1998) model proposed that conditions affect operations and products directly and have an indirect influence on monitoring and control processes via the learner's standards. Greene and Azevedo (2007) reported that the longer the time a learner spent on defining the task (phase I) and establishing goals and plans (phase II), the better the results in matching the students' standard (i.e. expected) performance and actual performance.

Furthermore, the learner's beliefs and dispositions regarding his or her own knowledge also affect standards (Winne, 2001) as illustrated by Greene and Azevedo (2007) who noted that learners possessing more mastery-oriented beliefs tend to create goals because effort leads to successful performance. For instance, if students believe effort relates to performance, they should be more inclined to persist when strategies fail in phase III (i.e. utilizing study tactics). Beliefs can also affect metacognitive adaptation in phase IV (Winne, 2001) such that if students possess an entity view of intelligence (i.e. have the right conceptual understanding) (Dweck, 2000), they may be less likely to modify beliefs when they do not gain correct conceptual understanding.

Moreover, Winne (2001) reported a high correlation between the degree of students' self-efficacy, goal selection and decisions to participate as well as persistence in tasks. For example, during phase IV, Winne (2001) noted that learners modify their self-efficacy beliefs as they evaluate their standard and actual performance, as exemplified by an instance in which unsuccessful performance impacts more strongly on the learners' efficacy beliefs when they begin with high expectations than when their performance expectations are initially low.

Task conditions are characteristics of the external environment which include resources, instructional cues, time, and the social context. Winne and Hadwin's (1998), for example can be used to explain relationship between time and regulation in the following way: a context in which a learner chooses to study only easy information after phase I (i.e., task definition) is a consequence of the learner perceiving the cognitive and task conditions being unfavourable, whereas the same action performed after phase III (i.e., applying learning strategies) may indicate the use of a strategy to make the most efficient use of time (Greene & Azevedo, 2007).

2.2.2.2: Standards

Standards entail the learner's perceptions of how each stage should optimally end (Winne, 2001). According to Winne (2001), learners develop standards based on what information is needed for learning as well as their beliefs about studying. Standards are translated into goals which become the determinant factor which measures when a learner is successful or not. Winne and Hadwin (1998) used a bar graph to demonstrate how a student actively determines criteria for "success" in terms of each aspect of the learning task, with each bar representing a different standard with varying qualities or degrees. The overall profile of these phase I standards makes up the person's goal. These standards or goals are used to determine the success of any operations the person might perform within each phase.

2.2.2.3: Operations

These are cognitive information-processing functions, such as less sophisticated memory processing and retrieval processes, and the use of more complex strategies, which occur during learning processes. Moreover, Winne (2001) pointed out that memory processes include searching memory, monitoring how new information compares with prior knowledge, assimilating knowledge, rehearsing information in order to remember it, and changing knowledge learned in one form (e.g., verbal) to another (e.g., pictorial). These processes are cognitive in nature, not metacognitive. Therefore, they result only in cognitive products, or information for each phase. For example, the product of phase I is the definition of a task, whereas the product of phase III might be the ability to remember a specific piece of information for a test. These products are then compared with the standards by way of monitoring the learning processes. #

2.2.2.4: Monitoring

In cognitive monitoring, learners compare products with standards to establish whether their goals are met. Greene and Azevedo (2007) reported that when learners are unhappy with the relationship between the standards set and the performance attained, they tend to exercise control over learning operations to modify products, revise conditions, or give up. Monitoring also occurs at the metacognitive level as learners monitor SRL processes. For example, learners may employ information about a particular learning task to create standards in phase II which are then compared to performance in phase III in order to establish appropriate strategies for problem-solving. Moreover, if during phase III, individuals realise that task difficulty is not as anticipated (i.e., metacognitive monitoring), they may initiate a metacognitive control strategy to modify standards in phase II. Therefore, following Greene and Azevedo (2007), monitoring the relationship between performance and standards can lead to modifications to previous phases in the model.

In summary, SRL process cycles, which may differ depending on learners' attributes or tasks, begin with a clear definition of the task, followed by the production of goals and plans to accomplish them. Depending on the results achieved in phases I and II, learners create learning strategies and products. SRL processes occur throughout the learning process as learners compare standards with products, beliefs, efficacy, and time constraints. In a situation learners notice differences, they react immediately by modifying task and/or cognitive conditions. Moreover, when the differences persist over the long term, learners form more permanent changes to their conditions and strategies. Although, learners' memory capacity may limit the effectiveness of these processes (Paas & Kester, 2006), as automaticity develops learners are able to perform multiple steps of a strategy in one memory unit (Logan, 1988). Therefore, as Greene and Azevedo (2007) pointed out, Winne and Hadwin's (1998) model elaborates on the SRL strategies involved in cognitive functioning monitoring in addition to exemplifying the recursive nature of SRL processes guided by effective and control activities. Because learners regulate areas other than their cognition, it is important to examine Pintrich's (2000) model of processes and areas of SRL that account for how learners regulate their motivation and behaviour in the next section.

2.2.3: Pintrich's (2000) Model of Processes and Areas of SRL

Pintrich's (2000) model modifies both Zimmerman (1989a) and Winne and Hadwin's (1998) models by dividing Zimmerman's (1989a, 2000) performance phase into monitoring and control processes and by discussing strategies that individuals use to regulate other areas of learning including motivation, behaviour, and aspects of the context.

SRL processes in Pintrich's model include planning, activation of previous knowledge, monitoring, control, and reflection. Planning entails strategies employed by learners to organise and prepare for the attainment of the goals set on the given task. Self-monitoring activities refer to learners' strategies which are used to evaluate their performance with their learning goals. Pintrich (2000) pointed out that in response to information gathered during the self-monitoring phase, learners initiate control related activities. Pintrich (2000) also reiterated the operational difficulty encountered in distinguishing between monitoring activities and control activities because the activities associated with these processes are quite similar.

Table 2.1: Pintrich's (2000) Model of Self-Regulation Processes

Phases	Areas for Self-Regulation			
	Cognition	Motivation	Behaviour	Context
Phase I: Forethought, Planning, and Activation	-Target goal setting -Prior content knowledge activation -Metacognitive knowledge activation	-Goal orientation adoption -Efficacy judgments -Perceptions of task difficulty -Task value and interest activation	-Time and effort planning -Planning for Self-observation of behaviours	-Perceptions of task -Perceptions of effort
Phase II: Monitoring	-Metacognitive awareness -Monitoring of cognitions	-Awareness and monitoring of motivation and affect	-Awareness and monitoring of effort, time use, need for help, -Self-observation of behaviour	-Monitoring and changing task or context conditions
Phase III: Control	-Selection and adaptation of cognitive strategies for learning and thinking	- Selection and adaptation of strategies for managing motivation and affect	-Increase/ decrease effort -Persist, give up, seek-help	-Change or Negotiate task -Change or leave context
Phase IV: Reaction & Reflection	-Cognitive judgments -Attributions	-Affective reactions	-Choice behaviour	-Evaluations of task -Evaluation of context

Reflection, the last phase in Pintrich's model, includes strategies that learners use to evaluate whether they should continue, modify, or cease their actions. According to Montalvo and Torres (2004), learners apply SRL strategies to regulate four areas related to their learning: cognition, motivation, behaviour, and context. Although, regulatory processes within each area often occur linearly, they can also occur simultaneously and dynamically, and in some instances the processes may become automated and outside of the individual's consciousness as observed by Winne and Hadwin (1998). In sections 2.2.3.1 to 2.2.3.4, the SRL strategies are relayed to cognition, motivation, behaviour, and context.

2.2.3.1: Regulating cognition

Wolters *et al.* (2003) pointed out that regulation of cognition refers to the cognitive and metacognitive processes which learners employ to adapt and change their cognition during learning processes. Planning processes include setting goals, activating prior and metacognitive knowledge, recognising the difficulties in a particular task, and identifying the relevant knowledge and skills to address the task. Self-monitoring strategies for regulating cognition entail metacognitive awareness, which describes how students monitor their understanding. These processes provide real-time information to the learners about the relative discrepancy between his or her goals and current progress toward that goal. Learners also employ control-related strategies such as selection and utilisation of thought control strategies (e.g. elaboration, organisation) to regulate cognition. According to Weinstein and Mayer (1986), learners utilise strategies such as imagery, mnemonics, paraphrasing, outlining, networking, and note taking to help them encode newly learned information into working memory. Learners also regulate cognition using reflection processes. In summary, these strategies help learners evaluate the success of their performance by comparing it to previously established standards.

2.2.3.2: Regulating motivation

According to Wolters *et al.* (2003), learners regulate their motivation by employing strategies which enable them to start, persist, and finish a particular goal for a given task. Activation of stored motivational beliefs such as judgments of self-efficacy, goals, perceived task value, and interest are the planning processes learners employed to regulate motivation. In addition, learners use self-monitoring strategies to help them become aware of their motivational patterns in order to regulate motivation. Furthermore, strategies of emotional control include the selection and adaptation of strategies such as mastery of self-talk that students can draw upon to regulate their motivation. Finally, individuals use reflection processes to evaluate how well they are regulating their motivation and meeting their goals.

2.2.3.3: Regulating behaviour

Pintrich's (2000) model also illustrates how learners use self-regulatory processes to observe their own behaviour and monitor, regulate and control it. Here, planning processes used to regulate behaviour may include estimating the time and effort one will need to complete a task. According to Pintrich (2000), learners also use self-monitoring strategies to monitor their effort, time use, and need for help in relation to their goals and task difficulty. On the basis of the information gathered during the monitoring phase, Wolters *et al.* (2003) noted that learners may modify their behaviour by setting time limits or focusing attention toward tasks that can be completed in the time allotted. Eventually, learners use reflection strategies to evaluate their performance related to their goals, and this information informs future planning activities.

2.2.3.4: Regulating context

Learners do regulate certain aspects of the environment using a number of SRL strategies. Planning processes employed to regulate context include activating prior knowledge to form perceptions of the task, the contextual environment, and the effort needed in the current task. In addition, learners employ self-monitoring processes to regulate aspects of the external environment by considering what class rules exist, how performance is evaluated, reward and punishment systems, teacher behaviour, and so on. According to Pintrich (2000), control-related activities aimed at regulating the context include activities that structure parts of the environment within the students' control such as changing aspects of the task or redesigning a particular part of environment. Reflection processes help individuals regulate their contexts by creating self-assessment information related to how the learner is performing given his or her current environmental surroundings.

Following Winne and Hadwin (1998), these reflection processes indicate whether learners should continue, modify, or cease their actions.

In summary, in this section, three social cognitive theories of SRL that focus on how learners use certain processes to regulate aspects of their cognition, motivation, and behaviour have been explored. Zimmerman (1989a, 2000) and Winne and Hadwin's (1998) models show how learners regulate cognition, while Pintrich (2000) extends SRL theory to include how learners regulate motivation, behaviour, and aspects of the context. In the next section, SRL theory based on socio-cultural principles and research will be discussed. Attention will be paid to how it is different from social cognitive theories. Its implications for students' learning processes are explored.

2.3: Socio-Cultural Models of Self-Regulated Learning

Socio-cultural theory provides a useful framework for investigating the social processes involved in SRL (Schunk, 2001; McCaslin & Hickey, 2001; Järvela & Järvenoja, 2007; Hadwin & Oshige, 2007). The concept of co-regulation underlies the approach of the socio-cultural model to SRL. According to McCaslin and Hickey (2001) and Yowell and Smylie (1999), co-regulation, from the socio-cultural perspective, entails the interactions between two or more peers who employ strategies of planning, monitoring, and evaluating processes in order to enable the less capable peer to self-regulate independently. In co-regulation, peers collaboratively engage in setting goals and planning strategic approaches to problem solving; monitoring task, effort, or attention; co-ordinating multiple goals and ideas; and sustaining engagement through positive talk and support (Patrick & Middleton, 2002). Co-regulation provides insight into the interpersonal interactions existing among peers as they collaboratively regulate their intrapersonal learning processes. The ultimate goal of this is for learners to become autonomous through self-regulated learning.

Reciprocal teaching exemplifies an instructional approach based on Vygotskian constructivist theories of regulation (Palinscar and Brown, 1984) that enables learners to attain autonomous self-regulated learning through co-regulation (McCaslin and Hickey, 2001). In reciprocal teaching, the teacher models comprehension strategies such as summarising, making predictions, and identifying parts of a text that are hard to understand so that learners may employ these as they read the text. Then, the learner begins to practise aspects of a strategy with the teacher co-regulating his or her processes. As learners gain competency in using these strategies, the support given by the teacher fades and the learners ultimately become models for other students.

According to Patrick and Middleton (2002), co-regulation in a collaborative context involves a group member who possesses strong regulatory skills (i.e. leader) working one-on-one with another group member in order to jointly regulate, plan, monitor, or evaluate learning processes. This is best illustrated in a group research project where the member with higher SRL ability supports another group member as he or she creates a graphical organiser to organise information he or she has gathered related to their topic. Consequently, when peers with less developed behaviour, cognitive, or motivational regulation strategies collaborate in carrying out a task, there exists an opportunity to learn strategies from other group members which in turn might develop their own self-regulated learning. Although co-regulation enables a learner to attain autonomous SRL capability, this process may take time and involve continued experiences working with more regulated peers in order to develop. In the next paragraph, an example is given from Patrick and Middleton (2002) to illustrate how a group member co-regulated her peer's learning, during a learning session on global warming, which eventually lead the peer to self-regulate.

During the learning session on global warming, learners were engaged in groups to investigate issues related to colour and heat absorption. A member queried his peers: "Why are deserts hotter than rain forests, even though the yellow sand is a lighter colour than the green vegetation of rain forests?" In order to explain this phenomenon, his peers proposed a number of hypotheses, such as there are no clouds over the desert to reflect the heat, certain minerals found in sand cause more sunlight to be reflected, and there was no greenhouse effect overhead. A group member who suggested the final hypothesis offered numerous explanations to support his reasoning. In monitoring this group member's reasoning, another person in the group co-regulated his learning by helping him to realise a misunderstanding in his reasoning "that there is a greenhouse effect around the whole earth so why not the desert." Patrick and Middleton (2002) explained that this caused the student who suggested the hypothesis to re-evaluate his initial assumptions and as a result he rejected his own hypothesis. This illustration is adjudged to be consistent with McCaslin and Hickey's definition of CRL. This is evident by the fact that the student had not engaged in any actions to evaluate his own reasoning prior to the time the peer monitored and evaluated his argument, the students therefore assumed responsibility for self-evaluating his argument independently following the action of the peer. Ultimately, this student had been able to attain SRL.

Whilst a search through the available literature reveals that Patrick and Middleton (2002), Butler (2002), and Jarvela *et al.* (2007) all agreed with McCaslin and Hickey's definition of co-regulated learning (CRL), it must be noted there are other forms of co-regulation that may occur in a collaborative learning context. These forms of CRL suggest that several group members possess strengths in different regulatory processes, some of which are better suited to a particular aspect of the task than others. Therefore, in this context, described by Resnick *et al.* (1991) as socially shared cognition, the role of more able regulated peers alternates among group members depending on whose regulatory strategy is best suited for the task. Because the target is to achieve success on a given task, learners alternate in regulating planning, monitoring, and evaluating activities to accomplish their goals. Corno (1994) in his illustration showed that members of the group interacting collaboratively (1) modelled and co-regulated other group members (2) practised and refined their own regulatory processes, and (3) externalised a number of strategies that their peers then use to self-regulate. They achieved these by regulating peers' motivation several times throughout using strategies such as goal-oriented and self-efficacy talk as all group members shared responsibility for monitoring each other's thinking processes by questioning, making judgments about the accuracy of each other's answers, and offering solutions.

Finally, in Patrick and Middleton's (2002) example, co-regulation occurred between a more knowledgeable group member and a learner, whereas in Corno's (1994) example that regulation was shared among all the group members. In summary, co-regulation includes various types of regulation that may occur when students learn collaborative in a group. These include (1) a single more capable group member co-regulating another, (2) each group member taking on the role of more regulated individual depending on the strengths of a particular learner, or (3) several group members sharing together in regulating the groups' activities. It should be noted that common to all types of CRL is the fact that an individual or a group of individuals share(s) in regulating other individuals' regulatory processes.

2.4: Integrating Social Cognitive and Socio-cultural Theories

The literature review guiding this research is premised upon social cognitive and socio-cultural theories of regulation which provide insight into how learners develop, use, and refine regulatory processes in a collaborative context. Social cognitive theory explores how learners learn a number of strategies to regulate their cognition, motivation, behaviour and their characteristics (e.g. cognitive and motivational orientations) affect their use of SRL during learning processes. Social cognitive theory plays an important role in creating and sustaining model systems of educational activities. Barron (2003) and Volet *et al.* (2009) employed social cognitive theory to explain the nature and emergence of productive interactions when a group of students are engaged in collaborative learning activities. A common trend that runs through all the cited studies is the manner of emergence of collective thinking and co-construction of understanding among the group members. The emphasis on relationship between individuals' behaviours during collaborative learning activities and learning outcomes appears to suggest the neglect of the interdependent nature of engagement, participation and knowledge construction in studies dwelling on collaborative learning research. Also, findings from the available literature on high-school students' negative group work experiences (Gokhale 1995, Peterson & Miller 2004) suggest the pertinence of exploring what these students actually do when they interact as a group, in addition to collecting their self-reports on how they interact with one another in a social learning context. Therefore, a social cognitive perspective seeking to understand groups' actual interactions in real time is expected to show how groups negotiate collaborative learning. One particularly attractive feature identified from the works of Greeno (2006) and Volet *et al.* (2009) on the social cognitive perspective on learning through activity is the integration of an interactional focus on participatory processes with a cognitive focus on information processes.

Socio-cultural theory on the other hand, examines if and how a more able peer in a group co-regulates a learner's strategy use until the learner internalises these strategies and is able to self-regulate independently. It may also be recalled that when learners employ co-regulation in a collaborative context, several types of co-regulation are present: co-regulation can constitute a single more capable group member co-regulating another; each group member taking on the role of regulating others depending on the strengths of a particular learner, or several group members sharing together in regulating the groups' activities. Although available studies (Hadwin & Oshige, 2007; Järvela & Järvenoja, 2007;

McCaslin & Hickey, 2001; Schunk, 2001) emphasise the role of the social context in the development of learners' regulatory processes, the present research employs both social cognitive and socio-cultural theories to analyse a learning environment in which it is conceptualised that both self- and social forms of regulation are present.

By integrating these theories of regulation, the present research uses a theoretical framework which proposes that:

- students possess individual characteristics (i.e., orientations) that affect their SRL
- in the collaborative context, learners will engage in co- and self-regulatory processes to regulate their cognition, motivation, and behaviour
- instances of co-regulation may potentially lead to increases in self-regulated learning
- self-regulation, co-regulation, and group performance may be measurable predictors of the outcomes.

Figure 2.2 illustrates this research's theoretical framework for co-and self-regulated learning processes during collaborative learning in a computer based science simulation learning environment. In this framework the importance of the individual student planning, monitoring and evaluating their own learning processes is incorporated. The individual student may be aware not only of what they do not understand, but also of how to learn and what kind of materials to learn from. A learning environment where students were allowed to discuss their learning processes and opportunities for learning will enable students to negotiate their SRL behaviour.

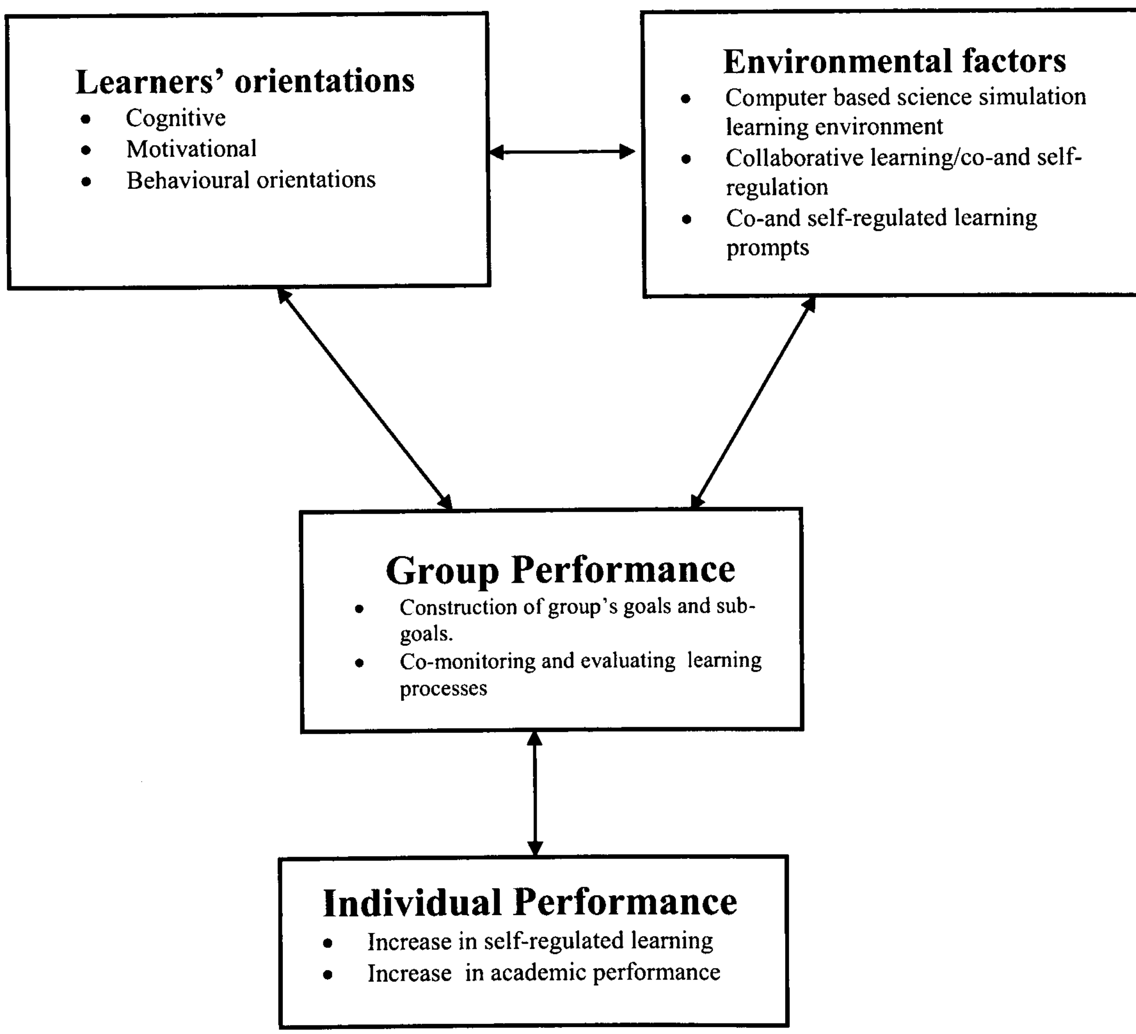


Figure 2.2: Theoretical framework for the research

The process where students discuss their SRL processes as a group during the collaborative learning is referred to as co-regulatory processes. Co-regulatory processes have the potential to make learning more effective but tend to increase the complexity of the planning, monitoring and evaluating processes further. A computer based science simulation learning environment can support students' ability to plan, monitor and evaluate their learning processes at group level. This research proposes that when students co-regulate their learning behaviour during collaborative learning, it increases their self-regulated learning which in turn leads to the overall improvement in the group and the individual performance. In summary, CRL incorporates the transitional process in a learner's acquisition of SRL, during which both experts and learners share a common problem solving plane. Consequently, SRL is gradually appropriated by the individual learner through interactions with his or her peers in the learning group. Moreover, CRL examines ways in which social practices support individuals in appropriating SRL knowledge and processes. Therefore, to co-regulate well, a student must self-regulate well. In the next section, co- and self-regulated learning are discussed in the context of the present study.

2.5: Co- and Self-Regulated Learning in this Study

2.5.1: What is Self-regulated Learning (SRL)?

SRL refers to strategic and metacognitive behaviour, motivation, and cognition aimed toward a learning target. According to Zimmerman (1989b), students are regarded as self-regulated to the degree that they are metacognitively, motivationally, and behaviourally active participants in their own learning process. Therefore, social cognitive models of SRL highlight modelling and prompting as key instructional tools for promoting SRL. Moreover, the social environment is a key determinant factor in imparting self-regulation into students with the aim of improving the individual's regulation of cognition, metacognition, behaviour, and motivation. According to Hadwin *et al.* (2010), the social and the self are viewed as distinct entities whereby social influences shape the development of SRL by defining conditions for tasks and providing standards, feedback, and modelling. On this premise, following Jackson *et al.* (2000), SRL may be viewed as an individual process, within which contextual and interpersonal feedback affect acquisition, while the individual's goals and efficacy influence their motivation. In this research, the focus is on an individual as a regulator of behaviour (individual-oriented process). From a social cognitive perspective, learners actively interpret and reorganise ideas according to their understanding as opportunities for learning are orchestrated by an instructor or other social influences. This implies that learners actively take control of their learning while being influenced by self and social environment (Schunk & Zimmerman, 1997). Therefore, SRL is socially influenced, beginning with observational learning (modelling, verbal description, social guidance, and feedback) and later by self-imitation and self-regulation.

This suggests that students learn through a process of modelling in which thoughts, strategies, and behaviours reflect those displayed by one or more models (Schunk, 1998).

Furthermore, social cognitive theory argues that SRL is situation specific such that students can vary dramatically in their demonstration of SRL behaviours depending on the given task and the subject domain in which the student is learning. According to Schunk (2001) and Zimmerman (2000), the social context and the learning instruction embedded in a learning environment provide modelling, opportunities for guided practice, and instrumental feedback. Therefore, these social processes help students to develop competence thereby becoming self-regulated learners with the given task, content, and context. According to Hadwin *et al.* (2010), self-regulated learners rely on internal standards, self-reinforcement, self-regulatory processes, and self-efficacy beliefs. Rosenthal and Zimmerman (1978) noted that adult models withdraw their support as observing youngsters display emulative accuracy. Zimmerman (2002) also illustrated that as youngsters gain increased proficiency, they seek to perform on their own, such as when a young boy spurns further assistance from his mother when he feels he can tie his own shoelaces. At this point, the boy's reliance on his mother as a social model becomes selective, and he will seek assistance from her mainly when he encounters obstacles, such as a novel type of shoelace. In Zimmerman's (2002) analogy, the mother is a social influence on the child's self-regulation. The mother is not viewed as self-regulating for the child; rather, she models how to tie the shoelace (the task) and provides feedback and instrumental support as the child learns to master the task himself. It is on this basis that Hadwin *et al.* (2010) viewed SRL as a developing process within the individual, which is assisted by task modelling and feedback provided by others.

SRL as discussed in this review is applicable to a technological environment such as CSCL which has increasingly changed the way we learn. Also, due to the fact that instructional paradigms are changing, teaching is becoming more student-centred and less teachercentred, therefore requiring that a higher degree of SRL strategies are acquired by students. Moreover, Dettori *et al.* (2006) provided deeper insight into the relationship between SRL and CSCL environment by investigating evidence of SRL practice and/or development in the CSCL environments. The SRL indicators were drawn from the SRL literature (Zimmermann, 1989b; Zimmermann & Schunk 2001). The results of their study suggest that a CSCL environment, if adequately designed, can encourage and support both SRL practice and its development. In particular, SRL seems to promote independence, both in individual activities and in collaborative activities and encourages social support, help seeking, planning, monitoring and evaluation of both individual and group activities. According to Roy and Chi (2005) and Lajoie (2008), when a learner self-regulates, he or she is able to manage the given tasks on his or her own by adopting strategies such as time management, goal setting, monitoring, as well as help seeking from peers or tutors. In addition, a self-regulated learner has been found to mobilise and maintain these identified task management strategies as the situation requires. Boekaerts *et al.* (2000), Roy and Chi (2005) and Lajoie (2008) identified cognitive, affective, motivational and behavioural components of SRL which enabled individual learners to adjust his or her actions and goals to achieve the desired results in the light of changing environmental conditions.

A lot of research on SRL during its emergence in the 1980s focused on educational quality and learners' mental abilities, as well as various educational reforms (Zimmerman 2002). Learners were then perceived mostly as reactive individuals rather than proactive learners who took control of their own learning and employed various motivational strategies to make the learning environment suitable for themselves. The relationship between the concepts of metacognition and that of SRL had been elucidated by Flavell (1971). Although Flavell differentiated between metacognitive knowledge and metacognitive experience, nevertheless Hacker (1998) distinguished between a learner's cognitive processes and the monitoring and regulation of these processes. Therefore, in this study, metacognition will be regarded as a component of SRL.

Jackson *et al.* (2000) proposed that SRL can be thought of as self-in-social-setting regulation in which individual actions are embedded within the group and personal goals are inseparable from social goals and are achieved through social interaction. This implies that in co-regulation, the regulatory processes and products are distributed among the individuals constituting the group. Yowell and Smylie (1999) highlighted the developmental processes of SRL using Bronfenbrenner's (1994) ecological theory by applying Dewey's (1963) and Vygotsky's (1978) theories of social cognitive development. They hypothesised that many theories of SRL address individual regulatory processes. On this basis, SRL is considered to have emanated from the product of relationships between and within interpersonal and environmental interactions, as well as through individual processes. Following Yowell and Smylie (1999), SRL in this study is viewed as a goal-directed process through which the learning goal should be adaptable and enhance individual development and social change. Therefore, behaviours of individuals are affected by the opinions, comments, and behaviours of other people within the same collaborative setting. Consequently, these behaviours are socially constructed regardless of whether the learners are aware of the social interaction. On this premise, this study argues that personal goals are inseparable from social goals and are achieved through social interactions. However, the role of SRL-prompts in promoting and developing the group's co-regulatory behaviours in a CSCL environment needs to be clearly understood.

2.5.2: What is Co-Regulated Learning (CRL)?

Co-regulation is the focus of this study because it provides insight into the understanding of the dynamics and relational nature of collaboration in learning activities. Moreover, co-regulation elucidates the adaptive learning and development at the levels of both social contexts and the individuals that constitute them. According to Hickey (2003) and Volet *et* *al.* (2009), co-regulation refers to the process by which social environments support individual participation and learning. Meanwhile, investigations have been conducted into understanding how groups of individuals as multiple self-regulating agents socially regulate each other's learning (Vauras et al. 2003; Volet *et al.* 2009). In addition, several forms of social regulation have been identified in different learning contexts. For example, Volet *et al.* (2009) employed the term "other-regulation" to describe situations in which a "momentary unequal situation" arises (e.g. when one student becomes more confident in his/her understanding of a particular segment of the task than the rest of the group and takes on a more instructive role to guide the others' understanding). Moreover, Vauras *et al.* (2003) identified "shared regulation" as the most effective mode of co-regulation and described it as multiple members' constant monitoring and regulation of joint activity, which cannot be reduced to mere individual activity.

The concept of co-regulated learning (CRL) derives from the idea that, in an ideal learning context, learning is a naturally social act in which the participants talk among themselves and involve one another in the learning process. McCaslin (2004) argues that the CRL approach involves inter-personal processes of motivation (including prior self-knowledge and future expectations), enactment (including overt and covert goal-coordination strategies), and evaluation. These processes are considered in the context of relationships with other participants, structural supports, and affording opportunities in the social environment. Although the ultimate goal of CRL is to enable students improve on their SRL behaviours as individual student establishes relationships with teacher, peers and their social environment during co-regulation. Therefore, CRL engages students in challenging tasks and enables them to develop higher-order reasoning and problem solving skills (McCaslin, 2004).

A summary of literature cited so far in this section suggests that in student-led collaborative learning activities the regulatory process may shift from a context whereby an individual temporarily leads by providing information or taking an informal instructional role, to a more symmetrical, co-regulatory metacognitive activity in which group members engage in collaborative learning task. For the purpose of this study, two forms of social regulation are hereby conceptualised on a continuum from "self-regulation within a group" to "co-regulation as a group". Meanwhile, "self-regulation within a group" could be described as individual temporary regulation of the learning activity within the group while effective co-regulatory metacognitive activity leads to the construction of meaningful knowledge and understanding if the group is engaged in high-level content processing and not merely sharing information.

Volet *et al.* (2009), Sitzmann *et al.* (2009), Hadwin *et al.* (2010), and Pifarre and Cobos (2010) examined the development of metacognitive behaviours demonstrated by learners in technology rich learning environments, such as CSCL, over time. These studies suggested that students who do not continuously use CSCL environments with regulatory prompts are at risk of being unable to collaborate as effectively as students who use such an environment. Moreover, Sitzmann *et al.* (2009) and Hadwin *et al.* (2010) described the metacognitive behaviours demonstrated by students as unfolding and iterative processes that must be examined over time in order to fully understand the recursive flow of goals and strategies that ultimately determine the ability of students to regulate their learning behaviours. In order to gain an understanding of gradual development in students' regulation of learning processes over a period of time, Yeo and Neal (2004), Ilies and Judge (2005), Vancouver and Kendall (2006), and Sitzmann *et al.* (2009) advocated a within-subjects (longitudinal) comparison as being appropriate.

A search through the available literature reveals that adequate consideration had not been given to the continuous and simultaneous incorporation of CRL and SRL prompts into a CSCL environment. According to Morris *et al.* (2010), this is necessary in order to investigate if there will be more positive, gradual effects on the ability of students to co-regulate their learning activities over time, in comparison with a CSCL environment having only SRL- prompts. It is important to note that the present research was carried out in order to investigate the consistency of the results with the claim that the metacognitive behaviours demonstrated by students are unfolding, iterative processes, and within-subjects designs are more likely to detect the effect (Sitzmann *et al.,* 2009; Hadwin *et al.,* 2010). Finally, the concepts of co- and self-regulation have generated a considerable amount of research on the potential benefits for learning in a computer supported collaborative learning (CSCL) environment. The next section discusses the concept of self-regulation as it is applied in this present study. Having defined what SRL and CRL are, the concept of CSCL is discussed in the next section.

2.6: Collaborative Learning and Computer Supported Collaborated Learning Environments

In educational research in general it is widely believed that, through discussion and collaboration, students instead of passively receiving knowledge from teachers can develop their cognitive and metacognitive skills (Guan *et al.,* 2006). Collaborative learning (CL) as the second half of the acronym, CSCL, is one of the pedagogical methods that can stimulate students to discuss information and problems from different perspectives. According to Roberts (2004), collaborative learning implies working in a group of two or more to achieve a common goal, while respecting each individual's contribution to the whole. Collaborative learning is a learning method that uses social interaction as a means of knowledge building. The participating students exchange ideas, experiences and information to negotiate about knowledge in order to construct personal knowledge that serves as a basis for common understanding and a collective solution to a problem (Roberts, 2004). Dillenbourg (1999) describes collaborative learning as a situation in which particular forms of interaction among people are expected to occur, which would later trigger learning mechanisms. However, there is no guarantee that the expected interactions will actually occur when students are learning in a collaborative setting.

Likewise, collaborative learning also provides a context for students to practice and develop their co- and self-regulatory processes when students engage in high quality discussions. Discussion refers to the turn-by-turn exchanges that occur among students in a group (Sawyer & Berson, 2004), and high-quality discussion is necessary for success in collaborative learning settings (Webb & Palinscar, 1996). High-quality discussion occurs when students explain their ideas and strategies to each other, uphold their own perspectives, ask high-level questions, allow for alternative interpretations and suggestions, evaluate each other's' reasoning, modify plans, and in general reach agreed-upon understandings (King, 1999). Although collaborative learning has been found to be a successful pedagogy that teachers use in the classroom (Webb, 1992; King, 1999; Chinn *et al.,* 2000), there is a general concern to develop ways to increase the probability of some types of interaction that occur during collaborative learning.

In order to promote high-quality interaction among students during collaborative learning, a growing body of evidence in the field of the educational research has suggested that particular applications of technology in educational contexts can benefit learners and facilitate teaching. CSCL environments are widely employed as instructional tools in the classroom because they facilitate students' ability to control various aspects of their learning (i.e. the CSCL environment and social aspects of the learning context). Following Jonassen and Reeves (1996), CSCL environments provide opportunities for students to engage in the collaborative learning process (in accordance with the proposal of the constructivist theory) by giving them access to and allowing them to manipulate models, representations, and data that may not be available in the traditional classroom setting.

According to Lipponen (2001; 2002) CSCL is focused on how collaborative learning, supported by technology, can enhance peer interaction and work in groups and how collaboration and technology facilitate sharing and distributing of knowledge and expertise among community members. CSCL is progressing based on socially oriented theories of cognition and learning. Whilst the antecedents of CSCL relied strongly on experimental research design, CSCL adopts a variety of methods from the fields of communication science and linguistic research. Unlike the earlier paradigms that studied human cognition with experimental design in laboratories, CSCL research is conducted in real world contexts. In addition, CSCL utilises the new possibilities of networked technology, which were not, of course, previously available. Even if a new paradigm emerges in instructional technology, the old types of software and ideas are still popular among educators and instructional designers. Nowadays these ideas are usually loosely veiled as different types of multimedia programs (Lipponen, 2001).

Furthermore, embedded features such as synchronous chat tools and simulation programmes in the CSCL environment have the potential to cognitively and metacognitively facilitate students' CRL and SRL behaviours and enhance academic performance (Hannafin *et al.,* 1999; Jacobson & Kozma, 2000). With the presence of synchronous chat tools in CSCL environments, students are able to make decisions on what to learn, how to learn through planning, monitoring and managing their time during the learning processes while the simulation programmes enable students to explore, manipulate and observe the scientific phenomena being studied. Therefore, CSCL environments are contexts in which the various tools described above are used. Roschelle & Teasley (1995) described the collaboration as a coordinated, synchronous activity that resulted from a continued attempt to construct and maintain a shared conception of a task. Meanwhile, Dillenbourg *et al.* (1996) identified interactivity, negotiability, and dialogic interactions as key criteria for collaborative interactions.

The potentials of a CSCL environment can be fully realised only when students possess regulatory skills such as goal setting, monitoring their progress toward those goals, task difficulty and demand, help seeking and giving, and motivation to regulate their learning processes (Volet *et al.,* 2009). However, my own widely varied teaching experiences using technology rich environments suggested that it might be the case that students with high academic ability are able to regulate their learning processes by using these skills more effectively than students with lower academic ability whose attention may be overwhelmed by new information in CSCL environments. Furthermore, it has been discovered that the collaborative learning activities in a CSCL environment do not led to improved usage of CRL behaviours and academic performance of students because students lack the appropriate cognitive, motivational, metacognitive, and scientific-reasoning skills and strategies to engage in the learning process in an effective manner (de Jong & van Jooligen, 1998; White & Frederiksen, 1998; Jacobson & Archodidou, 2000; Singer *et al.,* 2000). Because students engaging in CSCL environments to learn collaboratively are required to effectively co- and self-regulate their learning, it is envisaged that the difficulties hindering their ability to improve on their demonstration of CRL behaviours and academic performance may be a result of their inability to employ key co- and self-regulatory skills.

The regulation of students' learning processes in a CSCL environment needs to be empirically addressed because of the assumption that a CSCL environment incorporated with CRL and SRL behaviours will improve the demonstration of CRL behaviours and conceptual understanding in comparison to a CSCL environment incorporated with only SRL prompts. On the basis of this assumption, it is expected that students working in a CSCL environment incorporated with CRL and SRL behaviours will become more cognitively and motivationally involved with the learning processes and content as compared to a CSCL environment incorporated with SRL behaviours alone (Azevedo &

Jacobson, 2008; Pifarre & Cobos, 2010). Therefore, this present study was designed to explore the possibility of whether collaborative learning can be enriched by providing CRL and SRL prompts to help students co- and self-regulate their learning in order that they may better manage and evaluate their learning processes in CSCL. The longer term aim is to enhance the process of collaboration and to integrate individual and group-level perspectives of learning. The next section is devoted to the review of the co- and self-regulation in a CSCL environment.

2.7: Co- and Self-Regulation in a CSCL Environment

Computer Supported Collaborative Learning (CSCL) can be supported and facilitated in many ways. From the literature on CSCL, co- and self-regulation are significant features when students are engaged in CSCL and it may be used to determine whether or not the learning process will be successful in that environment. CSCL environments, to some extent, have emerged in reaction to previous attempts to use technology within education and to earlier approaches to understand collaborative phenomena with the traditional methods of the learning sciences. Learning science as a whole has shifted from a narrow focus on individual learning to the incorporation of both individual and group learning with the evolution of CSCL environments.

CSCL usually involves a combination of individuals and groups performing together around or through computers to complete a given task or goal. Individuals and groups are driven by metacognitive behaviours such as CRL and SRL behaviours causing challenges that affect the environment, and at the same time this environment affects "initial" regulatory behaviours that students bring to the task. Learners collaborate in CSCL based on their co-and self-regulatory behaviours. That is, co- and self-regulation are essential in the learning process, and this is very evident in CSCL, taking into account that students must be committed to collaboration. Co- and self-regulation concepts stimulate learning processes and development. In self-regulation, an individual student constructs their understanding of the educational environment for themselves and figures out how they will engage in it and to what degree. Research on individual regulation has shown that there are differences between the self-regulated learning abilities of learners with poor SRL strategies and learners having effective SRL behaviours who can monitor and evaluate their on-going learning, as well as plan and select appropriate strategies (Everson & Tobias, 1998).

Instructional methods like Reciprocal Teaching (Palinscar & Brown, 1984) or Communities of Learners (Brown & Campione, 1994) were developed to facilitate and prompt students' regulatory behaviours in collaboration with a teacher or peers. These methods were designed to structure interaction in order to encourage learners to follow sequences of activities or particular patterns of dialogue. Co-regulation offers group insight and ideas derived by the individuals for the group as a whole helping or aiding the control of the group for the group's development. Co-regulation is then an indicator that collaborative learning is working, as it implies that students self-regulate and co-regulate with expertise. If students are not efficient in regulating themselves, it is then difficult for them to co- and self-regulate during collaborative learning. Learning how to co- and self-regulate evaluation and motivation processes may prove vital to the success of CSCL. The individual's intrinsic understanding and performance of co- and self-regulation will support the development of the group when working in CSCL and can possibly contribute to the personal development of the individual outside of CSCL.

In conclusion, the review of the available literature carried out so far establishes the need to combine computer support and collaborative learning in order to enhance students learning in CSCL environments (Leinonen *et al.* 2005, Wang & Lin 2007, Gress, & Hadwin 2010). High-level discussion during collaborative learning in a CSCL environment may facilitate the development of co- and self-regulatory processes among the group members in the same way that it promotes the acquisition of new knowledge. When students engage in high-quality discussion, they make their thinking and regulatory processes explicit and available to the other group members. Externalising self-regulated learning processes may provide opportunities to monitor or evaluate a particular plan or strategy, making it easier to identify inferior strategies that may need to be abandoned or improved in the future learning. Furthermore, it may allow for the possibility that the student himself or herself may acquire more control over regulatory skills by the very act of making them explicit. Engaging in high level discussion in group learning may also enable others to learn new strategies or modify existing regulatory processes as a result of co-regulation. For instance, as the group members cope with challenging tasks, there are opportunities for them to share various planning approaches to solve the problem. The high level of discussion during collaboration helps to make overt the rationale and benefits for the regulatory strategies employed.

However, no known study has been specifically directed to empirically assess the use of CRL and SRL prompts to support Key Stage 3 students' science learning in a CSCL. This present study contributes to knowledge by filling this gap. The ability to combine computer support and collaborative learning in order to successfully enhance learning remains a challenge which the CSCL environment is designed to address. This present study aims to address this challenge by deploying CRL and SRL prompts in a CSCL environment with a view to assisting science learners to improve social learning processes which involve active knowledge construction over a period of time. In the next section, I will discuss the instructional features in the form of CRL and SRL prompts as employed in encouraging co- and self-regulated learning in this study.

2.8: Supporting Students with CRL and SRL Prompts in a CSCL Environment

Collaborative learning environments may be appropriate environments to examine students' co- and self-regulated learning processes (Järvela & Järvenoja, 2007); however, collaborative learning techniques are not always appropriate, and not all groups are always productive (O'Donnell & O'Kelly, 1994). According to Cohen (1994) and Perry (1998), some tasks are more likely to result in productive collaborative learning groups and increased use of SRL processes. These studies on SRL established that tasks that are complex and personally meaningful can provide natural opportunities for students to apply and develop their SRL strategies. The literature also argues that complex, personally meaningful tasks are particularly suited to studying the social origins of CRL and SRL because these tasks require students to work together, coordinating multiple cognitive, motivational, behavioural processes to construct various products. In order to investigate co- and self- regulation in this present study, the nature of the tasks used included a number of the characteristics suggested by the literature to support the development, use, and refinement of CRL and SRL strategies. The tasks to be designed consist of fairly directed learning tasks which are open-ended and collaborative. As a result, I expected the context to help promote the students use of co- and self-regulatory strategies.

Following Hadwin *et al.* (2010), who viewed the socio-cultural perspective on SRL as the appropriation of SRL through prompting and joint problem-solving efforts, it may then be considered that CSCL environments must provide space for acquiring joint problem-solving skills, as well as individual space for representing ideas and self-regulatory knowledge. Consequently, the CSCL environment provides shared real-time space for the collaborating students to exchange their ideas during collaborative learning processes. Therefore, the socio-cultural nature of co-regulation necessitates a shift in the ownership of regulation of learning from individuals to peers by prompting. With respect to this study, this perspective in the CSCL environment was implemented by the instructions in the activity sheets or in the *InterLoc* tool. The activity sheets and *InterLoc* tool were employed to prompt CRL and SRL strategies in a CSCL environment. The prompts were instructions that enabled students to demonstrate CRL and SRL behaviours. According to Hadwin *et al.* (2010), regulatory prompts are instructions about CRL and SRL phases which include planning, monitoring, task demand and effort regulation, help seeking and giving, and motivation. In a CSCL environment, these prompts were incorporated into the activity sheets and *InterLoc*. Therefore, the activity sheets and *InterLoc* tool guided the co- and self-regulatory behaviours among the students with the aim of promoting and developing co- and self-regulatory behaviours. Interloc is a combination of a specially designed interface that scaffolds and supports synchronous discussion. It is an environment for setting up and managing suitable sequences of discursive activities for the students (Ravenscroft, *et al.*, 2006). (See details in section 3.4.1)

According to Makitalo and co-investigators (2005), CRL prompts specify and sequence collaboration through instructions. CRL prompts may be categorised into social or epistemic prompts. Weinberger *et al.* (2007) noted that social CRL prompts help learners to structure their discussions in a collaborative setting while O'Donnell and Dansereau (1992) suggested that epistemic CRL prompts promote cognitive processes by providing strategies to solve tasks. Therefore, CRL prompts have the potential to support collaborative learning processes by offloading some metacognitive monitoring and evaluation that guide students through regulation activities step by step. For example, Bannert *et al.* (2009) reported that prompting a group of students with metacognitive activities helped them to demonstrate better transfer performance compared with the control group. Molenaar *et al.* (2010) found that prompting students with structuring scaffolds or problematising scaffolds has a significant effect on stimulating their metacognitive activities especially on the interpersonal plane. Moreover, scaffolding has a significant development effect on students' metacognitive activities even after the scaffolding is ceased. However, none of these studies have reported the effects of continuous and simultaneous incorporation of CRL and SRL prompts into a CSCL environment on the ability of students to co-regulate their learning activities over time. Therefore, this literature review establishes the need to investigate further whether or not the incorporation of the CRL and SRL prompts into a CSCL environment will bring about further improvement in the students' ability to co-regulate their learning processes over a period of time. To address this issue, it was envisaged that data from various phases of the study collected over time would be presented and analysed. Furthermore, it was intended that the deployment of CRL and SRL instructions in a CSCL environment consisting of *InterLoc* and a simulation would assist the students in the experimental group to improve further with respect to social learning processes which involved active knowledge construction, in comparison to the control group students learning in a CSCL environment with only SRL prompts.

2.9: Detecting the Nature of CRL Behaviour in CSCL Environments

An intensive search of the available literature indicated that low-level quantitative measures such as duration of communication or time of communication had been adopted for the analysis of CSCL data. For instance, Harasim *et al.* (1996) and Benbunan-Fich *et al.* (2003) established relationships between participation level and the number of posts to forums as well as the quality of the message content and the mean number of words in a message respectively. Although Strijbos *et al.* (2006) observed that these two studies did provide a rough account of the quality of interaction, nevertheless they pointed out that such measures gave little information about a message's content. Petropoulou *et al.* (2007) and Xenos *et al.* (2009) employed interaction analysis tools which allowed teachers to have a deeper understanding of the learning process (e.g. patterns of communication) for evaluating computer-supported collaborations. According to Serce *et al.* (2011), these approaches (employing content analysis to understand interactions within CSCL environments) involve creating a coding scheme that represents all the interesting categories of a particular type of communication, such as the rules being displayed in a conversation (Emmert & Barker, 1989), the types of speech (Contractor & Grant, 1996), or the actual meaning of the discussion (Fortuna, Mendes, & Milic-Frayling, 2007). Emmert & Barker (1989) reported that the transcribed discourse is then divided into the smallest units of meaning, and those pieces of text that correspond to the categories of interest are tagged. For example, Bonk and Kim (1998) developed an evaluation framework consisting of 12 forms of electronic learning, mentoring, and assisting, which was then used to characterise online instructors' interaction styles such as social (and cognitive) acknowledgement, questioning, direct instruction, and modelling. Meier *et al.* (2008) also introduced a coding scheme that included aspects of communication, joint information processing, coordination, relationship management, and motivation. This was adopted by Kahrimanis *et al.* (2009) for categorising group interactions as well as to provide feedback to teachers and students.

Furthermore, Azevedo (2005), Dettori and Persico (2008), and Pifarre and Cobos (2010) identified the following as predominant behaviours that occur within a collaborative learning environment: planning; help giving/receiving; exchanging resources and information; explaining and elaborating information; sharing existing knowledge with other; giving and receiving feedback; challenging others' contributions; advocating increased effort and perseverance among peers; engaging in small group skills; monitoring each other's efforts and contributions. On the basis of the review of the models adopted by Azevedo (2005), Dettori and Persico (2008), and Pifarre and Cobos (2010), a coding scheme for exploring the nature of CRL behaviours that occur within the CSCL environments incorporated with either CRL and SRL or only SRL prompts when learning scientific concepts was developed for the present study. (Details about the development of the coding scheme are presented in Section 3.4.1.) It consists of 15 behaviours grouped into five behaviour categories (Table 2.2), for analysing behaviours associated with positive social interdependence, in contrast to behaviours associated with a more individualistic and competitive learning environment.

According to Azevedo (2005), Dettori and Persico (2008), and Pifarre and Cobos (2010), the planning behaviour category indicates that the message contains a statement that relates to organising work, initiating activities, or group skills. Monitoring involves checking learning content and context to be sure that the set goals are met. Task difficulty and demand means statements that the students make to express how easy or difficult a given task is.

Table 2.2: Categories, and associated definition of the learners' co-regulatory behaviours in a computer supported collaborative learning environment

	Categories	Categories definition
	Planning	
I	*Goal setting*	➢ Making proposals on how to proceed in the learning process through breaking the given tasks into sub-tasks ➢ Commenting on others' goal ➢ Discussing expectations and motivation about the current learning task
II	*Prior knowledge activation*	➢ Linking what the students knew previously with the new task
		➢ Allotting time to achieve each of the sub-goals.
III	*Time planning*	➢ Agreeing on the time to be spent on each of the set goals.
	Monitoring	
IV	*Self-questioning*	➢ Posing a question and re-reading the content of the activity to the group in order to improve understanding of the learning content.
V	*Feeling of knowing*	➢ Having knowledge of something in the past but not being able to recall it during the learning process.
VI	*Content evaluation*	➢ Monitoring the learning content in accordance with the set learning goals.
VII	*Monitoring progress toward goals.*	➢ Assessing whether previously-set goal has been met. ➢ Contributing to the group task
VIII	*Monitoring time*	➢ Checking time to be sure the task will be completed with the given time

	Categories	Categories definition
	Task Difficulty and Demands (Evaluating/ Efforts regulation	
IX	*Task difficulty*	➢ Commenting on task difficulty
X	*Effort regulation*	➢ Giving commendation for peers' efforts, contributions and results.
XI	*Evaluating the learning process*	➢ Commenting on group achievement. ➢ Reflecting on group learning
XII	*Evaluating the learning context*	➢ Commenting on the learning context.
	Help seeking and giving during collaborative learning	
XIII	*Affective help seeking*	➢ Encouraging peers to express their emotions and motivation. ➢ Disclosing oneself to peers. ➢ Encouraging and providing emotional support for peers.
XIV	*Cognitive help seeking*	➢ Asking task related questions.
	Motivation	
XV	*Interest statement*	➢ Showing a certain level interest in the learning content

The help giving and seeking code is assigned to messages that give help, provide feedback, exchange resources, share knowledge, challenge others or explain one's position; seeking input and reflection. Motivation involves statements showing the students' level of interest on the given task. Because the present study is primarily concerned in both categorising and improving the CRL behaviours among collaborative groups, it is argued that the coding schema in Table 2.2 provides an accurate model of the types of behaviours that could occur within the CSCL environments. The schema was used to determine which sub-categories of CRL behaviours occur in the interactions of students working collaboratively within the CSCL environments. This coding scheme was applied to the students' spoken interaction and the *InterLoc* chat scripts collected in this research.

2.10: Measuring Co- and Self-regulation

The measurement of co- and self-regulation processes during learning is of paramount interest to discussions of CRL and SRL because researchers must draw inferences about cognitive operations that they cannot directly observe. As such, issues related to establishing reliable construct validity remain at the forefront of this present research. Winne and Perry (2000) emphasised that measuring regulatory processes in real time as a series of events has the advantages of better alignment with social cognitive and socio-cultural theories of SRL and afforded more accurate data regarding learners' decisions to monitor and control their cognition, motivation, behaviour, and context.

2.10.1: Measuring SRL Processes

The instruments that measure the self-regulated learning processes that students use during learning include think-aloud activities, methods of error detection in tasks, trace methodology, and measures to observe task execution (Winne & Perry, 2000). In the think-aloud method, students verbally report their thoughts as they complete any given activity. This method can be highly effective for measuring SRL processes (Winne & Perry, 2000). When using methods of error detection in tasks, a researcher purposefully enters errors into students' materials to assess if they can detect them and, if so, the corrective actions they take. Trace methodology is used in computer-supported programs to record signs or observable indicators of students' cognitive processes as they perform tasks (Winne & Perry, 2000). In other words, the computer programs will collect detailed information about which tools students use as they navigate through the site and explore different functions of the program. Trace methodology can be aligned temporally, allowing for the comparison of data that are collected across given time.

Finally, measures to observe task execution involve detailed observations of students as they complete their task while keeping a structured record of their self-regulated processes. These methods are particularly effective because they provide evidence of what the children are actually doing that can be tied to the context in which it was performed (Perry, 1998). Videotaping is a particularly effective observational technique because it stores verbatim conversations of students engaging in self-regulating activities. The researcher is able to compare and contrast differences in the students' self-regulated learning strategy over time without having to rely on the accuracy of his or her memory (Winne & Perry, 2000). This however explains why most researchers consider observational methods more objective than self-reports questionnaires and often pair them with interviews to gather students' reactions to the researcher's observations (Winne & Perry, 2000).

2.10.2: Measuring Co-regulated Learning Processes

To measure forms of co-regulation requires analyses aimed at capturing group regulation processes (Arvaja *et al.,* 2007). Group level processes describe the collaborative processes group members use to co-regulate each other as they work together on the given task in their group. Capturing this type of data requires an understanding of students' discussions and the tools they use to support their learning (Hmelo-Silver, 2003). In social theories of SRL, it is hypothesised that regulation takes place within a context, and as such researchers cannot examine learning without taking account of the context in which it occurred. Here, "context" refers to students' patterns of interaction and their use of common tools (Arvaja *et al.,* 2007).

While the research methodology in this area is limited, Arvaja *et al.* (2007) borrowed from process analysis to develop a method for measuring how students co-regulate a task. To analyze co-regulated processes in the group, researchers can conduct both quantitative and qualitative content analyses. Quantitative content analysis can enable the researcher to determine the frequency of occurrence of CRL behaviours during learning. Qualitative content analysis on the other hand can enable the researcher to bring out the major themes, noting the particular context in which they occur. For example, the researcher not only codes for instances of planning, but also describes the context in which planning occurred. Students' discussion during collaborative learning can be analysed to examine the communicative functions of individuals' co-regulated learning behaviours.

In order to analyse students' reactions to collaborative activity, self-report questionnaires are distributed at specific points throughout the task. These data are analysed to determine students' perceptions of their co-regulated learning behaviour in order to make inferences about how group members co-regulate the task. More importantly, this information serves as a method of triangulating the qualitative data, providing the researchers with a way to examine individuals' perceptions within the learning situation that were not "observable" in the qualitative analysis. Self-report data serve to complement and triangulate the qualitative data of group members' co-regulation processes (Arvaja *et al.,* 2007). However, no existing questionnaire was found suitable for measuring the co-regulated learning behaviour that students were expected to demonstrate in the present research. Therefore this research developed and validated a co-regulated strategy for learning questionnaire to be used in determining the CRL that students adopted in the context of this research. By embedding the research in context, using mixed methodology, and triangulating the data, this method espouses a holistic description of the co-regulated processes used in a task (Miles & Huberman, 1994). In regard to this present research, this was expected to provide significant challenges, and opportunities to enable valid inferences about science students' engagement in cognitive and metacognitive regulatory processes in a CSCL environment.

2.11: Conclusion

To summarise, this research investigated how collaborative group work served as an appropriate context in which to examine the development, use, and refinement of co- and self-regulated learning processes. The chapter started off with an overview of current theories and research of co- and self-regulated learning. Emphasis was placed on the social cognitive and socio-cultural theories of SRL. It was proposed that collaborative learning environments were an appropriate context in which to study co-regulatory behaviours among a group of students working on a given task. Discussion on how to encourage students to co-and self-regulate their learning behaviour during group learning was also presented in the review. Finally, it examined the data collection techniques that researchers have used to investigate self-regulated and co-regulated processes. In the next chapter, the research methodology will be presented.

CHAPTER THREE: Design and Methods

3.1: Introduction

This thesis examines co- and self-regulation processes that students use as they work in a computer supported collaborative learning (CSCL) environment over a period of time. The CSCL environment used in this research involved a computer based simulation that was used to support collaborative learning of various science topics. In order to measure the students' co-regulated learning (CRL) behaviours, it was necessary to develop and validate an instrument to measure CRL behaviour. Therefore Study 1 consisted of the development and the validation of the Co-regulated Strategies for Learning Questionnaire (CRSLQ) for a CSCL environment. In Studies 2, 3, and 4 students undertook scientific learning activities on Simple Circuits (SC), Flowering Plants (FP), and Blood Circulation (BC) respectively. These studies were carried out in order to investigate factors affecting the nature of CRL behaviour in CSCL environments as discussed in the literature review (Sections 2.8 and 2.10 respectively). The studies also enabled an investigation of the impact of supporting students with CRL and SRL prompts in a CSCL environment. In order to investigate co- and self-regulation processes that students use in a CSCL environment, the research questions outlined in Section 1.4 were explored through a mixed-method research design. Using a mixed methods approach for both data collection and analysis of this study provided the opportunity to gain a deeper understanding of the nature of the co-regulated learning strategies that students demonstrated when learning science over the course of this research (Igo *et al.* 2008).

This chapter focuses on the research design and methodology underlying this investigation. The overview for the development of this research is presented in Figure 3.1. The rest of the chapter provides a discussion of the following areas: (1) rationale for the research approach (2) overview of the research design (3) description of the research sample (4) methods of data collection (5) analysis and synthesis of data (6) ethical considerations. The chapter ends with a brief conclusion.

3.2: Rationale for the approach

This research employed a mixed methods approach. Mixed methods researches are those that combine the qualitative and quantitative approaches in the methodology of a single or multiphase study (Tashakkori & Teddlie 1998, 2003; Tashakkori & Creswell 2007). Often, in mixed studies, the researcher first conducts a qualitative phase of a study, then a quantitative phase or vice-versa (Creswell 1995; Tashakkori & Teddlie 2003; Teddlie & Tashakkori 2008). Using a mixed methods approach in data collection and data analysis offers educational researchers a path toward a deeper understanding of their findings (Igo *et al.* 2008). In this research, a mixed-method approach utilising a longitudinal-experimental research method guided data collection over a two school year period from the Autumn term in 2009 to the Autumn term of 2010. Bird & Hammersley (1996), Tashakkori & Teddlie (2003), Teddlie & Tashakkori (2008) are of the opinion that the use of several methods to explore an issue greatly increases the chances of accuracy. Mixed methods research is an expansive and pluralistic approach that "can answer a broader and more complete range of research questions" than a single method (Johnson & Onwuegbuzie, 2004). Furthermore, multiple methods are advantageous for capturing both depth and breadth of complex issues (Tashakkori & Teddlie 2003; Creswell, 2003).

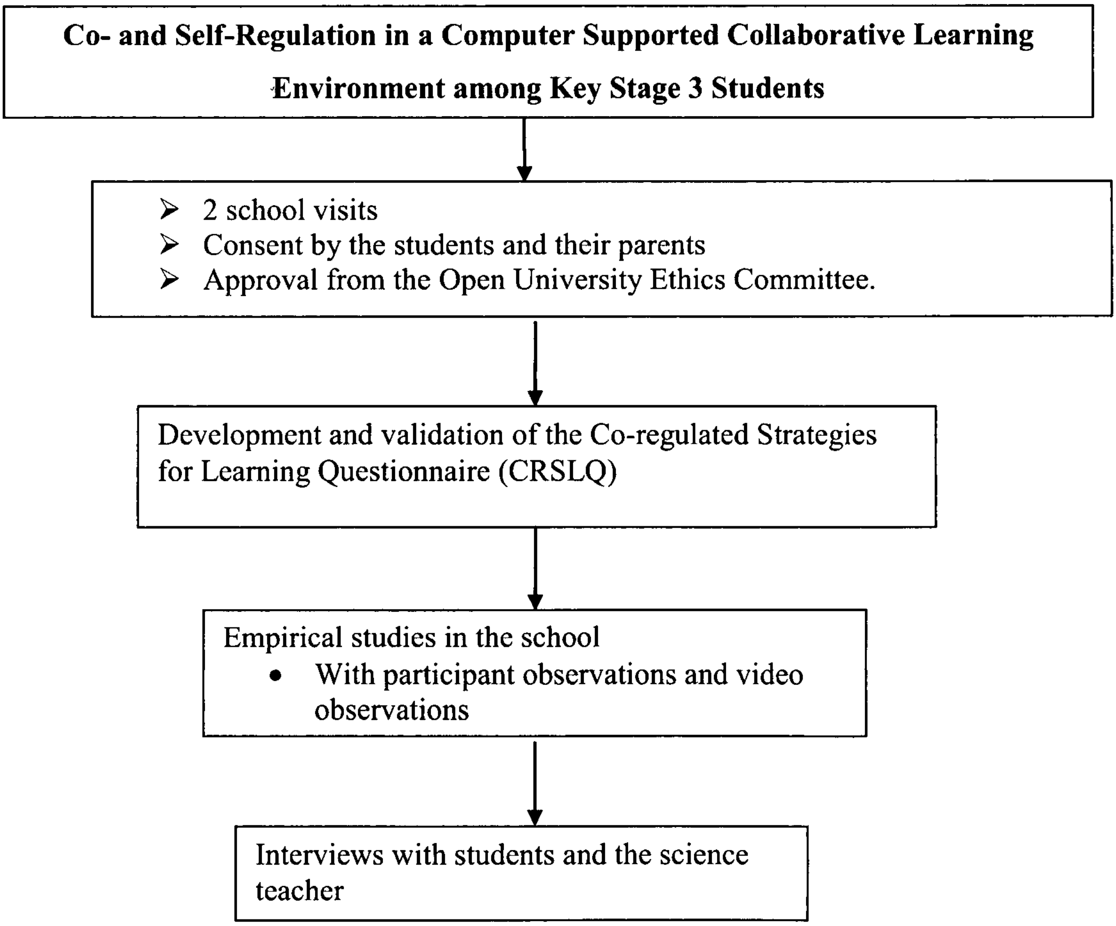


Figure 3.1: An overview of the development of this research

Therefore employing both qualitative and quantitative methodological tools for this study is expected to lead to more valid, reliable and diverse construction of outcomes in regards to understanding the dynamics of collaboration during the learning processes of scientific concepts by Key Stage 3 students.

Using the quantitative and the qualitative methods in this thesis helped in providing a more balanced approach, rather than adopting either a wholly qualitative or quantitative approach to the research. Whilst the quantitative approach was needed in order to investigate whether supporting students with CRL and SRL prompts made a difference in their CRL behaviour over time, it did not provide an in-depth view of the nature of co- and self-regulatory processes that students used during learning processes. Therefore, this was a research gap that the qualitative studies could fill with a view to identifying and analysing various categories of CRL behaviours that students demonstrate while learning science in a CSCL environment. The qualitative approach took a form of longitudinal observations of the students' interaction when learning various science topics in the classroom. Furthermore, adopting both quantitative data collection and analysis with qualitative data collection and analysis helped me to obtain a richer account of the issues identified in Section 1.4

3.3: Research design

This section gives an overview of the research design and the rationale behind the chosen design is also presented. In this research there were four studies. In the first study (Study 1), the Co-regulated Strategies for Learning Questionnaire (CRSLQ) was developed and validated. In Studies 2, 3, and 4 science tasks on Simple Circuits, Flowering Plants, and Blood Circulation were designed for students to learn by using a computer supported collaborative learning (CSCL) environment which involved computer based science simulation. The simulation was used to support collaborative learning of these science topics either by using paper-based activity or *InterLoc* (an online collaborative tool) (see Section 3.4.1). An overview of each of the studies showing the participants, data and methods is given below in Table 3.1.

In order to investigate the research questions outlined in Section 1.4, it was necessary to develop and validate Co-regulated Strategies for Learning Questionnaire (CRSLQ) for measuring the students' co-regulated learning behaviours.

Table 3.1: Thesis Research Design

STUDY TYPE/ TIME PERIOD	SOURCE OF DATA/ NATURE OF DATA COLLECTED	PARTICIPANTS	METHODS USED
STUDY 1 (Autumn Term 2009)	**Classroom artefact;** -CRSLQ	214 students	Questionnaire validation
STUDY 2 (Spring Term 2010)	**Classroom artefacts;** -CRSLQ -SRSLQ -Knowledge test on SC -Activity sheets **Observations:** -Audio (MP3) recordings -Video recordings -Participant observation	40 students in total. (20 in each of the experimental and the control groups)	-Lesson on Simple Circuit(SC) -Pre- and post-CRSLQ - Pre- and post-SRSLQ - Knowledge pre- and post-tests on SC
STUDY 3 (Summer Term 2010)	**Classroom artefacts;** -CRSLQ -SRSLQ -Knowledge test on FP - *InterLoc* Chatscript **Observations:** -Audio (MP3) recordings -Video recordings -Participant observation	40 students in total. (20 in each of the experimental and the control groups)	-Lesson on Flowering Plants(FP) -Post- CRSLQ -Post- SRSLQ - Knowledge pre- and post-tests on FP
STUDY 4 (Autumn Term 2010)	**Classroom artefacts;** -CRSLQ -SRSLQ -Knowledge test on FP - *InterLoc* Chatscript **Observations:** -Audio (MP3) recordings -Video recordings -Participant observation	40 students in total. (20 in each of the experimental and the control groups)	-Lesson on Blood Circulation(BC) -Post- CRSLQ -Post- SRSLQ - Knowledge pre- and post-tests on BC
	Interviews: -Audio (MP3) recordings of Small group interviews - Audio (MP3) recordings of teacher interview	- 5 students in each of the experimental and the control groups - 1 Science teacher	

After validating the questionnaire in Study 1, the questionnaire was administered to the participants in Study 2 where the effects of co- and self- regulated learning (CRL and SRL) prompts on the students' co-regulated learning behaviours and academic performance were investigated. In Study 2, an experiment was set up which involved two versions of a CSCL environment that were used to teach the topic "Simple Circuits". The two versions of the CSCL environment represented two conditions in which either CRL and SRL-prompts or SRL-only prompts were provided to the students in each condition. An experimental approach in which participants were randomly assigned to either experimental (CRL and SRL-prompted group) or control (SRL-prompted group) learning conditions was adopted because it minimised the risk of extraneous variables that might have confounded the outcome of this present study (Cohen & Manion, 1989).

The CRL and SRL-prompts introduced into the students' tasks when learning Simple Circuits were expected to encourage co-regulated learning behaviours that were necessary for the collaborative learning in a CSCL environment. The prompts used in the CRL and SRL-prompted condition included: *Please try and comment on goals of others in your group; It will also be good if you can all agree on three goals here* among many others (see Section 3.5.1 for further details). In the control group condition, SRL-only prompts were incorporated into the students' learning tasks. The SRL-prompts included the following: *Can you look through the whole activity before starting to see how it is organised? Please set three specific learning goals that you want to achieve in this activity*. The students were not supported with any co-regulated learning prompts.

Students in both learning groups completed the Co-regulated Strategies for Learning Questionnaire (CRSLQ), the Self-Regulated Strategies for Learning Questionnaire (SRSLQ) before they were embarked on working in a CSCL environment consisting of either a computer based science simulation alone or a combination of the science simulation and *the InterLoc*, a collaborative tool. The essence of administering the questionnaires was to ensure that the degree of usage of both CRL and SRL strategies by students in both groups was equal prior to their embarking on working in a CSCL environment incorporated with CRL and SRL or SRL only prompts. Pre- and post-knowledge tests on Simple Circuits (KTSC) were used to determine the level of prior knowledge of students on Simple Circuits and helped in evaluating the effect of CRL and SRL prompts on the students' academic performance. In Study 2, students' worked on the activity sheets on Simple Circuits and the activity sheets were scored. The activity sheets' scores also helped in investigating the effect CRL and SRL prompts on the students' academic performance.

The qualitative aspect of Study 2 involved the classroom observations and video observation in which the researcher and the science teacher undertook the roles of facilitators and observed students as they worked together. The facilitation role involved helping students during the science lessons when they requested help, while the observation role involved note taking during and after all the lessons by both the researcher and the science teacher. Patton (1987) stated that field notes are the description of what was observed during the field work; in this study, the participant observation helped in identifying the students' behaviours and their interaction patterns when learning in a CSCL environment. The transcribed notes obtained via video observations as well as written notes from classroom observation were coded according to the emerging categories of how students made use of CRL skills when learning science in a CSCL environment (see Section 3.7.1.5). The students' spoken interactions as they learnt Simple Circuits were also collected through audio recording for analysis.

Also because of the paucity of longitudinal analysis in the research on CRL and SRL, it was decided to investigate the effect of prompting students with co- and self-regulated learning behaviours when learning collaboratively in a computer based science simulation learning environment over a period of time. Therefore, Studies 3 and 4 were also designed to achieve this aim. In Studies 3 and 4, students learnt Flowering Plants and Blood Circulation respectively; these learning tasks made use of the *InterLoc* (a communication tool that enabled students to collaborate effectively as described in section 3.4.1).

During Studies 3 and 4, students were in the same groups as they were during Study 2. At the beginning of each of Studies 3 and 4, pre- knowledge tests on Flowering Plants (KTFP) and pre- knowledge tests on Blood Circulation (KTBC) were administered to the students to determine their prior- knowledge on each of these topics. Students worked collaboratively on Flowering Plants and Blood Circulation using a computer based science simulation learning environment after the administration of pre- knowledge tests. After working on Flowering Plants and Blood Circulation, post-CRSLQ, post-SRSLQ and post-knowledge tests on Flowering Plants (KTFP) and post- knowledge tests on Blood Circulation (KTBC) were administered to the students in their groups as shown in the research design (see Table 3.1).

In each of Studies 3 and 4, qualitative data were collected in the form of classroom observations and video observation in which the researcher and the science teacher undertook the roles of facilitators and participants' observer (as in Study 2). All the observations made for Studies 3 and 4 were also coded according to the emerging categories (anticipated key CRL indicators) of how students made use of CRL behaviours when learning science in a CSCL environment (see Section 3.7.1.5). The students' *InterLoc* chat scripts containing written expressions of their interactions as they learnt Flowering Plants and Blood Circulation, written notes from the classroom observation, and the small group interview with a group of students from experimental group and the control group were also collected for analysis. The science teacher who participated in the study was interviewed at the end of the study in order to get her perception of how students co-regulated their learning behaviours over the three studies. This research also employed qualitative data to investigate the changes in the students' co-regulated learning behaviour over a period of time. The next section discusses the rationale for the longitudinal method adopted in this study.

3.3.1: Rationale for longitudinal methodology

As a form of research methodology, longitudinal methodology involves repeated observations of the same variables in the same participants over a period of time. Longitudinal studies enable the researcher to analyse the duration of social phenomena, highlight similarities, differences and changes over time. A longitudinal research design was deemed appropriate for this study in order to investigate changes in the CRL and SRL behaviours that students learning scientific concepts in a CSCL demonstrate over time (see Section 1.4).

According to Ruspini (2002), gathering information about the same individuals using the same questions at intervals provides the most reliable data on change in knowledge or attitude. Therefore, employing longitudinal approach using repeated measures in this study helped in monitoring changes and developments taking place within the groups over a period of time. Meanwhile, the pre-tests enabled me to assess differences between the experimental and the control groups on the dependent measures of the usage of CRL and SRL strategies after the intervention. Subsequent post-tests were used to verify changes that occurred in CRL and SRL behaviours in each group after exposing them to the learning environment over a period of time. The changes in the CRL and SRL behaviours were assessed by comparing the pre-test measures for each group with their post-test measures at each interval.

Furthermore, longitudinal studies in particular allow for dynamic measures such as how the demonstration of CRL behaviours by students changes over time or measures of association between the demonstration of CRL behaviours and the incorporation of either CRL and SRL or SRL prompts into the CSCL environment. For example, this was reflected in the structure of the chosen questionnaires and the underpinning theory of co- and self-regulation. The theories of both co- and self-regulation suggest that the more an individual does something the more they get better at it, that their co- and self-regulation will increase, and that other factors will be dependent on CRL indicators (Schmitz and Wiese, 2006). For instance, if an individual improves their co- and self-regulation behaviours then another factor like their motivation towards learning will also increase (Schmitz and Wiese, 2006). This present study investigated how co-regulation variables changed over time when students were learning science in a CSCL environment. Also, a longitudinal design was employed because I did not believe that I would get a true picture by focusing solely on the short-term phenomena and by adopting a multi-method approach to include the qualitative element, I knew I could obtain much richer, valuable data from the student's own experiences of how they improve in collaborative discussion in their groups over time. Both quantitative and qualitative data collected in this study were investigated longitudinally within and between the groups of the participants. Although the longitudinal approach has many advantages over studies based on one-time observations, it is also beset with many methodological problems, some of which have led to a variety of design refinements which were carried out in this study.

3.4: Procedure

For the validation of the Co-regulated Strategies for Learning Questionnaire (CRSLQ), the researcher explained to the science teacher the purpose and the process of validating the questionnaire before using it for Studies 2, 3 and 4. In agreement with the teacher, the questionnaires were administered to other students in year 7 and 8 whom we were sure would not participate in the studies 2, 3 and 4. After collecting the questionnaire back in the Autumn Term of 2009, the researcher analysed the data to test for both content and construct validity as well as the reliability of the instrument (see Chapter 4).

In order to progress with Studies 2, 3 and 4, consent forms were distributed in January 2010, and teachers collected them during regular science classes. All students (214 in number) and their parents gave consent to participate in the study. It should be noted that it was explained in the consent letter and form sent out to both students and their parents that the science activities to be undertaken by students were part of the school science curriculum and that the study would take place during the students' normal science lessons over three terms.

Each of the Studies 2, 3 and 4 was undertaken over three separate 50-minute lessons. During the first lesson of Study 2, students completed the pre-CRSLQ, pre-SRSLQ, and pre- knowledge test on simple circuit (KTSC). They were given 15 minutes to complete each questionnaire and the knowledge test on simple circuits (KTSC). The second lesson took place in the school's computer suites. Students were introduced to the Sunflower science simulation programme teaching the SC. Students sat in eight sub-groups of five (four sub-groups in each of the experimental and the control group), each person with their own computer and they were encouraged to discuss the given task together as a group.

Learning activity sheets with either CRL and SRL prompts or SRL prompts only were designed for the study 2, and students were instructed to work collaboratively using a science simulation on SC. Thereafter, they were asked to discuss their learning with other members in their group. Two versions of the learning activity sheets designed for use by students in the respective groups are described in Section 3.7.4.

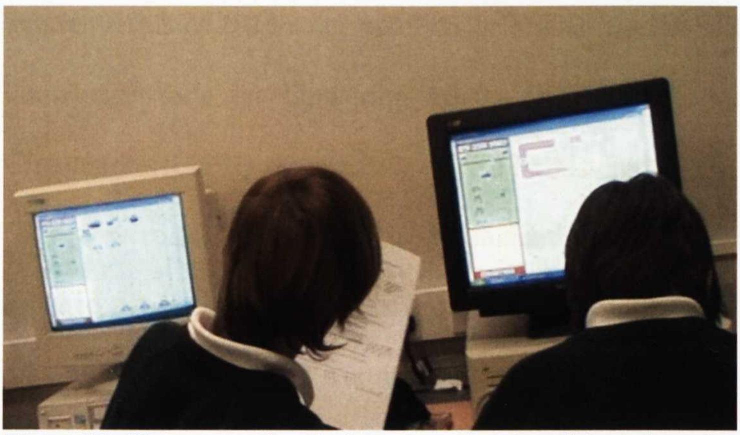


Figure 3.2: Picture showing students engaging in collaborative science learning using computer-based simulation and discussing the task together during study 2

One video camera was positioned in each of the experimental and the control group for observation as they learnt in the computer suites. These video cameras were focused on one particular sub-group in each of the experimental and the control groups throughout the research (see Figure 3.2). This helped in capturing processes that the group of students used in co-regulating their learning behaviours. The researcher also collected all the four sub-groups' spoken interaction through audio recording. Furthermore, both the researcher and the science teacher observed the students in both learning conditions as they learnt simple circuits. The third lesson in study 2 was used to administer post- CRSLQ, post-

SRSLQ and post-KTSC. Thereafter, measurements of scores obtained by the participants in each of the instruments (CRSLQ, SRSLQ, and KTSC) before and after exposing them to the CSCL environment incorporated with either CRL and SRL or SRL prompts were reported. Content analysis was also carried out on the audio and video recordings, interview, and observation notes, to investigate the process of students' co-regulation in the groups. Table 3.2 provides a summary of the categories of CRL- behaviours that were observed when the students learnt in groups.

Turning to the procedure used during studies 3 and 4, note that the purpose of these two studies was to investigate the effect of the co-regulated learning prompt on the students' co-regulated learning behaviours when learning in a CSCL environment over time. Each of the studies 3 and 4 was carried out during three separate 50-minute lessons in summer, and autumn terms of 2010 respectively. During the first set of lessons of Studies 3 and 4, pre-knowledge tests on Flowering Plants (KTFP) and pre- knowledge tests on Blood Circulation (KTBC) respectively were administered to the students. Pre-CRSLQ and pre-SRSLQ were not administered to the students during the first lessons of Studies 3 and 4 in order to avoid over exposure of the participants to the questionnaire. They were given 15 minutes to complete each Knowledge test on Flowering Plants and Blood Circulation.

The second set of lessons took place in the same two computer suites in the school employed for study 2 as reported above. During the lessons, students were introduced to the computer based science simulation learning environment, consisting of the Sunflower Science Simulation programs, which were used to teach Flowering Plants and Blood Circulation. In addition to the Sunflower Science Simulation programme, the CSCL environment also consisted of *InterLoc* (a communication tool that was developed to support collaboration) (See section 3.5.1). Students sat in sub-groups of five as they sat during study 2, each with his or her own computer and were encouraged to discuss the tasks together as a group by using *InterLoc.*

Participants in both experimental and the control groups were facilitated and observed by the researcher and the science teacher respectively in each class as they learnt collaboratively. The same group of students that were videotaped during study 2 in both learning conditions were also videotaped for Studies 3 and 4. Students' work in the InterLoc (InterLoc chat scripts) was also saved for the purpose of analysis. Moreover, both the researcher and the science teacher continued to facilitate and observe students in the control and experimental groups respectively as they learnt during Studies 3 and 4.

Finally, the third lesson in both studies 3 and 4, were used to administer post-CRSLQ, post-SRSLQ and post-Knowledge tests on the Flowering Plants (KTFP) and Blood Circulation (KTBC) (for Studies 3 and 4 respectively). Both the quantitative and qualitative data obtained during Studies 3 and 4 were combined with data collected during study 2 to investigate co-regulation over time. The next section gives a brief description of the learning environment used in this research as well as the two learning conditions which formed between-subject variables in this research.

3.4.1: Learning Environment/Learning Conditions

In order to achieve the aims of the research outlined in Chapter one, an interactive learning environment including science learning activities was put together for the purpose of this research. The learning environment composed of a computer based science simulation and a collaborative component. The computer based science simulation employed in the research is called Sunflower for Science Simulation. The simulation was produced by the Sunflower Company, a company which produces science software for schools. Their simulations consist of a suite of curriculum-focused programmes designed to help teachers in tackling problematic topics in secondary biology, chemistry and physics. The present research made use of their simple circuits, flowering plants and blood circulation simulations for designing collaborative learning activities where CRL and SRL behaviours were encouraged.

In study 2, there was a technical problem with the operability of *InterLoc* (a collaborative tool). Consequently, it was decided that a CSCL environment consisting of a science simulation but incorporated with paper-based learning activity sheets and prompted with either CRL and SRL or SRL only instructions be employed in order to explore the research objective in study 2. This explains the rationale for the design of study 2.

During the second lesson of study 2, students worked through Simple Circuits simulation and expressed their understanding of the topic by writing answers on the space provided on the activity sheets. Two types of learning activity sheets were designed on the topic which enabled learners to interact with and use virtual components in the simulation such as wires, bulbs, ammeters and voltmeters to make circuits. Students were able to see how electrons flow in a circuit. Students in both the experimental and the control groups were provided with an introduction at the beginning of the lesson, so that they would know what they were supposed to do. During study 2, students in both the experimental and the control groups engaged in collaborative synchronous discussion by talking about the activity together as a group. Both the researcher and the science teacher also encouraged the students to discuss their work together in their groups. The researcher and the science teacher also read out the instructions to all the students to be sure the learners understood what they were expected to do before they started. Students in the experimental group were given activity sheets that contained both co-regulatory and self-regulatory learning strategies prompts along with instructions on how to work with the simulation. A list of the co- and self-regulation prompts is presented in Table 3.2.

The co- and self-regulatory learning prompts in the activity sheets of the experimental group supports students to co-regulate their learning behaviours when learning in their various groups. These prompts were in italicised texts, and were based on the developed Co-regulated Strategies for Learning Questionnaire (see Chapter 4). The CRL and SRL-prompts covered metacognitive strategies that students used when learning as a group in a CSCL environment.

Table 3.2: Overview of the co- and self-regulation prompts in the experimental condition

CRL and SRL Categories	o Co- and Self-Regulation Prompts
Planning	o *Can you all look through the whole activity before starting to see how it is organised?*
	o Please set three learning goals for this activity.
	o *Please try and comment on goals of others in your group. It will also be good if you can all agree on three goals here.*
	o *Can you all agree on the time you would like to spend on each goal? Note that you have just 50 minutes for the whole activity.*
	o Using your everyday experiences, please tell each other what you know about electricity, electrical current and electric circuits. You can give some examples.
Monitoring	o Please raise your hand if you need any help at any point during the activity.
	o Please take note of the concepts you do not understand in the task and ask for help from others.
	o *Please write down your conversation with others in your group*
	o *Please check your answers with other group members.*
	o *Please make sure you remind others to write down their observations.*
Evaluating	o *Ask questions from your group members to be sure you are on the right track.*
	o If you have any questions at this stage, please type them here.
Effort and time management	o *Please check the time and remind others of the time remaining to complete the task.*
	o You have spent more than half of your time
	o You have only few minutes to round up the task
Peer learning and help seeking	o *Ask your group members if they need help with the group activity and try to respond to them.*
	o *If you have any questions, please ask others.*

Students in the control group were given activity sheets that contained self-regulatory learning strategies prompts only. A list of the self-regulation prompts is presented in Table 3.3. The SRL-prompts were also in italicised texts, and covered the metacognitive strategies that individual students used when learning.

Table 3.3: Overview of the self-regulation prompts in the control condition

CRL and SRL Categories	Self-regulated learning prompts
Planning	o Can you look through the whole activity before starting to see how it is organised? o Please set three specific learning goals that you want to achieve in this activity o Please indicate how much time you intend to spend on each goal? Note that you have just only 50 minutes for the whole activity. o Using your everyday experiences, please write what you know about electricity, electrical current and electric circuits. You can give some examples.
Monitoring	o Please raise your hand if you need any help at any point during the activity. o Please take note of the concepts you do not understand in the task and ask for help from your teacher.
Evaluating	o If you have any questions at this stage, please type them here.
Effort and time management	o You have spent more than half of your time o You have only few minutes to round up the task
Peer learning and help seeking	o If you need help please ask.

In addition to the Sunflower Science Simulation programme employed in Study 2, during Studies 3 and 4, students' learning tasks were designed in a communication tool that enabled students to collaborate effectively. *InterLoc* according to Ravenscroft & McAlister, (2006), is described as a socio-cognitive tool which mediates, structures and manages educational dialogue games. *Interloc* has some features which allow the teachers/tutors to adapt it for different use based on their circumstances. *Interloc* was adapted for use in this research because it enabled a synchronous discussion during the lesson. Also, the researcher was able to prepare the learning tasks which contained co- and self-regulated learning prompts for the experimental group and self-regulated learning prompts for the control group as well as instruction on how to work with the simulation (See Tables 3. 2 and 3. 3). Figure 3.3 shows an example of *InterLoc* activity prepared for the students. Students sat in sub-groups of five in both Studies 3 and 4. These five students were assigned to the same *InterLoc* 'room'. Each student was given a user name and password which enabled them to access *InterLoc.* The researcher and the science teacher explained how the students would use the tool in their groups; students were also encouraged to discuss the given tasks together as a group by using *InterLoc.* Participants in the experimental and control groups were facilitated and observed by the researcher and the science teacher respectively as they learnt collaboratively with the Sunflower Flowering Plants (FP) and Blood Circulation (BC) science simulation programmes.

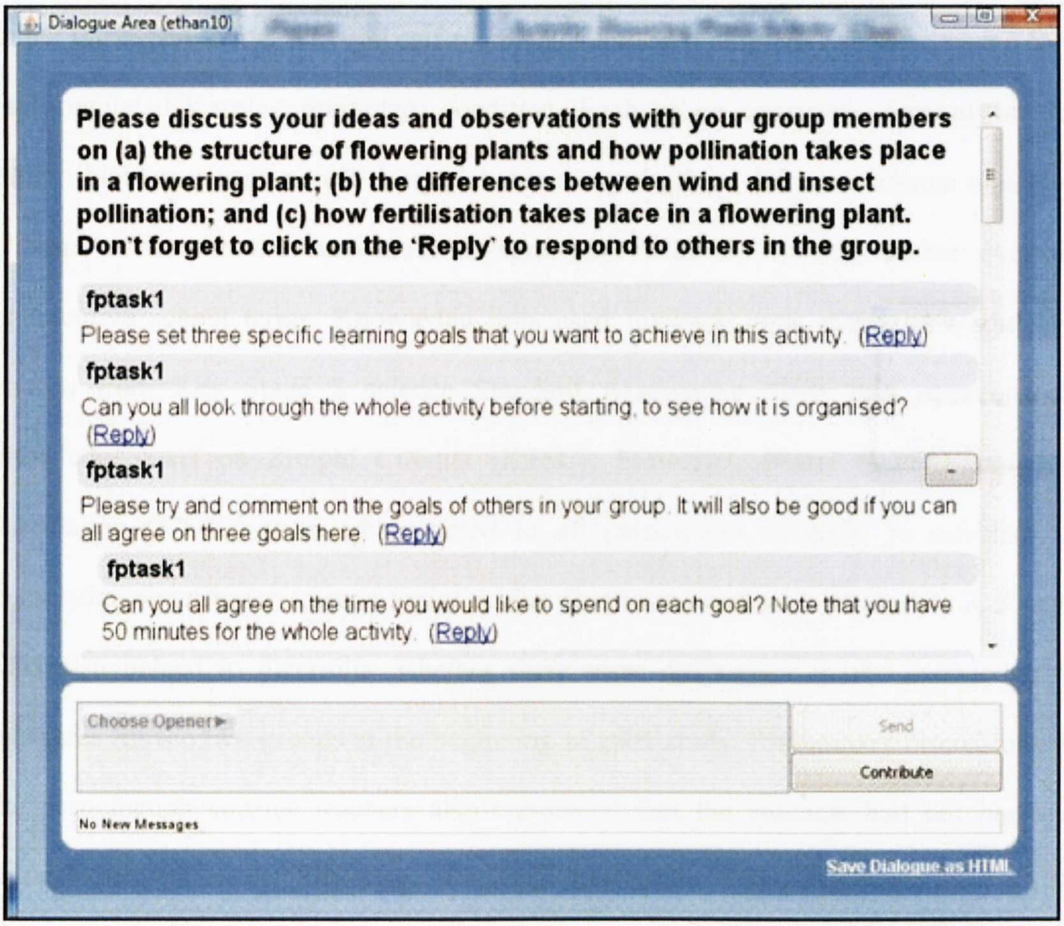


Figure 3.3: InterLoc tool for collaborative discussion

3.5: Sampling Participants

This research employed mixed methods sampling techniques to investigate the research questions highlighted in section 3.1. The research took place in a high school in Bedfordshire. The school is a middle school for 8 to 13 year old students (i.e. is made up of Key stages 2 and 3 only). The school has two computer suits with 22 to 24 computers in each. This met the technological needs of this present research. A total of 214 year 7 and 8 (11-13 years old) students who didn't participate in studies 2, 3, and 4 were used to pilot the developed Co-regulated Strategies for Learning Questionnaire (CRSLQ) during Study

1. This group of student was chosen because they were similar in age to the students who participated in Studies 2, 3, and 4.

For Studies 2, 3 and 4, 40 year 7 students (11-12years olds) were randomly assigned to either the experimental (co- and self-regulated learning prompted) condition or the control (self-regulated learning prompted) condition. Each group consisted of twenty students. After obtaining permission to carry out this research, three different science topics were chosen to fit with the curriculum in agreement with the science teacher over three consecutive school terms. Knowledge tests used for each topic during this study were chosen from Key Stage 3 science Standard Assessment Tests past questions. Pre-knowledge tests on Simple Circuits (KTSC), Flowering Plants (KTFP) and Blood Circulation (KTBC) were administered to all participants in order to establish their knowledge about those science topics during first lessons of each of Studies 2, 3, and 4. This also helped to determine whether there were differences in the knowledge tests measures for the two groups at the beginning of each study. Preliminary discussions with the participating science teachers also confirmed that the students had not previously studied the topic in the Key Stage 3 science curriculum. The participants used a CSCL environment (consisting of either science simulation only or a combination of science simulation and *InterLoc*) to study Simple Circuits, Flowering Plants, and Blood Circulation in the science curriculum over a total period of three terms.

Purposive random sampling was used for an in-depth study of a group of five students in each of the experimental and the control groups. This sampling strategy involves taking a random sample of a small number of units from a much larger target population (Kemper *et al.*, 2003, Teddlie & Yu 2007). Out of the four sub-groups in each of the experimental and the condition, one group was chosen in each group to examine various co-regulatory patterns in greater depth. In this research, the random nature of this sampling procedure is characteristic of probability sampling, and the small number of cases it generates is characteristic of purposive sampling.

Kalafat & Illback (1999) used purposive random sampling in evaluation of a large state wide programme that used a school-based family support system to enhance the educational experiences of at-risk students. Before the intervention began, Kalafat & Illback used a purposive random approach to select a few cases from the overall target population. The researchers then closely followed these cases throughout the life of the project. According to Kalafat & Illback, using purposive random sampling of a small number of cases from a much larger target population added credibility of their evaluation processes. The qualitative data collected from the small sample were used to complement the larger-scale, quantitative research. In this research, the same approach was adopted by focusing on a particular group of students in both groups over the three studies that took place in the classroom. These same students were then interviewed after the three empirical studies. Adopting this sampling technique added credibility to the result of this research because it enabled me to really concentrate on instances of co-regulation between the experimental and the control groups.

3.6: Instruments of data collection:

This section discusses the instruments used in collecting data for this research namely: the Self-Regulated Strategies for Learning Questionnaire (SRSLQ), the Co-regulated Strategies for Learning Questionnaire (CRSLQ), knowledge tests (on simple circuits (KTSC), Flowering Plants (KTFP) and Blood Circulation (KTBC)), learning activity sheets, observations and interviews. The two questionnaires were adapted from existing measures in the literature and are described in detail below with other instruments.

3.6.1: Self-Regulated Strategies for Learning Questionnaire (SRSLQ)

Participants taking part in this research completed the Self-Regulated Strategies for Learning Questionnaire (SRSLQ) on paper (see Appendix A). The SRSLQ is a sub-set of the Motivated Strategies for Learning Questionnaire adapted from (Pintrich *et al.*, 1993). This study employed the SRSLQ because it assesses the degree to which students regulate their self-regulatory strategies. The SRSLQ consisted of 29 items detailing metacognitive self-regulation, time and study environment, effort regulation, peer learning and help seeking. The SRSLQ has reasonably good construct validity, internal consistency, reliability, and predictive validity (Pintrich *et al.* 1991). For example, the SRSLQ consists of various subscales with example statements as shown in Table 3.4 below.

Table 3.4: List of sub-scale in SRSLQ with examples

Subscale(s)	Example
Metacognitive self-regulation	During science lessons, I set goals for myself in order to direct my activity in the class
Time and study environment	During science lessons, I make good use of my time
Effort regulation	I often feel so lazy or bored when I am doing a science activity that I quit before I finish what I planned to do
Peer learning	During science lessons, I often try to explain the activity to my classmates
Help seeking	When I can't understand the science activity, I ask other students in the class for help

In order to measure self-regulatory learning strategies, students were instructed to respond to statements based on a six-point scale where the number indicated the degree to which their group did what the item described. Choices included very true of me (6), somewhat true of me (5), moderately true of me (4), somewhat untrue of me (3), untrue of me (2), and not at all true of me (1). The questionnaire items which had been previously used for college students were considered to be suitable for Key Stage 3 science students.

3.6.2: Co-Regulated Strategies for Learning Questionnaire (CRSLQ)

The Co-Regulated Strategies for Learning Questionnaire (CRSLQ) contained 21 items and was intended to measure the same constructs as the Self-Regulated Strategies for Learning Questionnaire (SRSLQ) (see Section 3.6.1). However, the CRSLQ asked students to respond on paper to items that measured their co-regulation behaviours instead of their individual regulation strategies. For example, statements such as, "During science lessons, I set goals for myself in order to direct my activity in the class" was restated as "When working in our science group, I try to make sure we set learning goals and allocate time for various activities" (see Appendix B). The sub-scales included in this questionnaire are shown in Table 3.5 below. (see Appendix B for detail).

Table 3.5: List of sub-scale in CRSLQ with examples

Subscale(s)	Example
Planning	When working in our science group, I try to make sure we set learning goals and allocate time for various activities
Monitoring	When working in our science group, I often ask for clarification if I do not understand something
Evaluating/ efforts regulation	When working in our science group, I try to make sure we all make efforts to achieve our set goals
Help-seeking and help-giving	When working in our science group, I often help others who have difficulties in understanding the group task

Students responded to statements based on a six-point scale where the number indicated the degree to which their group did what the item described. Choices included very true of me (6), somewhat true of me (5), moderately true of me (4), somewhat untrue of me (3), untrue of me (2), and not at all true of me (1).

3.6.3: Knowledge tests: on Simple Circuits (KTSC), Flowering Plants (KTFP) and Blood Circulation (KTBC)

In order to investigate the students' academic performance on various science topics used in this present research, a paper-based test was developed for each topic on Simple Circuits, Flowering Plants, and Blood Circulation. The format of each test was similar to that which is used for the Key Stage 3 science Standard Assessment Tests. There were two parts to each of the knowledge tests, the first part included 7 multiple-choice questions, each with five alternatives. The students were instructed to choose the correct answers from the given options by placing a tick in the box next to their chosen answer. The second part of each of the knowledge tests was a labelling task: students were asked to label 5 components of the circuit; the reproductive organs and the heart during studies 2, 3 and 4 respectively (see Appendix C.1- C.3 for details). The pre-knowledge test and post-knowledge tests were identical in all the studies, as these tests aimed to capture students' conceptual knowledge of those topics before and after learning in their various groups. All the knowledge tests used in this research were validated by the three supervisors of this research who are expert in the field. The science teacher also worked through all the tests to make sure they were suitable for the students.

3.6.4: Students' activity sheets

Two types of students' activity sheets were designed for the purpose of this research in Study 2. The activity sheets were designed around the Sunflower Simple Circuits simulation. Activity sheets for the experimental group consisted of co- and self-regulated learning prompts (Appendix D.1) whereas the activity sheets for the control group contained self-regulated learning prompts only (Appendix D.2). Students were encouraged to work together as a group. This served as an avenue for the researcher to investigate co- and self-regulation in the classroom settings. Students in both the experimental and the control groups reported their predictions, observations, and inferences on the given tasks by filling in the spaces provided in the activity sheets. The students' activity sheets were collected after the lesson and scored for academic performance.

3.6.5: InterLoc Chat script

In Studies 3 and 4, both the experimental and the control groups worked on Flowering Plants and Blood Circulation in a CSCL environment combining *Interloc* and a simulation rather than in a CSCL environment combining simulation and paper based activity sheets. *Interloc* was employed as an electronic version of the paper-based activity sheet used during Study 2. It enabled the researcher to prepare and group students into groups of five electronically, therefore, students were able to express their ideas on the science topic being discussed by typing on the screen. As with the activity sheets in Study 2, the students in the experimental group were prompted with the same CRL and SRL behaviours while the students in the control group were prompted with the SRL behaviours only (see Appendix D.3 to D.6 for the paper version of Flowering Plants and Blood Circulation activity sheets for the experimental and the control groups). Students were instructed to work collaboratively in their groups, they responded to various questions on the tasks set by the researcher and also responded to each other's contributions, questions and comments on the tasks. At the end of each of the Studies 3 and 4, researcher saved the students' work on the *InterLoc* and the data enabled her to investigate the co-regulatory behaviour that emerged as students learnt in their groups.

3.6.6: Observation of the Participants

In order to investigate co-regulatory behaviours in CSCL effectively, additional qualitative approaches were used in this research. Observing what the students were doing during the lessons provided a valid basis for accurate descriptions of what learners were doing instead of what they remembered or thought that they were doing (Turner, 1995). This approach was adopted in order to relate students' co-regulatory behaviour to the conditions required by the tasks. The use of observation techniques decreases difficulties associated with measuring the process of CRL in young learners. Observation also helped in triangulating the questionnaires data. According to Turner (1995), this approach is associated with measuring the process of task performance in students. Observations were recorded in two ways; the observation notes and the video recording.

During the lesson, pupils were assigned to a computer each, which consisted of a desktop computer connected to "my science folder" on the individual students' computer. A video camera was directed at one sub-group in each of the experimental group and the control groups in such a way to capture the sub-group's interaction with each other and the learning environment. I tried as much as possible to set the camera to the students' side profile and what appeared on the computer screens. The aim was to collect richer observational data in both the experimental and the control groups during science lessons.

Although it is understood that there is a limited amount of data that a video camera could capture in the classroom, in this research the video data collected enabled me to have in-depth data on the case study students over the three studies. The video cameras in both classrooms were positioned to minimise disruption during the pupil's learning.

3.6.7: Interviews

In addition to the observational data, semi-structured interviews were conducted with the video recorded students in each of the experimental group and the control group. This was a form of small group interview. The science teacher who participated in this research was also interviewed. The objectives of the interviews were firstly to fill in the possible gaps in the data that could be lacking in the quantitative data and could be missing from the observational data too. Secondly, the interview data with a smaller group in each of the learning conditions enabled me to gather different perspectives of the learning processes from the students and the teacher. These factors explain why the interviews were conducted in this research to further support and inform issues that the research addressed.

Having worked with the students and the teacher over three consecutive terms, a semi-structured approach to questioning was chosen so that the interviews would appear less intimidating (especially for the video recorded students). I was able to ask the students some other follow-up questions based on their replies and responses to some of the prepared interview questions. This did not interfere in any way with the natural flow of my conversation with the interviewees. Doing the group interview at the end of the three studies enabled me to gather general information at the end of the research. This included the extent to which the students enjoyed working in their groups and learning science in a CSCL environment, the problems they encountered with the simulation and the *InterLoc* (technical or otherwise). Examples of questions that the students in both groups were asked are as follows:

- Did you enjoy working in your group?
- Did you all set learning goals and allocate time for your various activities?
  - Follow up question: Can you say a bit more about how easy or difficult you found the activities?
- Did all your group members participate in the discussions to reach an agreement?
  - Follow up questions: (a) What made everyone in your group participate in the activities? And (b) Do you know why some students in your group didn't participate? (See Appendix E for details).

In order to investigate the nature of the co-regulatory behaviours that the students used in their groups when learning in a CSCL environment, the science teacher's feedback was very important to this research. This enabled me to gather information about the learning process of the students as observed by their science teacher. The teacher's responses helped in recapping the processes of co-regulation when students were working as a group in a computer supported collaborative learning environment. Examples of interview questions addressed to the teacher are as follows:

- Do you think the activities undertaken so far in this research were helpful to the pupils' understanding of scientific concepts? If yes can you think of an example?
- Did the students develop skills of collaborative learning during the study?
  - Did they plan, monitor and manage their time effectively? (See Appendix F for details).

The interview data were transcribed in full, coded and analysed.

3.7: Data Analysis techniques

This research employed mixed analytic procedures to answer the research questions outlined in Chapter 1. The details of quantitative and qualitative methods of analysis are given below.

3.7.1: Quantitative Analysis Procedures

Among the different quantitative analyses were factor analysis and reliability analysis, carried out on CRSLQ designed for the purpose of this research, during Study 2 (see details in Chapter 4). Multivariate analysis of variance (MANOVA) and Student's *t* test were also used in analysing quantitative data collected from students' scores on CRSLQ, SRSLQ, and KT during Studies 2, 3 and 4. Quantitative content analysis was also used to investigate the occurrence of CRL categories in both the experimental and the control groups. Brief discussions of the relevant characteristics of each quantitative analysis procedure used are given below.

3.7.1.1: Factor analysis

This is a statistical procedure used to explain the variability in a relatively large number of observed variables in terms of a smaller number of unobserved "factor" variables. In this sense, factor analysis is employed as a data reduction technique in which factors were linear combinations of the variables and the relationships among the observed variables are used to reduce the dataset. I also used factor analysis as a construct validity tool in this study. Kerlinger (1986) writes, "It may be called a constitutive meaning method, since it enables the researcher to study the constitutive meanings of constructs and thus their construct validity" (p. 590). Specifically, I used Principal Axis Factoring (PAF) to compute the best linear combination of the variables in the CRSLQ. The result of this analysis was used to construct factor scores and to confirm the construct validity of the underlying constructs I intended to measure in the questionnaire. Therefore, for the purposes of this research, factor analysis was used to confirm the underlying constructs in the CRSLQ.

3.7.1.2: Reliability analysis

The purpose of a reliability analysis is to measure the stability or internal consistency of results. In general it provides an estimate as to how consistently participants perform either over time, format, or on items or sub-tests within a test. For the purposes of this research, I was concerned with the latter; that is, consistent performance of participants on a sub-set of items within the questionnaire. If participants performed consistently on a sub-set of items within the questionnaire, it would connote item homogeneity, which would be an indication that I could have some confidence that participants would answer similarly to other possible items within the same content domain. Specifically, I used both split-half reliability and Cronbach's coefficient alpha as a measure of how well a set of items measured an underlying construct. In general, when Cronbach's alpha was high (greater than .8; Kline, 1998), this was interpreted as evidence that the items in a particular questionnaire all measured the same underlying construct (e.g., co-regulated learning). For the purposes of this study, split-half reliability and Cronbach's coefficient alpha were used to justify using the items to form composite scores for the questionnaire.

3.7.1.3: Multivariate Analysis of Variance (MANOVA) and Student's *t* test

According to Tabachnick and Fidell (2007), MANOVA is a statistical technique which involves two or more dependent variables. It helps the researcher in answering the question on whether changes in the independent variable(s) have significant effects on the dependent variables; it also helps in exploring how independent variables influence some patterning of response on the dependent variables. Doubly multivariate analysis of variance was employed for data analysis in this research because it helped in examining the effect of different types of learning conditions (experimental and the control conditions) on co- and self-regulated learning behaviours as well as academic performance over time. For Study 2, MANOVA was used to ask whether a combination of the three dependent variables varied as a result of the learning conditions. The analysis emphasised the mean differences and statistical significance of differences among the groups. In order to investigate the change in co- and self-regulatory behaviours over time, MANOVA was also employed. Analysing all the dependent variables together helped in reducing the probability of making Type 1 errors (deciding there is a difference when there is none) when making the comparisons (Bryman, 2008).

However, due to the nature of this research design it did not make sense to investigate academic performance over the course of the three studies because participants learnt different science topics in each study. As a consequence, I used independent-samples t-test in analysing knowledge test data collected in each of the Studies 3 and 4. Independent-samples t-tests helped in comparing the means of pre- knowledge test with post-knowledge test on each of Flowering Plants and Blood Circulation scores for the experimental and the control group. The tests of statistical significance helped to reject the possibility that the effects of learning conditions and time on academic performance and the demonstration of CRL behaviours as being too improbable as an explanation that the results happened by chance and random error rather than because of a true relationship between the learning conditions/time and academic performance/ demonstration of CRL behaviours. If the results obtained from the analysis are statistically significant, then the researcher can reject the hypothesis that they occurred by chance as being too improbably an explanation of the results (Tashakkori & Teddlie 1998).

3.7.1.3.1: MANOVA Assumptions and Statistical Terms

To evaluate the overall effects of the different learning conditions on the co-and self-regulated learning strategies and test performance during collaborative learning of Simple Circuits, Flowering Plants and Blood Circulation a doubly multivariate analysis of variance with learning condition as a factorial variable was initially conducted. The reason for using doubly multivariate analysis rather than separate mixed repeated multivariate analyses of variance (RM-ANOVA) test was to reduce the inflation of Type I error rate that occurs with multiple ANOVAs. Furthermore, using MANOVA tests for this study helped to reflect the multivariate reality of the data presented in Study 2.

An alpha level of .05 was used for all statistical tests. The concept of effect sizes is also used in this thesis. An effect size represented by partial eta squared (η_p^2) is used to understand how large a difference is found when a significant difference ($p < 0.05$) is obtained in an MANOVA. The effect size measures the proportion of variance in the dependent variable that is explained by the independent variable. In this research, partial effect size (η_p^2) is used as an effect size instead of eta-squared (η^2) because there were several variables in this Study (Tabachnick & Fidell, 2007). Based on Cohen (1988) and Richardson (2011) the guidelines used in determining the partial effect size in this research were 0.01, 0.06 and 0.14 represented 'small', 'medium' and 'large' effects, respectively.

3.7.1.4: Content analysis

Content analysis is a research technique used in analysing documents and text which may be printed or visual that seeks to quantify contents in terms of pre-determined categories and in a systematic and replicable manner (Bryman, 2008). According to Bryman, content analysis is firmly rooted in the quantitative research strategy because it aims to produce quantitative accounts or the raw material in terms of the categories specified by the rules. Content analysis was employed in this research because it allowed the researcher to count the number of instances of emerging co-regulated learning behaviours that the students demonstrated through their spoken interaction and *InterLoc* chat scripts learning in a CSCL environment.

Using content analysis in this research helped in identifying as well as quantifying specific ideas, concepts and their associated patterns, and trends of ideas that occurred within each of the experimental and the control group over time. In this research, the audio data of the students' spoken interaction was transcribed and this enabled me to count the number of instances of each of the categories of co-regulated learning strategies. In order to examine what happened over time, both students' spoken interaction and their written expressions in the *InterLoc* chat scripts were examined for the number of occurrence the CRL behaviours. In the next section, the descriptions of the coding scheme used for the analysis are given.

3.7.1.5: Coding

In this study, a coding scheme was developed to identify and categorise students' CRL behaviours as they interacted in both the experimental and the control groups. Moreover, the metacognitive processes required in the development of co-regulatory learning behaviours among participants in each of the groups were also identified. The development of the coding scheme was based on the categorisation of metacognitive skills adopted by Azevedo (2005); Dettori and Persico (2008); and Pifarre and Cobos (2010), a schema used extensively to analyse students' regulatory behaviour in collaborative processes. This coding scheme analyses the regulation of collaborative learning processes by establishing whether the participants demonstrate any of the following five main categories of co-regulatory learning behaviours (namely planning, monitoring, task difficulty and demands, help seeking and, and motivation) during learning in a CSCL environment as depicted in Table 2.2.

The coding process consists of two steps: (a) dividing the transcribed students' interaction into main categories such as planning, monitoring, task difficulty and demands, help seeking and motivation and (b) assigning a code to each unit in each of the sub-categories I to XV (Table 2.2) (Chi 1997; Creswell, 1998; Laat & Lally 2003; Pifarre & Cobos, 2010). To ensure objectivity in the coding process, validity, and reliability aspects were considered in the study. Two coders (the researcher and another research student in the same department with experience in this type of coding) participated in the segmentation and categorization process (Table 2.2).

The coders separately searched for spoken interactions containing examples of CRL indicators and then compared and discussed their selections. After coding, the inter-rater reliability was calculated (Holsti's and Cohen's Kappa coefficient) for both coders (Lombard *et al.*, 2005, Pifarre & Cobos, 2010). After the computation of the inter-rater reliability, the coders discussed any controversial cases until they reached 100%

agreement. The data reported in this study refer to the agreed coding. The procedure adopted for calculating Holsti's and Cohen's Kappa coefficient as well as justification for their adoption in this research is described in the next section.

3.7.1.6: Determination of inter-rater reliability (Holsti's and Cohen's Kappa coefficient)

Inter-rater reliability was measured by determining the percentage of agreement between the raters 1 and 2 through Holsti's method (1969) and Cohen's Kappa (κ) (1960). Holsti's method (1969) involved simply adding up the number of agreements between the two raters 1 and 2 and then dividing by the total number of units the two coders have coded for the test (also the maximum agreement they could achieve) as depicted by equation 3.1.

$$PA_o = \frac{2A}{n_1 + n_2} \qquad \textbf{3.1}$$

Where

PA_o = The proportion agreement observed.

A = The number of agreements between two coders.

n_1 *and* n_2 = The numbers of units coded by coders 1 and 2 respectively.

This statistic can be within the range of 0.00 (no agreement) to 1.00 (perfect agreement).

However, Cohen (1960) noted that the problem with a percent agreement approach is that it does not account for the fact that raters are expected to agree with each other a certain percentage of the time simply based on chance. In order to combat this shortfall, reliability was also calculated by using Cohen's Kappa, which approaches 1 as coding is perfectly reliable, goes to 0 when there is no agreement other than what would be expected by chance, and a negative value of kappa reveals that the observed agreement is worse than expected on the basis of chance alone (Haney *et al.,* 1998). Kappa κ was computed as follows:

$$\kappa = \frac{(PA_O - PA_E)}{1 - PA_E} \qquad 3.2$$

where:

PA_O = Proportion of agreement observed (obtained from 3.1)

PA_E = Proportion agreement expected by chance.

Cross-tabulation (see Table 1 Appendix G) was generated for the experimental and the control group data obtained from the analysis of CRL indicators detected by coders 1 and 2 from the transcription of the audio recording and the *InterLoc* chat scripts. A = Agree; D = Disagree.

The bold numbers were the hits, the numbers of units for which coders 1 and 2 agree. By using the marginals (totals) for each coder (see Tables 2 to 4 in Appendix G), the product of the marginals (pm_i) was determined for each category and their summation was estimated ($\sum pm_i$). The summation of the product of marginals was employed in calculating PA_E (proportion agreement expected by chance) which was inserted into equation 3.2 alongside the PA_O (proportion of agreement observed using Holsti's method) to estimate the value of Cohen Kappa co-efficient (κ) for each period of study for the experimental and the control group. The results of the inter-rater reliability co-efficient of coders 1 and 2 obtained for each of the experimental and the control group as they learnt Simple Circuits, Flowering Plants, and Blood Circulation over time is presented in Chapter 6.

3.7.2: Qualitative Data Analysis

The qualitative methods in this study consisted of longitudinal observation of a group of five students in each of the experimental and the control group. This resulted in a form of case studies. Doing these longitudinal case studies was very valuable to this research because they provided a rich description of various co-regulatory behaviours demonstrated by students in their groups. Doing case studies with a small number of students provide an in-depth understanding of how the group co-regulated their learning behaviours over time. It also helped in capturing the "real-life context" that offered insights into how to explain complex co-regulatory processes in this particular context (Yin, 1994). In addition, case studies allow for flexibility with a variety of techniques to understand the case, which also enhance data triangulation (Stake, 2000). Overall, the in-depth longitudinal case studies provided a multi-dimensional account of the students' co-regulatory behaviours and offered multiple measures for investigating the various research questions.

The observational data from the researcher's observation notes were analysed by describing the contacts with the participants in the classroom setting, details of the participants involved, and the events or situations witnessed. This assisted in identifying the relevant emerging themes or issues. Meanwhile, analysis of the observation notes included my reflections on the relationships formed between the participants in the same group, thoughts on what the participants said and how it was said, and reactions. Analysis of the video observations, via categorisation was used to identify discrete behaviours or events with regard to dimensions of the students' interaction when employing computer supported collaborative learning environment for learning science. The video observations for both groups were analysed through breaking the data into manageable units, synthesising the data in order to search for the patterns of co-regulated learning behaviours that students demonstrated (Bogdan & Biklen 1998). Therefore, the existence, meanings, and relationships of the words or concepts that were related to CRL were explored and noted down during the process of analysis. The interview data from the students used for case-study and the science teacher were also transcribed and analysed by categorisation.

3.8: Ethical Considerations

This present research involved working with young people in the school; it therefore conforms to the British Educational Research Association (BERA) Ethical Guidelines. According to the guidelines, children who are capable of forming their own views should be granted the right to express their views freely in all matters affecting them, commensurate with their age and maturity. Children should therefore be facilitated to give fully informed consent. A consent form was designed for the purpose of this research to obtain permission from the participants and their parents. The participants and the parents were informed that their personal data will be used for the purpose of this research in accordance with the Data Protection Act which ensured full confidentiality that the data will be kept secured and used for the purpose of this research only. Prior to this, permission to carry out the research was also obtained from the school's Head teacher, Head of science co-ordinator and Head of science department.

I applied for and obtained approval from the Open University's HPMEC (Human Participants and Materials Ethics Committee and the research adhered to the requirements of the committee establishing ethical principles (see the ethical approval in Appendix H.1) for research involving human participants. However because this study involved research into young people in the school settings, there were additional ethical dilemmas. This involved the issues of privacy, confidentiality, and informed consent surrounding the ethical issues in this present research.

On the issue of privacy and informed consent, research participants and their parents needed to both understand and consent to their and their children's participation in the research. For consent to be truly informed, the information given to potential participants and their parents' needs to clearly communicate not only the research procedures but also confidentiality or anonymity arrangements as well as their right to withdrawal from participation at any time during the research. An information sheet (see Appendix H.2) explaining the research and the derivable benefits to the education community; and the consent forms for both students and their parents (see Appendix H.3 and H.4) explaining the rights of withdrawal at any time during the data collection were sent out to the participants and their parents before data collection.

In order to ensure confidentiality of the participants in this research, all the information about the participants were kept confidential. The students' real names in all the activities have been changed to pseudonyms and their test results have been anonymised. None of the students' identities has been revealed in this account. All students and their parents gave written permission that their or their children's images or videos could be used for conference presentation or written material (for example in this thesis). However, the researcher used images that were taken over the students' shoulders for the purpose of illustration in her written work (including this thesis). Also the researcher could blur any student's face out of the video if they or their parents were not comfortable with her using the images or the video in future.

At the time when information was given out about this research to the participants and their parents, the researcher considered that no harm could result from their or their children's participation in the research. In fact, the researcher hoped that the finding from the research will help young people in the future to learn science on a computer better than how they learn presently. Upon a careful consideration again, the thought of harm in form of fatigue that might arise from using the computer was considered. In order to prevent such harm, experts in the field and the science teacher were consulted for advice. Therefore, the length of time that the students worked at the computer in all the studies was kept to a minimum of one period of science lesson, which was 50 minutes. The students were also informed during all the lessons that if they became bored or tired and decided that they don't want to finish the activities on the computers, they were free to tell the researcher or the science teacher.

As the research design involved an experimental manipulation, this dictated that there was both an experimental group that received the intervention and a control group that did not. This presented a rather difficult dilemma in terms of which information should be given to the participants and their parents in terms of the research design. Although denying the control group the intervention in itself did no harm to them, since they were as well off as they would have been had they not participated in the study, it could be argued that they have been denied a possible benefit. It was decided that information about the research design would not be given in the information sheet. This is common practice in educational research. However, the researcher discussed how to treat the comparison group after the experiment was completed with the science teacher. It was decided that all the materials used for the experimental group would be left in the school to be used for the control group in their own time. In this way, treatment was not withheld from any of the students who participated in the research and the data were not contaminated.

All the data collected for the purpose of this research was protected under the Open University regulations. Raw data have been anonymised, and some may be deleted later on depending on how suitable it may be for the further research.

3.9: Conclusion

In this chapter, justification has been provided for the adoption of a mixed approach in this study, and the research design, instruments of data collection, methods of data analysis, and ethical considerations used in this study have been described. The subsequent analysis of data will lead to discussion on the effect of CRL and SRL prompts on students' regulatory behaviours and academic performance when learning science in a CSCL environment.

CHAPTER FOUR: Development and Validation of the Co-regulated Strategies for Learning

4.1: Introduction

This chapter presents the first study (Study 1) on the validity and the reliability of the new Co-regulated Strategies for Learning Questionnaire (CRSLQ) developed for the purpose of this research to measure Key Stage 3 students' co-regulated learning behaviours when learning science collaboratively in a computer supported collaborative learning environment (CSCL). This study is very important for the present research because co-regulated learning strategies have been shown to profoundly influence the quantity and quality of the student's interaction and their engagement during learning processes (Zimmerman, 1990; Zimmerman *et al.*, 1992). Also, recent research and theory has suggested that the way students regulate their social learning processes may affect their learning outcomes on the given task (McCaslin, 2004; and Volet *et al.* 2009). As regulating social learning is referred to as students' co-regulated learning processes in this present research, it implies that co-regulated learning processes may also affect students' learning and achievement on the given tasks, it would therefore be advantageous to have an instrument available which accurately measures students' CRL behaviour during collaborative learning.

The development of instruments to measure co-regulated learning behaviour becomes an urgent task in this research in order to contribute to better understanding of this phenomenon. The lack of an instrument limits the development of more empirical research on this important topic, and could partly explain why we know so little about the co-regulated learning behaviour that students use when learning together in groups. In this chapter, Co-regulated Strategies for Learning Questionnaire was developed and validated to measure co-regulated learning behaviour during collaborative learning. New instruments should have the following characteristics: (1) they are developed on the premise of socio-cultural and social cognitive theoretical framework; (2) they are able to capture various categories of CRL behaviours that students are expected to demonstrated when learning science in a CSCL environment (see Table 2.2); (3) they are able to distinguish between various categories of CRL; (4) they are able to emphasise the CRL behaviours that are carried out by students who learn as an on-going process; and (5) they should have good psychometric properties. Given the above, the development and validation of a new instrument designed to measure CRL behaviour appears to be warranted and necessary. The subsequent sections of this chapter present the process used in developing the instrument, the methods as well as the analysis of the validity and reliability of the newly developed CRSLQ.

4.2: Instrument development

In phrasing the questions for CRSLQ, a key link between the research aims (Section 1.4) and the individual questions via the research issues was established. Relevant issues and questions were determined through a combined process of exploring the literature and thinking creatively and their validation is discussed in section 4.3.2 below. Pools of items were generated for the draft Co-regulated Strategies for Learning Questionnaire (CRSLQ). These were based on the relevant literature on the self-regulated learning (SRL) and co-regulated learning (CRL) theoretical frameworks and SRL tools:

- Self-regulated learning (SRL) (Zimmerman, 1989b and Zimmerman, 2000).
- Co-regulated learning (CRL) (Hickey, 2003; McCaslin, 2004; and Volet *et al.* 2009).
- The Self-Regulated Strategies for Learning Questionnaire (SRLQ) (a sub-scale of the Motivated Strategies for Learning Questionnaire (MSLQ) developed by Pintrich *et al.* (1991). The Self-Regulated Strategies for Learning Questionnaire (SRLQ) section consists of 31 items with a good internal reliability of .79 (Pintrich *et al.* 1991).

Moreover, observations emanating from my initial visit to the school (of how students learnt in groups during science lessons) also formed part of the draft for the CRSLQ.

Twenty three items were generated for the initial pool, about which my supervisors, the school science teacher and I reached a consensus as to their clarity, appropriateness and content validity. The initial questionnaire, showing both the 24 items and the response scale are presented in Appendix I. These items included different aspects related to the SRL constructs explained in the literature and used in the Self-Regulated Strategies for Learning Questionnaire (SRLQ): that is, planning, monitoring, evaluating, effort regulation, peer learning, time management and help-seeking and giving behaviours. This questionnaire has a 6-point Likert scale ranging from "not at all true" of me to "very true of me".

4.3: Method

4.3.1: Data collection

Participants were 214 Key Stage 3 students (years 7 and 8). Of these students, 98 (46%) were female and 116 (54%) were male. Data were collected in the Autumn Term of 2009. The questionnaire was administered to the students in their classroom during their normal science lessons. The entire questionnaire took them about 15 minutes to fill. Their participation was voluntary, and the teachers and the researcher explained the objective of the research. While the participants were answering the questionnaire, the teachers and the researcher were there with them to deal with any problems or to answer any questions they might have.

4.3.2: Procedures

The following methods had been used to validate the CRSLQ:

- Face validity
- Content validity
- Construct validity: factor analysis.
- Reliability tests: internal consistency (Cronbach's coefficient alpha) and split-half reliability coefficient.

A flow chart depicting the processes used to examine the validity and the reliability of the CRSLQ is presented in Figure 4.1.

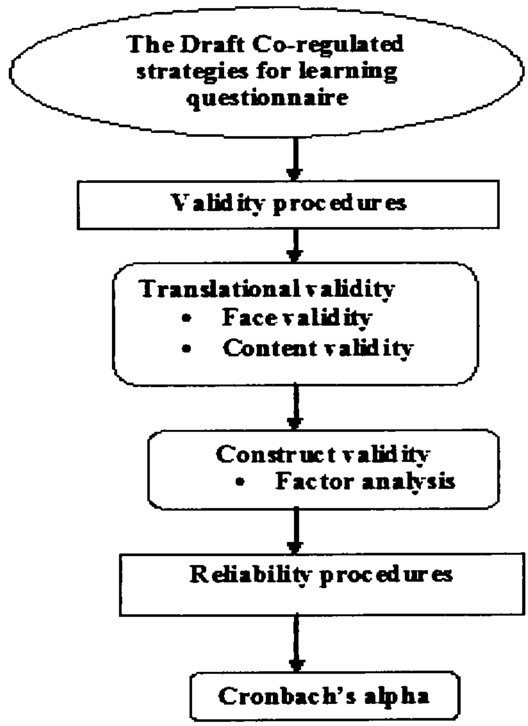


Figure 4.1: A flow chart depicting the process used to validate the CRSLQ instrument.

4.3.2.1: Translational validity

One of the fundamental requirements of a research instrument is that it should be valid in the sense that it measures the personal qualities or traits that it purports to measure. Instrument validity can be judged in a number of different ways. These could be determined by the properties of the instrument itself, the relationships among the scores on different items or the relationships between scores on the instrument itself and scores on other measures (Richardson, 2004). Translational validity according to Parsian & Dunning (2009) was used to describe what both face and content validity are getting at. In essence, both of these validity types are attempting to assess the degree to which the construct had been accurately translated into the operationalisation.

4.3.2.1.1: Face validity

The purpose of determining face validity of the CRSLQ was to ascertain its appropriateness in regard to its appearance in terms of feasibility, readability, consistency of style and formatting, and the clarity of the language used (DeVon *et al.* 2007, Parsian & Dunning 2009). Therefore, face validity in the context of this study, is a form of usability. In order to assess the face validity of the CRSLQ, evaluation forms/ administration procedures (see Appendix J) were included in the questionnaire for the participating teachers to assess each question in terms of:

- The clarity of the wording,
- The likelihood that Key Stage 3 students would be able to answer the questions,
- The layout and style.

4.3.2.1.2: Content validity

The purpose of carrying out content validity was to establish the appropriateness of the contents of the CRSLQ as well its relevance to the aims of this research work. This implies that the contents of CRSLQ should replicate a complete range of the attributes being investigated in this research work. In accordance with the procedure undertaken by Uzuntiryaki & Aydın (2009), content validity was carried out by the researcher, her three supervisors, and five participating teachers who reached a consensus, via a thorough review of the draft 23-item CRSLQ, as to its clarity, appropriateness and content validity in regard to the CRL theoretical framework. The expertise of these reviewers is in the specialties of science and science education, educational psychology, educational technology, collaborative learning in science class-room settings, and questionnaire design.

4.3.2.2: Construct validity

Construct validity is the extent to which an instrument is measuring exactly what it supposed to measure (Parsian & Dunning 2009; Uzuntiryaki & Aydın 2009). Construct validity is theory driven and defined as the fit between the theoretical structure and the empirical structure. Exploratory factor analysis (EFA) was performed, using SPSS 14 software programme, with a view to examining factorial structure and construct validity. This makes provision for examining whether the proposed dimensions are adequately associated with the different factors of CRL, and whether they explain the CRL theoretical construct (DeVon *et al.* 2007; Parsian & Dunning 2009; Uzuntiryaki & Aydın 2009). The sampling population for factor analysis was drawn from Key Stage 3 learners from the general population in a UK school (n = 214).

4.3.2.2.1: Factor analysis

Clustering of items into common factors, interpretation of each factor according to the items having a high loading on it, and summary of the items into a small number of factors during the development of CRSLQ instrument was achieved using factor analysis (Bryman & Cramer 1999). The two most common methods of undertaking factor analysis are Principal Component Analysis (PCA) and Principal Axis Factoring (PAF) (Bryman & Cramer 2005, Field 2009). In PCA, all the variance of a variable (total variance) is analysed, while PAF only analyses common variance (Bryman & Cramer 2005). Loadings were obtained in order to measure the association between an item (part of the construct that can be grouped together) and a factor (list of items that belong together) (Bryman & Cramer, 2005).

PAF combined with oblique rotation using the direct oblimin procedure were performed on the responses to the CRSLQ in order to clarify its underlying structure. For a clear interpretation of these factors, specific inclusion criteria were used concerning the heights of the factor loadings. In the literature, many different criteria for the salience of factor loadings can be found. General loadings of .30 are assumed as a minimum level, loadings of .40 are assumed more important and loadings of .50 and greater are assumed practically significant (Hair *et al.,* 1995). However, Hair *et al.* (1995) suggested relating the significance of loadings to the sample size. For a sample size similar to that in the present study, they suggested considering factor loadings of .40 as significant. Items that cross-loaded on two factors were excluded in order to make interpretation as clear as possible (Munro 2005). Also, possibly due to the large number of items, 7 students had overlooked or skipped some items in the questionnaire. Therefore, cases with missing values were excluded pairwise instead of listwise to prevent information loss. With pairwise exclusion, the data of these 7 respondents could be analysed, whereas listwise exclusion would have resulted in only 207 complete questionnaires. Field (2009) pointed out the necessity of having a sufficiently large sample in order to affirm the reliability of the factor analysis. However, the number of participants required to undertake factor analysis remains under debate. Following Kass & Tinsley (1979), and Field (2009) who recommended having a sample size which allows test parameters to be stable regardless of the participant to variable ratio; this present study had adopted a minimum of ten participants per variable. In order to ensure an appropriate sample size was obtained for this study to enable factor analysis to be undertaken, the following criteria were considered:

- Kaiser-Meyer-Olkin (KMO) sampling adequacy. The KMO statistic varies between 0 and 1. A value of 0 suggests that the sum of partial correlations is large in comparison to the sum of correlations, which indicates diffusion in the pattern of correlation, and that factor analysis is inappropriate. Furthermore, a value close to one indicates factor analysis will yield distinct and reliable factors (Field 2009). Kaiser (1974) recommended accepting values ≥ 0.50 and described values between 0.50 and 0.70 as mediocre; 0.70 and 0.80 as good, 0.80 and 0.90 as great, and > 0.90 as superb.
- Factor loadings and the correlation between a variable and a factor (Hayes 2002).

Following Bryman and Cramer (2005), two main criteria considered in determining how many factors should be retained are:

- The Kaiser criterion to select those factors that have an eigenvalue > 1.00. Although Kaiser criterion represents the norm in the literature in terms of factors to be retained in factor analysis, research has shown that this criterion is not a reliable guide to the true number of factors in a data set (Costello & Osborne, 2005, Field, 2009). The general criterion of an eigenvalue > 1.00 could misrepresent the most appropriate number of factors (Field, 2009). It systematically overestimates the true number of factors. The bias is worse (a) if the sample is small (which doesn't apply in this present study) or (b) if the number of variables is large (which might apply in this present study).

- A scree plot to depict the descending variances that account for the factors extracted in graph form. The factors that lie before the point at which eigenvalues begin to drop can be retained. The scree plot is more accurate than the Kaiser criterion, but it is inherently subjective. Therefore, parallel analysis which was suggested to be the best criterion was carried out in order to confirm the number of factors to retain in the analysis (O'Connor, 2000, Richardson, 2007).

Direct oblimin, the most commonly used oblique rotation was undertaken to rotate the factors because there are theoretical grounds that suggest that the factors might correlate with each other (Field 2009).

4.3.2.3: Reliability

Having completed the validity procedures, the final version of the CRSLQ was examined to assess its reliability. Reliability is another fundamental requirement of a research instrument. When an instrument is reliable it means it would yield consistent results if used repeatedly under the same conditions with the same participants and is therefore relatively unaffected by errors of measurement (Richardson, 2004). This can be measured by a number of different coefficients of reliability such as test-retest reliability, split-half or interrater reliability. All of which vary in principle between zero (reflecting total *un*reliability) and one (reflecting perfect reliability). Test-retest reliability involves calculating the correlation coefficients between the scores obtained by the same individuals on successive administrations of the same instrument. In Split-half reliability, the items are divided into two distinct subsets, and a correlation coefficient is calculated between the scores obtained on the two halves. Interrater reliability is used to obtain assessments of a particular individual by a number of different judges, it is appropriate to ask whether the judges are consistent in their evaluations. Due to some of the shortcomings of the test-retest which include high probability of attrition as well as the participants becoming too familiar with the instrument (Richardson, 2004), split-half and Cronbach's coefficient reliability were used to measure the CRSLQ's reliability. This provided a basis for judging the extent to which the scale's items all measure the same underlying construct. The results of the internal consistency analyses are displayed in Table 4.3

4.3: Results

4.3.1: Translational validity

4.3.1.1: Face validity

All the responding participating teachers commented that each parameter in the CRSLQ was excellent in terms of the following:

- The clarity of the wording,
- The likelihood that Key Stage 3 students would be able to answer the questions,
- The layout and style.

They all agreed that they understood the questions and found them easy to answer, and that the appearance and layout of the CRSLQ would be acceptable to the target Key Stage 3 students.

4.3.1.2: Content validity

The feedback from the nine experts from the specialties of science learning, educational psychology, educational technology and questionnaire design resulted in deleting the one item

- When I can't understand the task, I ask other members of our group for help.

This item was deleted because it was found that it was almost identical to another item in the CRSLQ. In addition, other items were revised to make them clearer. Three supervisors of this research also examined the CRSLQ for grammar and clarity with some items being adjusted accordingly.

4.3.2: Factor analysis

A principal axis factoring analysis (PAF) was conducted on the remaining 22 items of the questionnaire with direct oblimin rotation. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO=0.78. Bartlett's test of sphericity χ^2 (231) = 2909.55, $p < .001$, indicated that correlations between items were sufficiently large for PAF. Using Kaiser's scale, the sampling adequacy value of 0.78 obtained for the CRSLQ was considered to be good.

On the first run of principal component analysis, five factors with eigenvalues greater than one were identified and these five factors explained 66.80% of the variance in the data. However, one of these components had eigenvalues less than 1.2, and the eigenvalues-one rule is known to overestimate the true number of components in a matrix of correlations because of sampling effects (Cliff, 1988). Figure 4.2 shows a 'scree plot' obtained from the PAF analysis performed on the data. The scree test indicated that just four components should be extracted (See Figure 4.2), and this was confirmed by a comparison with the results of a parallel analysis of 1,000 random correlation matrices using O'Connor's (2000) program. The results of the parallel analysis are shown by the line consisting of filled circles in Figure 4.2, this indicates the results of a parallel analysis of 1,000 random correlation matrices using a program written by O'Connor (2000). This analysis implies that the first four factors from the data should be extracted.

Finally, the four extracted components were submitted to oblique rotation, and the loadings of the 22 items on the four rotated components are shown in Table 4.1. The items in Table 4.1 had been re-ordered in order to make it easier to see the patterns of loadings. The first principal component can be identified with the monitoring scale; second principal components can be identified with the help-seeking and help-giving scale while the third and fourth components can be identified with effort-regulation and planning scales respectively.

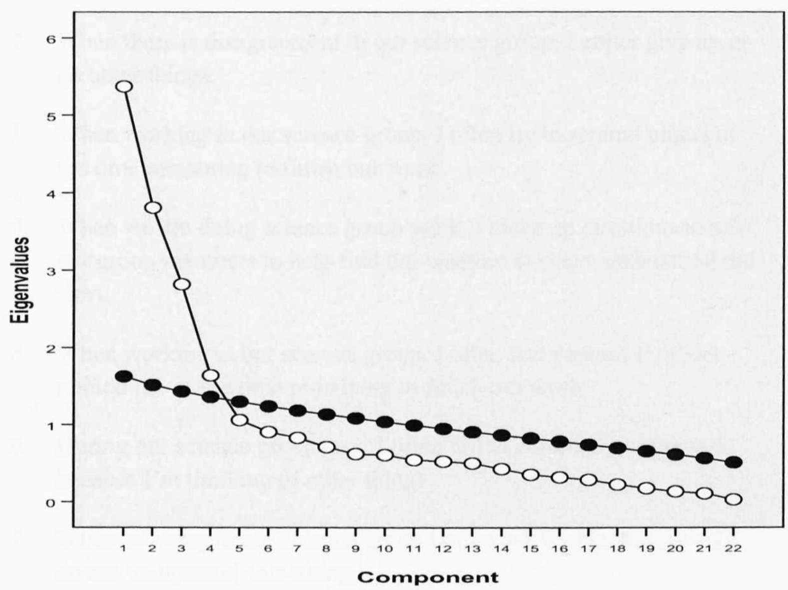


Figure 4.2: Scree plot obtained from the PAF analysis performed on the data

Table 4.1: Pattern loading matrix

	Item	Loadings			
		1	2	3	4
1.	When working in our science group, I often remind others to contribute their ideas	**0.95**	0.02	0.04	0.07
2.	When there is disagreement in our science group, I either give up or do other things.	**0.93**	0.04	0.01	0.05
3.	When working in our science group, I often try to remind others of the time remaining to finish our work.	**0.92**	0.05	0.01	0.00
4.	When we are doing science group work, I make up questions to ask our group members to help find out whether we have understood the work	**0.91**	0.10	0.00	0.01
5.	When working in our science group, I often feel pleased if others remind me of the time remaining to finish our work.	**0.76**	0.01	0.02	0.06
6.	During our science group task, I often fail to contribute to the task because I'm thinking of other things	**0.60**	0.01	0.02	0.01
7.	When working in our science group I often ask for clarification if I do not understand something.	**0.58**	0.02	0.16	0.02
8.	When working in our science group, I often ask myself questions to find out whether I've learnt what I want to learn.	**0.52**	0.01	0.08	0.03
9.	When working in our science group, I often give feedback to contributions made by others.	0.04	**0.92**	0.11	0.06
10.	When working in our science group, I often try to explain the task to others,	0.02	**0.89**	0.05	0.05
11.	When working in our science group, I ask others to explain concepts I don't understand well.	0.06	**0.75**	0.09	0.04
12.	When working in our science group, I often try to work with others to complete our task.	0.02	**0.60**	0.13	0.03
13.	When working in our science group, I often help others who have difficulties in understanding the group task.	0.02	**0.59**	0.06	0.06
14.	When our science group's task is difficult, I either give up or do other things.	0.02	0.08	**0.87**	0.10
15.	When working in our science group, I often try to participate in the group discussions.	0.04	0.01	**0.70**	0.05
16.	When working in our science group, I work hard to do well even if I don't like what we are doing.	0.01	0.04	**0.61**	0.01
17.	When working in our science group and the task is not interesting, I often manage to keep on contributing my ideas until we finish the task.	0.02	0.03	**0.58**	0.05

18. When working in our science group, I often feel so bored that I quit before we finish what we planned to do.	0.04	**0.57**	**0.55**	0.05
19. When working in our science group, I try to make sure we all make efforts to achieve our set goals.	0.05	0.10	**0.49**	0.11
20. I often think through our group's science task and decide what I am supposed to learn from it.	0.03	0.01	0.01	**0.73**
21. When working in our science group, I often read quickly through the activities to see how they are organised	0.07	0.01	0.01	**0.69**
22. When working in our science group, I try to make sure we set learning goals and allocate time for various activities.	0.05	0.01	0.04	**0.68**

Table 4.1 shows that all the items had pattern matrix coefficients higher than 0.4, which was suggested to be satisfactory by Stevens (2002). Analysis of the data from this study was used to construct the final form of the CRSLQ (see Appendix B) with 21 items on four factors. Item 18 (When working in our science group, I often feel so bored that I quit before we finish what we planned to do) was finally deleted from the questionnaire because it loaded on component 2 and 3.

The final part of the factor analysis presents the correlation matrix between the factors in Table 4.2. For N=214, any correlation coefficient greater than .09 is statistically significant.

Table 4.2: Factor correlation matrix

Factor	1	2	3	4
1	1			
2	0.10	1		
3	-0.01	0.16	1	
4	0.14	0.34	0.17	1

Factors 2 and 4 show high correlation while Factor 3 shows little or no relationship with any other factors (the correlation coefficient is low), but all other factors are interrelated to some degree. The fact that these correlations exist show that the constructs measured can be interrelated.

4.3.3: Internal Consistency Reliability

The internal consistency of the four scales of CRSLSQ questionnaire was estimated by the Split-half reliability coefficient and Cronbach's alpha coefficient. This measure is typically derived by splitting a scale into two equivalent forms, calculating their inter-correlation, and then estimating the reliability of the composite scale using the Spearman-Brown formula (Nunnally, 1978).

Table 4.3: Descriptive statistics of scale scores

Scale	Mean	Spearman-Brown Coefficient	Cronbach's alpha coefficient	Correlation with total scores	N of Items
Monitoring	3.33	0.88	0.92	0.78	8
Help seeking and giving	3.83	0.76	0.86	0.62	5
Efforts regulation	3.62	0.78	0.75	0.64	5
Planning	3.27	0.74	0.79	0.56	3

Note. N=214. Scale scores range from 1 to 6.

Table 4.3 shows the means of these scores. All of the scores tended to be above the mid-point of the response scale (i.e. .3). The Table also shows the values of Spearman-Brown Coefficient as an index of the internal consistency of the four scales. The reliability coefficients for the monitoring, help-seeking and help-giving, efforts regulation and planning were found to be 0.88, 0.76, 0.78 and 0.74, respectively. All of these values would be judged to be satisfactory by conventional research-based criteria (Nunnally, 1978, Robinson *et al.,* 1991). Furthermore, the average correlation between the items of the monitoring and the corrected-item total scores was 0.78 (range=0.38-0.95), suggesting that all of the items on this scale do, in fact, measure a common latent variable (see Appendix K). The comparable values for the help-seeking and help-giving, efforts regulation and planning were 0.62 (range = 0.42-0.84) and 0.64 (range = 0.29-0.55), and 0.56 (range = 0.45-0.53) respectively. Based on these data, monitoring, help-seeking and help-giving, efforts regulation and planning are all internally consistent measures.

4.5: Conclusion

This Study (Study 1) was designed to overcome some of the weaknesses present in previous research and to close some of the gaps in the current knowledge regarding the measurement of co-regulatory processes that students demonstrate during collaborative learning in the classroom. The Co-regulated Strategies for Learning Questionnaire (CRSLQ) was developed and validated. The major purpose of this Study was accomplished in that the validity and the reliability of the initial use of the Co-regulated Strategies for Learning Questionnaire (CRSLQ) were established.

A principal axis factoring analysis on all 22 items produced four components, this suggested that the evaluating, time management and peer learning scales could not be differentiated from the effort regulation, monitoring and help seeking and help giving respectively. In other respects, however, every item showed a salient loading on the appropriate component, and only one item showed salient loadings on other component. This suggested that the sets of items defining the four components were relatively discrete. CRSLQ reflected SRSLQ in the sense that CRSLQ too was concerned with the use of strategies that help students control and regulate their cognitions during group work such as planning, monitoring, and regulating (Garcia & Pintrich, 1995; Pintrich *et al.*, 1991). All the four factors retained from the factor analysis all have high reliability ≥ 0.70.

This newly developed CRSLQ will therefore be used to measure the students' use of co-regulated learning behaviour in Studies 2, 3 and 4. The next Chapter presents Study 2, which involved investigating students' co- and self- regulated learning behaviours during science learning in a computer supported collaborative learning environment.

CHAPTER FIVE: Effects of CRL and SRL prompts on the students' co- and self-regulatory behaviours and academic performance

5.1: Introduction

This chapter reports the findings from Study 2 see Table 3.1. This used an experimental design to investigate the effect of co- and self-regulated learning (CRL and SRL) prompts on students' regulatory behaviours and knowledge test performance when working collaboratively in a computer based science simulations learning environment. The computer based science simulations learning environment was employed to investigate the CRL and SRL processes that students demonstrated during science learning.

Forty year 7 students (11-12 year olds) were randomly assigned into either the experimental group (co- and self-regulated learning prompted group) or the control group (self-regulated learning prompted group). Students in the experimental group were given an activity sheet on Simple Circuits which contained CRL and SRL prompts, while the students in the control group were given an activity sheet on Simple Circuits which contained SRL prompts only. Students in both the experimental and the control groups were instructed by the researcher and the science teacher to discuss their learning with their group members.

The Co-regulated Strategies for Learning Questionnaire (CRSLQ) that was developed, validated and discussed in Chapter 4 was used to measure students co-regulated learning during collaborative learning. The CRSLQ was administered to the students before and after exposing them to the learning interventions. Other data collected during Study 2 were the pre- and post-self-regulated strategies for learning questionnaire (SRSLQ), the knowledge test on simple circuits (KTSC), students' work on the activity sheets, and observational data of the students through the use of video cameras/observation notes and audio data obtained via tape recorder.

Study 2 investigated the following research questions:

1. a). Does the computer based science simulation learning environment with both co- and self-regulated learning prompts support Key Stage 3 students to regulate their learning behaviour more effectively than using self-regulated learning prompts only?

   b). Does the computer based science simulation learning environment with both co- and self-regulated learning prompts result in a greater improvement in Key Stage 3 students' academic performance when learning scientific concepts than when using self-regulated learning prompts only?

Based on consistent findings that regulatory prompts can induce specific co- and self-regulatory behaviours as well as facilitate active participation during collaborative learning (Azevedo & Jacobson, 2008; Pifarre & Cobos, 2010), the following hypotheses were proposed and investigated in Study 2:

1. Supporting students with CRL and SRL prompts will increase their co-regulatory behaviours as measured by the CRSLQ compared to supporting students with SRL prompts only during collaborative learning.
2. There will be no significant differences between the two groups on self-regulatory behaviours as measured by SRSLQ.
3. Students in the experimental group will improve in their academic performance as measured by a knowledge test on simple circuits (KTSC) more than students in the control group

This chapter begins with the summary of the procedures used in carrying out this study (Section 5.2). Various statistical analyses were used to investigate the students' performance on co-and self-regulatory processes as well as their academic performance (Section 5.3). The quantitative and qualitative content analyses employed in the Study are presented in Section 5.4, which is followed by the presentation of the observational findings in Section 5.5. The chapter rounds up with a discussion on how the analysis in this present study relates to the research questions (Section 5. 6), as well as the concluding remarks (Section 5.7).

5.2: Procedure

Study 2 was carried out in three separate 50-minute lessons during the spring term of 2010. There was a day interval between the three lessons. During the first lesson, the CRSLQ, the SRSLQ, and the pre-knowledge test on Simple Circuits (KTSC) were handed out to the participating students in their regular classroom. Students were given 15 minutes to complete each questionnaire and the knowledge test on Simple Circuits (SC).

The second lesson took place in the computer suites in the school during which students were introduced to the Sunflower science simulation programme teaching Simple Circuits (SC). Figure 5.1 shows screen shots of the Simple Circuits computer based simulation that students worked with during Study 2.

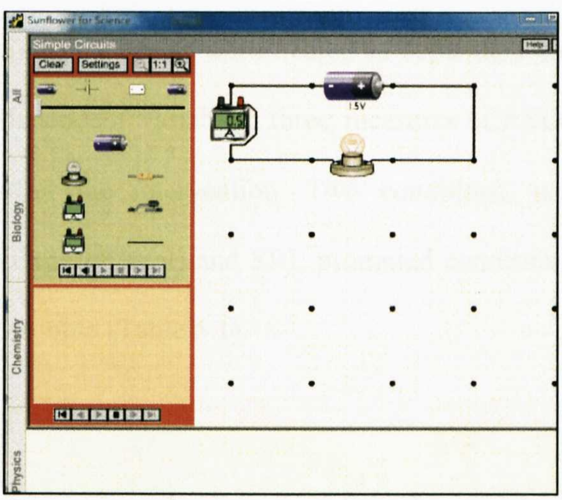
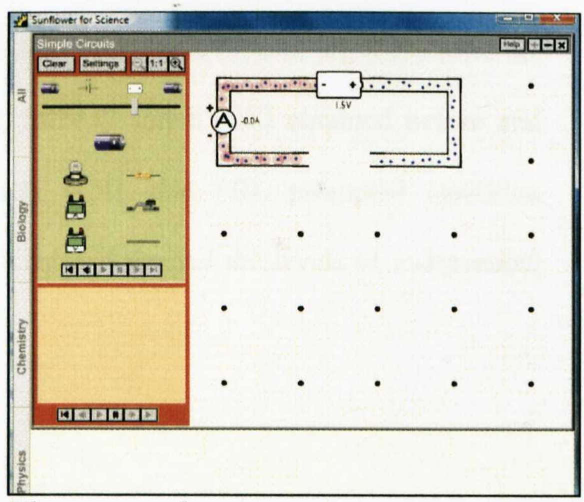


Diagram mode



Electrons mode

Figure 5.1: Simple Circuits Simulation

The simulation allowed students to make virtual circuits which enabled them to see pictures of the components in diagram mode or as electrons flowing through the components. Students were expected to use the tools provided at the left-hand side of the simulation to draw diagrams of electric circuits and explain the path of an electric circuit. The slider at the top of the simulation enabled the students to drag the circuit to change the view from picture to symbol and to electron modes.

Students in each of the experimental and the control groups were randomly assigned to sub-groups with five students in each of the sub-groups. Students sat in sub-groups of five, each with his or her computer, and were encouraged to discuss the given task together as a group. Learning activity sheets with either CRL and SRL prompts or SRL prompts only were designed for Study 2 (see Section 3.6.4 and Appendices D.1 and D.2 for details), and students were instructed to work collaboratively using a science simulation on Simple Circuits.

5.3: Students' Performance on co-and self-regulatory processes and academic performance

Table 5.1 shows Study 2's dependent variables and independent variable. The measures for co-regulated learning strategies, self-regulated learning strategies and test of knowledge on Simple Circuits were treated as dependent variables (see Table 5.1). In all, there were six dependent variables; three measures (CRSLQ, SRSLQ and KTSC) obtained before and after the intervention. Two conditions, namely (CRL and SRL prompted condition (Experimental) and SRL prompted condition (Control)) formed the levels of independent variable (Table 5.1).

Table 5.1: Dependent and Between-Subject Independent Variables for this Study

Dependent Variables	Levels of the independent variable
Scores on the CRSLQ(Pre and Post)	CRL and SRL prompted condition
Scores on the SRSLQ (Pre and Post)	SRL prompted condition
Scores on the simple circuit knowledge test (KTSC) (Pre and Post)	

The mean scores and standard deviations of the dependent measures are reported in Table 5.2. Students in both the experimental and the control groups started at the same level on co-regulatory behaviours as measured by the CRSLQ. This is reflected in the mean scores obtained in the CRSLQ pre-test scores of the experimental group (Mean, M= 73.80) and the control group (M = 72.05). Looking at the CRSLQ post-test scores, it is evident that there are differences in means between the control group (M = 87.10) and the experimental group (M = 100.30). Turning to the SRSLQ scores, one observes very little differences in means between the control group (M = 122.75) and experimental group (M = 129.95). Finally, knowledge test scores reveal differences between means of the control group (M = 10.25) and experimental group (M = 11.30).

Table 5.2: Means and standard deviations of the pre-and post-test, CRSLQ, SRSLQ and KT (SC) measures in the experimental and the control groups

Measures	Learning Conditions	Pre-Test		Post-test		Post -Test – Pre-Test	
		M	SD	M	SD	M	SD
CRSLQ	CRL and SRL Group	73.80	16.73	100.30	8.16	26.50	4.14
	SRL Group	72.05	13.34	87.10	12.66	15.05	4.14
SRSLQ	CRL and SRL Group	102.10	14.56	129.95	17.04	27.85	4.61
	SRL Group	103.30	13.41	122.75	12.99	19.45	4.61
KT SC	CRL and SRL Group	8.10	1.21	11.30	1.13	3.20	0.85
	SRL Group	7.50	1.10	10.25	1.29	2.75	0.85

The results of evaluating the assumptions of doubly-multivariate analysis of variance which tests the homogeneity of the variance-covariance matrices were found to be satisfactory as shown by Box's test. Box's test of equality of covariance matrices showed that the data were robust for multivariate analyses. The test is not significant at $P = 0.05$ (see Table 1 in Appendix L for more details).

Pillai's criterion which tests significance of main effects and interactions was adopted because it imparts robustness into this research design thereby nullifying the violation of the assumption of homogeneity of the variance-covariance matrices that might have been introduced by the small sample sizes in each group employed for this research. The investigation of the statistical interactions between the learning condition and on the students' scores on CRSLQ, SRSLQ and KTSC measures by the doubly multivariate analysis of variance (MANOVA) revealed some significant results. The MANOVA examined multivariate effect of learning conditions on the different CRSLQ, SRSLQ and KTSC measures from pre-test to post-test. Table 5.3 shows significant interaction between time and learning condition, there is also a significant multivariate effect of time (pre versus post-tests.

Table 5.3: Results of multivariate tests (within subjects' effects)

Source		Value	F	Hypothesis df	Error df	Sig.	partial η^2
Time	Pillai's Trace	0.89	106.81	3.00	36.00	0.00	0.89
Time * Learning-condition	Pillai's Trace	0.21	3.10	3.00	36.00	0.04	0.21

Moreover, the univariate analysis of variance (Table 5.4) also resulted in an F-ratio that was used to determine whether variations in the students' scores on the CRSLQ, SRSLQ and KTSC were affected by time and the various learning conditions (the experimental and the control group). The first within-subject comparison (time) in Table 5.4 confirms that students' scores obtained on CRSLQ ($p < 0.05$), SRSLQ ($p < 0.05$) and KTSC ($p < 0.05$) measures changed significantly from pre to post–test irrespective of the groups they belong.

Table 5.4: Tests of Within-Subjects contrast (within subjects comparison)

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig	partial η2
Time	CRSLQ	17264.03	1	17264.03	102.80	0.00	0.73
	SRSLQ	22372.90	1	22372.90	72.98	0.00	0.66
	KTSC	324.90	1	324.90	136.12	0.00	0.78
Time * Learning-condition	CRSLQ	1311.03	1	1311.03	7.81	0.01	0.17
	SRSLQ	705.60	1	705.60	2.30	0.14	0.06
	KTSC	0.40	1	0.40	0.17	0.69	0.00

The second within-subjects comparison (time and learning conditions) shown in Table 5.4 indicates that significant interactions between time and learning conditions exist for CRSLQ ($p < 0.05$) but not for SRSLQ ($p > 0.05$) and KTSC ($p > 0.05$) measures.

Table 5.5 shows that at the start of the study, there were no significant differences between the experimental and the control groups on any of the CSRLQ, SRSLQ and KTSC measures. This outcome helps in establishing the effects of CRL prompts on the students' regulatory behaviours and test performance on simple circuits. The findings in Table 5.5 are now related to hypotheses 1 to 3 in the subsequent paragraphs.

Table 5.5: Changes in scores from Pre-Test to Post-Test

Measures	Experimental (Mean)	Control (Mean)	Mean Difference between scores of the experimental the control groups	Std. Error	Sig.
CRSLQ					
Pre-Test	73.80	72.05	1.75	4.14	1.00
Post-Test	100.30	87.10	13.20*	4.14	0.01
SRSLQ					
Pre-Test	102.10	103.30	-1.20	`4.61	1.00
Post-Test	129.95	122.75	7.20	4.61	0.74
KTEST					
Pre-Test	8.10	7.35	0.75	0.85	1.00
Post-Test	11.30	10.25	1.05	0.85	1.00

Note: Pairwise comparisons were protected against Type I error using a Bonferroni adjustment.

To examine hypothesis 1 which states that "supporting students with CRL and SRL prompts will increase their co-regulatory behaviours as measured by the CRSLQ compared to supporting students with SRL prompts only during collaborative learning". Students' scores on CRSLQ in both the experimental and the control groups were examined for the group differences in the scores. Table 5.5 shows that significant differences exist among treatment groups at post-CRSLQ. Analysis of the results shows that the experimental group, on average, had a higher post-CRSLQ score than the control group (Table 5.5). The significant differences between the experimental and the control groups suggests that the learning conditions i.e. CRL and SRL prompted or SRL prompted only conditions had an effect on the students' scores on co-regulatory behaviours as measured by CRSLQ. This result supports hypothesis 1 above. The implication of this result is that the introduction of CRL and SRL prompts facilitates students' co-regulatory behaviours during collaborative science learning in a computer based simulation learning environment.

Next, the result of the SRSLQ score shows no significant difference (Table 5.5) between the experimental and the control groups on self-regulated learning behaviour during collaborative learning in a computer based science simulation learning environment. This outcome is quite expected as stated in hypothesis 2 stating that "there will be no significant differences between the two groups on self-regulatory behaviours as measured by SRSLQ". Students in both learning conditions were prompted to self-regulate their learning; therefore, there was an increase from their pre- to post-SRSLQ scores but no difference between the groups on SRSLQ scores (Table 5.5).

In order to investigate hypothesis 3 which states that "students in the experimental group will improve their academic performance as measured by knowledge test on simple circuits (KTSC) more than students in the control group". Students' scores on KTSC in both the experimental and the control groups were also examined for the group differences in their scores. The result presented in Table 5.5 shows that there were no significant difference between the experimental and the control groups on the knowledge test on simple circuits. This result rejects hypothesis 3. The result suggests that CRL and SRL prompts may not have had effect on the students' academic performance when learning Simple Circuits.

5.3.1.: Instructional conditions and students' attainment in activity sheets

In order to determine the effect of the CRL and SRL prompts on the students' academic performance as they learnt simple circuits, an independent-sample t test was employed to compare the means for the experimental and the control groups of students' scores in their activity sheets in addition to analyses using Knowledge test scores. Questions from a past GCSE paper were included in the students' activity sheets for both the experimental and the control groups. Students' answers were then scored by the researcher. In both cases, the total number of marks possible was 17 (see Appendix D.1 and D.2). The outcomes of the students' scores from activity sheets presented in Table 5.6 were found to be statistically significant favouring the CRL and SRL-prompted group, $t(38) = 3.112$, $p<0.05$) (see Tables 1 and 2 in Appendix M). This suggests that the experimental group produced better answers and scored higher than the control group in their activity sheets.

Table 5.6: Means of the students' activity sheets' scores.

Learning contexts	Mean(M)	Standard deviation(SD)
CRL and SRL-prompted	12.05	2.69
SRL-prompted	9.00	3.46

A detailed analysis for the distribution of activity sheets scores was carried out in order to confirm whether or not the introduction of CRL and SRL prompts in a computer based simulation environments enhanced the number of students who improved in their conceptual understanding of Simple Circuits than when they were prompted with SRL-prompts only. Table 5.7 shows how the students' activity sheets' scores were distributed into three categories of low, intermediate and high scores. Students' scores in the activity sheets were categorised in Table 5.7 as follows: low test scores (0 to 8 marks), intermediate test scores (9 to 12 marks), and high test scores (12 to 17 marks).

Table 5.7: Frequency and percentage of students' activity sheets' scores categorised by the learning context.

Learning contexts	Low activity scores	Intermediate activity scores	High activity scores
CRL and SRL-prompted	2(10%)	6 (40%)	12 (50%)
SRL-prompted	6 (30%)	9 (45%)	5 (25%)

The distribution of activity sheets' scores for the experimental group varied remarkably from that of the control group (Table 5.7). The experimental group had 12 students belonging to high score category compared to only five students categorised with high scores in the control group. 6 students in the experimental group were found to belong to the intermediate category, while only 9 students from the control group could be classified as intermediate scorers. Interestingly, only 2 of the students in the experimental group could be categorised as belonging to the low scores group while 6 students out of 20 students fell into this group in the control group. Therefore, this analysis could suggest that the introduction of CRL and SRL prompts into the instructional activity sheets could enhance students' ability to produce better answers than when are prompted with SRL instructions only.

In summary, the outcomes from the quantitative analysis carried out so far suggest that CRL and SRL prompts improve students' co-and self-regulated learning processes as well as their scores on the activity sheets. The need to provide further supporting evidence to corroborate the outcomes from the quantitative analysis necessitates carrying out both quantitative and qualitative content analysis of the data collected in form of observational data of the students through the use of video cameras/observation notes and audio data is carried out. In the next two sections the content analysis carried out in this study is discussed.

5.4: Quantitative and qualitative content analysis

This section presents both the quantitative and the qualitative content analysis carried out on the transcribed audio data of the students' interactions when learning collaboratively in their groups. The numbers of instances of emerging co-regulated learning behaviour that the students demonstrated through their spoken interactions are presented below. The categorisation was based on the coding scheme used to identify co-regulated learning behaviours presented in Chapter 3.

5.4.1: Reliability Analysis of CRL Coding

A coding scheme based on definition of self-regulated learning by Azevedo (2005); Dettori & Persico (2008); and Pifarre & Cobos (2010) presented in Chapter 2 Table 2.2 page 48 was extended to propose how regulation might appear within a group setting. Table 5.8 shows s sample of the coding scheme used in this study during Simple Circuits.

Table 5.8: Co-regulated learning examples of categories, categories definition, and examples of the categories used to code students' co-regulatory behaviour

Categories	Categories definition	Examples of Co-regulation
Planning: Goal setting	Making proposals on how to proceed in the learning process through breaking the given tasks into sub-tasks Commenting on others' goal	We should also aim to understand how cells produce electric current that gives us electricity.
Monitoring: Monitoring time	Checking time to be sure the task will be completed with the given time	We've spent nearly 40 minutes already,
Task Difficulty and Demands (Evaluating/Efforts regulation): Evaluating the learning process and the context	Commenting on the learning context	That sounds reasonable, it's a bit tricky
Help seeking and giving during: Cognitive help seeking	Asking task related questions.	How did you do it? Please show me
Motivation: Interest statement	Showing a certain level interest in the learning content	That's interesting

The chosen unit of analysis was a single individual student's complete statement during the group interaction. These were examined for CRL-indicators in all the groups' interactions. The numbers of instances of co-regulated learning behaviours were counted for each of the categories of CRL and narratives were constructed to provide descriptive summaries of the co-regulatory processes that each group used to regulate their learning. The analysed spoken interactions turned out to contain almost all the indicators proposed in Table 2.2 with the exception of feeling of knowing (V) and content evaluation (VI) for either of the groups. On the other hand, several messages contained more than one occurrence of the same CRL-indicator or of different ones. This made the analysis of the data slightly more difficult to interpret, since, for instance, the percentage of messages containing CRL-related expressions does not give an exact idea of the distribution of indicators detected.

Typical instances of categories used to code students' CRL behaviours are presented in Table 5.8. The result of the coding scheme of the audio recordings of students' spoken interaction is presented in Table 5.9 which shows that the proportion of spoken interactions containing CRL indicators vary from 59 % (105/177) to 80% (217/268) for each of the experimental and the control groups. This implies that CRL did take place extensively or that students in both the control and the experimental groups did express the CRL actions they were carrying out. Moreover, the inter-rater reliabilities estimated by Cohen's Kappa and Holsti's coefficients for the experimental and the control groups varied between 0.85 and 0.88. According to Haney *et al.,* (1998), an inter-rater reliability co-efficient which approaches 1 suggests that the coding is perfectly reliable, while values approaching 0 indicate there is no agreement other than what would be expected by chance, and a negative value of co-efficient reveals that the observed agreement is worse than expected on the basis of chance alone.

Table 5.9: Basic data for the experimental and control groups

	CRL and SRL group	SRL group
Total number of spoken interactions from audio recordings	268	177
Number of spoken interactions containing CRL indicators	217	105
Total number of CRL indicators	249	149
Holsti reliability (PA_O)	0.85	0.87
Cohen Kappa reliability (κ)	0.86	0.88

On the basis of the work of Haney *et al.,* (1998), the value of the inter-rater reliabilities obtained for this study indicates the replicability of this approach. The detail of the coding is presented in Tables 1 and 2 in Appendix G. The observation of a high degree of consensus shows that it was not difficult to classify the considered spoken interactions against the first column given in Table 2.2 on page 48. The implication of this finding from the perspective of content analysis adopted for this study is its importance in relation to its practicability (Dettori & Persico 2008).

5.4.2: Students' Verbal Interactions

The outcomes of the content analysis of the verbal interactions of students in both the experimental and the control groups are reported in Figures 5.2 and 5.3. The numbers of verbal interactions containing CRL indicators in each of the groups' interactions are presented in Figure 5.2. Actual numbers of CRL indicators found in each of the groups' spoken interactions are presented rather than percentages of spoken interaction because several spoken interactions contained more than one CRL-indicator. It is evident from Figure 5.2 that the total number of verbal interactions of students in the experimental group (268) is more than those of the control group (177).

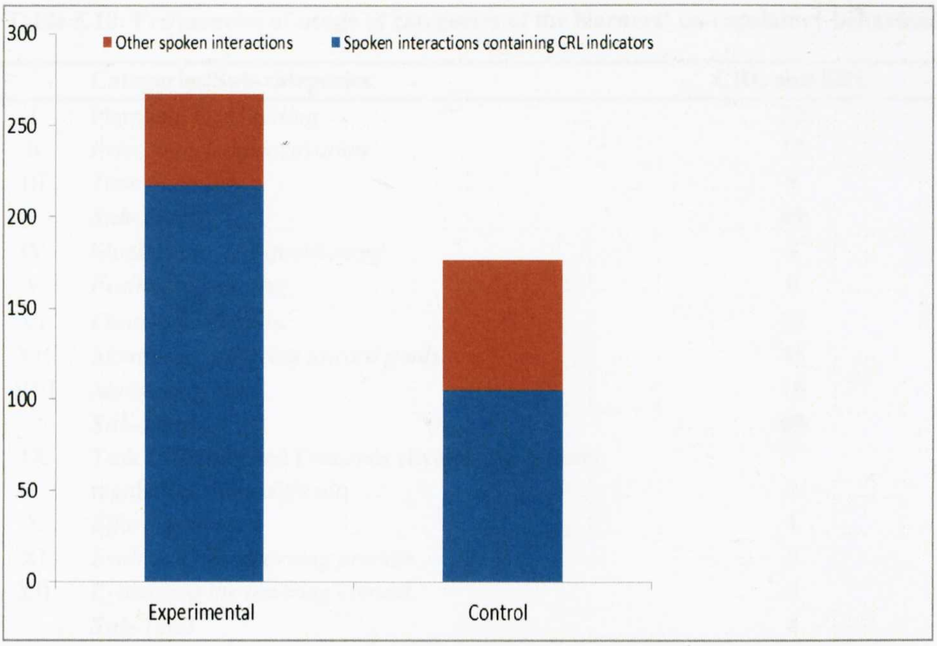


Figure 5.2: Number of total spoken interactions by the experimental and the control groups and the number of spoken interaction containing CRL indicators.

Moreover, there are more verbal interactions containing CRL indicators (217) and slightly fewer interactions containing SRL indicators in the experimental group than in the control group (105). It is important to note that the experimental and the control groups worked on their Simple Circuits activity for the same duration, which made the comparison of the raw data meaningful.

Table 5.10 summarises the frequency of occurrence of CRL indicators in the spoken interaction of both the experimental and the control groups in relation to the sub-categories of planning, monitoring, task difficulty and demands, help seeking and giving, and motivation (main categories of CRL).

Table 5.10: Frequencies of usage of categories of the learners' co-regulatory behaviours

	Categories/Sub-categories	CRL and SRL	SRL	Total
I	Planning: *Goal setting*	27	4	**31**
II	*Prior knowledge activation*	13	5	**18**
III	*Time planning*	9	7	**16**
	Sub-Total	**49**	**16**	**65**
IV	Monitoring: *Self-questioning*	1	7	**8**
V	*Feeling of knowing*	0	0	**0**
VI	*Content evaluation*	25	0	**25**
VII	*Monitoring progress toward goals.*	45	21	**66**
VIII	*Monitoring time*	18	15	**33**
	Sub-Total	**89**	**43**	**132**
IX	Task Difficulty and Demands (Evaluating/ Efforts regulation):*Task difficulty*	1	1	**2**
X	*Effort regulation*	1	1	**2**
XI	*Evaluating the learning process*	2	1	**3**
XII	*Evaluating the learning context*	0	0	**0**
	Sub-Total	**4**	**3**	**7**
XIII	Help seeking and giving during collaborative learning: *Affective help seeking*	39	20	**59**
XIV	*Cognitive help seeking*	32	44	**76**
	Sub-Total	**71**	**64**	**135**
XV	Motivation: *Interest statement*	37	22	**59**
	Sub-Total	**37**	**22**	**59**
	Total	**249**	**149**	**398**

The difference between the CRL and SRL and the SRL prompts introduced into the activity sheets of each group may also explain the data in Figure 5.3 below, which confirm that the frequency of CRL indicators of planning, monitoring,, help seeking and giving, and motivation obtained for the experimental group are higher than those obtained for the control group.

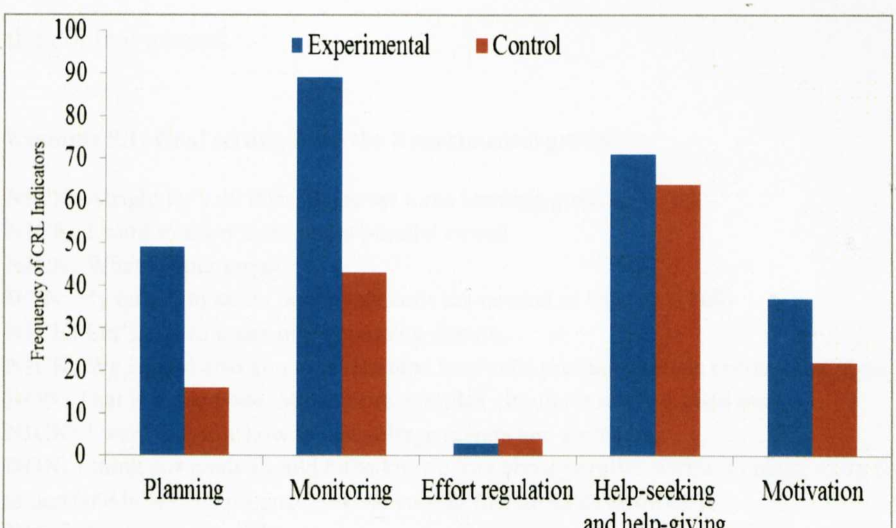


Figure 5.3: Coding results along the categories of CRL indicators which highlight the planning, monitoring, task difficulty/effort regulation, help seeking and help-giving, and motivation.

The next sections present the content analysis detailing how the CRL and SRL and the SRL prompts introduced into the computer based simulation learning environments shaped the demonstration of each of the main categories of the co-regulatory behaviours of the groups. The group interactions were observed in each of the sub-group in both experimental and the control class.

5.4.2.1: Planning

Based on the results obtained from Table 5.10 which presents the frequencies of the demonstration of categories of the learners' co-regulatory behaviours in a computer based simulation learning environment, students' behaviours (from both groups) associated with the category of planning accounted for just over 16.00 % (65/398) of all the coded spoken interactions.

Looking through the sub-categories of planning in more detail, it is also evident that the experimental group predominantly engaged in goal setting (27/65), followed by prior knowledge activation (13/65), and time planning (9/65) whereas the control group members regulated their learning in the following order of ranking by planning the time spent on the group activity (7/65), activating the prior knowledge (5/65) and goal setting (4/65). Below are two example interactions about goal setting from the experimental and the control groups.

Example 5.1: Goal setting from the Experimental group

NICK: Alright let's do this. Please set three learning goals....
NICK: I want to learn more about parallel circuit
NICK: What is your target?
DON: My target; to know how many cells are needed to light up a bulb
NICK: Let's aim to make more complex circuits
NICK: We should also aim to understand how cells produce electric current that gives us electricity.
DON: That is a good one. Make more complex circuits is really a good one.
NICK: I want to know how to use voltage meters and ammeters
DON: I think our goals should be to know more about parallel circuit, to make more complex circuits, and understand how cells produce electric current that gives us electricity.
NICK: Yeah, I agree with you.

Example 5.2 Goal setting from the control group

BETTY: What are our learning goals?
NATE: I want to know how to draw a simple circuit

It is clear from the spoken interaction of the experimental group that the CRL-prompt introduced into their activity sheets might have enabled the group members Nick and Don to progress from setting individuals goals such as *I want to learn more about parallel circuit* (Nick) and *my target; to know how many cells are needed to light up a bulb* (Don) to developing group goals such as "*I think our goals should be to know more about parallel circuit, to make more complex circuits, and understand how cells produce electric current that gives us electricity*" (Don).

Analysis of the spoken interaction on planning instances obtained from the control (see Example 5.2 above) suggests that students only set their goals at the individual level, therefore they could not progress to the stage of merging individual goals into group goals during their collaborative learning activity. Eventually, none of the students in the control group commented on each other's goals.

5.4.2.2: Monitoring

Students' verbal interactions associated with the category of monitoring accounted for 33.00 % (132/398) of all the coded spoken interactions (Table 5.10). It can be seen in Table 5.10 that both groups contributed equally to the monitoring time sub-category. Students in the control group did not engage in content evaluation and, none of the groups' interactions were classified as indicating a feeling of knowing. With regards to monitoring progress toward goals during the collaborative learning activity on simple circuits, there are twice as many instances from students in the experimental group in this sub-category compare to the control group. However, the control group contributed more than the experimental group to self-questioning. Overall, the frequency self-questioning in both groups could be considered to be quite low in comparison to their frequencies of interactions in monitoring progress towards goals and monitoring time (see Table 5.10).

Example 5.3: Monitoring time from the experimental group

NICK: How much time have we left?
DON: Fourteen minutes to go

Example 5.4: Monitoring time from the control group

BETTY: How are you getting on?
NATE: 4 minutes spent on goal setting already
NATE: Need to spend eight minutes on lighting up the bulb
BETTY: Just have only twenty four minutes to go

This analysis shows that members of the experimental group checked the time and reminded one another of the time remaining to complete the task (Example 5.3), whereas Example 5.4 illustrates that time monitoring was demonstrated by the control group members but no evidence to show that the control group members reminded one another of the time remaining on the task. While Betty in Example 5.4 inquired about the progress of Nate with regard to the learning activity, the responses of student Nate suggests that she is only reporting her own time monitoring strategies to Betty while the response of student Betty indicates that the twenty-four minutes remaining is just for her to complete her own work. This is contrary to Example 5.3 in which student Nick asked about the time left for the whole group to which student Don replied appropriately. This attribute reveals a marked difference in the usage of time monitoring strategy between the experimental and control groups.

5.4.2.3: Task difficulty and demands

Table 5.10 shows that students in both the experimental and the control groups were least engaged with the main category of task difficulty and demands. The few instances of the demonstrated CRL indicators under this category were equally distributed between the two groups. Example 5.5 gives the only example found in the expression of task difficulty and demands from the experimental group. None of the students in the control group demonstrated the co-regulatory behaviour associated with the sub-category of evaluating the learning process under the category of task difficulty and demands (evaluating/efforts' regulation).

Example 5.5: Task difficulty and demands from the experimental group

NICK:	But why is it brighter now?
DON :	I think the two bulbs were sharing the same electrical energy before
NICK :	The same energy is now for one bulb, I get it now.
DON:	That means one bulb now get more energy than before to power it
NICK:	That sounds reasonable, it's a bit tricky

5.4.2.4: Help seeking and giving

Help seeking and giving category of CRL behaviour accounted for 33.90% (135/398) of all the coded spoken interactions (see Table 5.10). The experimental group produced twice as many instances as the control group with respect to the help seeking/giving sub-category. The control group showed a greater proportion of the coded interactions associated with cognitive help seeking.

Example 5.6: Help seeking and giving from the experimental group

DON: How did you do it? Please show me
NICK: We connect the battery, add voltmeter, battery
NICK: Then, increase the volts to 2.0
DON: I've got it, 10 amps

Example 5.7: Help seeking and giving from the control group

BETTY: Miss, what can I do to get
Teacher: Look at your left side on the computer window
NATE: Click on the play button
BETTY: See there are more electrons
BETTY: What is the electric current in the circuit Nate?

It is evident that the experimental group members (Example 5.6) demonstrated affective and cognitive help seeking behaviours respectively by asking for help from one another. However, the demonstration of affective and cognitive help seeking behaviours by the control group (see Example 5.7) suggests that help was requested mainly from the science teacher in accordance with the prompt they received in their activity sheets, although the students in the control group also requested help from one another.

5.4.2.5: Motivation

Students also engaged in behaviours related to their motivation during the task, accounting for 14.80% (59/398) of all the coded spoken interactions (Table 5.10). Students in the experimental group engaged proportionally in more spoken interactions than the students in the control group (37 versus 22 respectively). Typical examples of demonstration of motivation by both the experimental and the control groups are depicted below.

Example 5.8: Motivation from the experimental group

NICK: See! it is glowing brighter
DON: This is really really fun
NICK: I'm loving it
DON That's interesting

Example 5.9: Motivation from the control group

BETTY: We need to work it more by putting one bulb, two more,
NATE: Yes, I've put it
BETTY: It glows again
NATE: Ehh!! That's good.
BETTY: Well done

It is evident from the spoken interactions of both groups that whenever something of interest occurred (e.g. *the glowing of bulbs*), other students complemented the action taking place with statements such as "*This is really fun" and "I'm loving it"* as reported for the experimental group. In the control group, statement like "*That is good*" and "*Well done*" were also observed in the students' interaction during learning.

In the next section, further evidences are provided from the observation notes developed from the classroom observation and video recording in support of the research questions 2a and 2b of this present research.

5.5: Observational Findings

The emerging categories of the co-regulated learning behaviours demonstrated by the students in both the experimental and the control groups obtained from the observational data are presented in the following section. The first category (students' cognitive behaviours) reveals that prompting students with CRL and SRL prompts might help more in improving the task and the team processes than prompting them with the SRL prompts only. It was observed that students in the experimental group used CRL and SRL prompts introduced into their learning activity sheets to develop a shared understanding of the team process and the task by asking other group members to clarify ideas they did not understand at every stage of the learning processes. On the contrary, students in the control groups asked their teacher to clarify their ideas. The students in the experimental group, for example, did try to agree on their planning behaviour in terms of goal setting, prior knowledge activation and time management behaviour before writing on their activity sheet. By contrast, students in the control group did not really come to an agreement through discussions with other students in their group before writing on their activity sheets.

The second category (students' metacognitive behaviours) shows that by supporting the students with CRL and SRL prompts, students gradually came to take responsibility for their own group. Prompts can be provided to groups in order for them to plan how the group will go about solving the given problem, monitor the group's progress towards a solution and finally evaluate the effectiveness of their group learning processes. Students in the experimental groups were observed to have settled down faster for their learning activity than did the students in the control groups. Most of the students in the experimental group read the prompts on their activity sheet and deemed it necessary to carry others students along with their planning in carrying out the task, monitoring and evaluating the learning goals. A lot of students in the control groups just read the SRL prompts on their activity sheets and interpreted them for individual regulation rather than group regulation.

5.6: Discussion

5.6.1: Students' Regulatory Behaviour

The results of the study suggest that students in the experimental group engaged more in collaborative activity and in more metacognitive activities within the learning environment compared to students in control group. No significant difference between the experimental and control groups was found in regard to their usage of SRL behaviours when learning simple circuits collaboratively in a computer based learning environment supported with either CRL and SRL prompts or SRL prompts only (Tables 5.2 and 5.4).

Figures 5.2 and 5.3 and Table 5.10 provide support for the claim that the experimental group students made use of key co-regulatory processes more frequently during learning as a consequence of the intervention of the CRL and SRL prompts. The extensive process data obtained from the students' verbal interaction detailing the quality of CRL indicators (planning, effort regulation, help seeking and giving, and motivational processes) used by students in both groups explains why the students in the control group demonstrated fewer and less effective co-regulatory behaviours as they learnt about Simple Circuits in a computer based science simulation learning environment in comparison to the experimental group (see Examples 5.1, 5.3, 5.6, 5.7, and 5.9, Tables 5.2 and 5.4). For example, the process data reveals that the students in the control group were using SRL behaviours such as setting individual goals but they did not progress to merging their individual goals into group goals (Example 5.2). Moreover, the pedagogical use of CRL prompts introduced into the learning activity sheets of the experimental group as a tool to support students' regulatory behaviour in planning, monitoring, help seeking and giving, and motivation was crucial in developing the students' co-regulatory skills. For example, students in the experimental group encouraged one another to give direct assistance to improve each other's work as seen in Examples 5.6 and 5.8.

These results are in agreement with other studies that explored the deployment of CRL processes used by students interacting with technological learning environments (Dettori & Persico, 2008; Volet *et al.,* 2009; Kirschner *et al.*, 2009; Pifarre & Cobos, 2010). The findings by these CRL researchers suggest that students who are not prompted with CRL behaviours when learning in a technology–rich learning environment are at the risk of being unable to use CRL strategies effectively. The benefit of introducing CRL prompts into a computer based science simulation teaching simple circuits is reinforced with the resultant improvement in the construction of social knowledge by students (Kreijns *et al.,* 2004). It is also important to note that the success of the incorporation of CRL and SRL prompts into a computer based simulation learning environment for enhancing co-regulation could be ascribed to the fact that the designed CRL prompts did not impose the burden of additional information processing that may interfere with the students' aim of concentrating on the to-be-learned information. That is, the designed CRL instructions were very simple to understand by the students such that they were able to carry out the given tasks on Simple Circuits. Furthermore, because the designed CRL prompts were pedagogically integrated into the learning resources, they assisted the students to work towards achieving their target goals within the allocated time.

5.6.2: Students' Academic Performance

The results presented in Table 5.2 showed that all students improved in their knowledge test scores after learning about simple circuits using a computer based simulation learning environment. This lends credence to the fact that all students (in both conditions) gained some conceptual understanding when learning using this environment. This result agrees with the outcomes from Azevedo (2005) and Olakanmi (2008) whose works focussed on the use of a technology enhanced learning environment to learn about the circulatory system in biology and rates of chemical reactions respectively. Findings from Azevedo (2005) and Olakanmi (2008) showed that science learners in a technology enhanced learning environment, tended to make gains in declarative knowledge from pre-test to post-test, regardless of whether they were prompted with CRL-instructions or not. The findings by Azevedo (2005) and Olakanmi (2008) agree with the result of this present study in the sense that all students who participated in this study gained some conceptual understanding of simple circuits as measured by the overall knowledge test scores.

5.6.3: Differences between the two groups in Academic Performance

This study investigated whether there are differences in the students' academic performance when learning science collaboratively in a computer based simulation learning environment with CRL and SRL or SRL prompts. The results show that there was a greater shift in the pre- and post-means of the simple circuit knowledge test scores of the experimental group (11.30 – 8.10 = 3.20) in comparison to that of the control group (10-25 – 7.50 = 2.75) as shown in Table 5.2. The result shows that the students in the experimental group improved in their academic performance as measured by a knowledge test on simple circuits (KTSC) more than students in the control group but there was no significant difference between the two groups (see Table 5.5). Although there was no significant differences between the experimental and the control groups in this present study, previous research suggest that students who are supported with metacognitive instructions display more learning gains in different domains and scientific tasks (Dettori and Persico 2008; Volet *et al.,* 2009; Pifarre and Cobos 2010).

Students in the experimental group supported with CRL and SRL-prompts were found to have attained higher marks in their activity sheets' scores than students in the control group supported with SRL-prompts only (Table 5.6). The significant difference in the scores of students in both learning contexts implies that most students in the experimental group gave correct answers on their activity sheets while in control group, fewer students did give correct answers. This might be associated with the presence of CRL and SRL-prompts on the experimental group's activity sheets. This finding suggests that supporting students' co-regulatory behaviours in the technology enhanced learning environment will have positive effect on the students' academic performance (Azevedo *et al.*, 2003). In summary, students in the experimental group outperformed students in the control group in both knowledge test on simple circuits and learning activity sheets' scores. The implications of the findings from this study are presented in the next section.

5.7: Concluding Remarks

This chapter presented the results from Study 2 of this research on the investigation of the effects of CRL and SRL prompts on students' regulatory behaviours and academic performance when working collaboratively in a computer based science simulations learning environment (Sections 5.3 to 5.5) and discussed how these results answered the research questions (Section 5.6). The outcome of this study shows that both CRL and SRL prompts were needed to enable students to engage in useful interaction during collaborative learning in a computer based science simulation learning environment. Students need to be aware of one another, of shared elements and of group learning whenever they are engaging in collaborative learning. The findings from this study confirm the suggestions by Njoo & de Jong (1993) and de Jong & Joolingen 1998) that technology-enhanced learning can be improved through the incorporation of CRL and SRL prompts into a technological environment.

The results of this study have implications and pose several challenges for the design of learning activities for enhancing students' CRL behaviours and academic performance in technology-rich dynamic science classrooms. As noted earlier on, findings from this study suggest that students working with learning activity sheets containing CRL and SRL prompts typically use more effective CRL behaviours such as planning, monitoring, and motivation when compared to students in the control group who were supported with SRL prompts only. These outcomes therefore establish the need for further investigation on how

CRL prompts can influence the students' demonstration of CRL behaviours as well as improve their academic performance over a period of time.

CHAPTER SIX: Effects of Co-Regulated Learning Prompts Over Time

6.1: Introduction

This chapter deals with Research Question 3 which investigated the effects of CRL and SRL prompts incorporated into a computer based science simulation learning environment on the students' ability to co-regulate their learning processes over a period of time during Studies 2, 3, and 4. This is compared to a computer based science simulation learning environment in which students were supported with SRL prompts only. In Chapter 5 (Study 2), there was a technical problem with the operability of *InterLoc* (a collaborative tool). Consequently, it was decided that collaborative learning which involved the activity presented on paper rather than on screen should be used. The activity sheets were designed and used collaboratively by students in each of the experimental and the control groups when learning science in their groups. In Study 2, the activity sheets had been used to expose the students to either CRL and SRL or SRL prompts only in the experimental and the control groups respectively. The outcome of Study 2 suggests that the incorporation of CRL and SRL prompts into the computer based science simulation learning environment helped students to demonstrate CRL behaviours much better than when they are prompted with SRL prompts only. The students in the experimental group also performed well in their scores on the activity sheets in comparison to a computer based science simulation learning environment incorporated with SRL prompts only. Regarding the knowledge test performance, students in both the experimental and the control groups improved from their pre-test to post-test scores on simple circuits but no significant difference was found between the groups.

As stated earlier on, this present chapter investigates further whether or not the incorporation of the CRL and SRL prompts into a computer based science simulation learning environment will bring about further improvement in the students' ability to co-regulate their learning over a period of time during Studies 2, 3 and 4. Students' academic performances were also assessed in each of the studies. To address this aim, data from Study 2 (already presented in Chapter five), and Studies 3 and 4 which were collected in spring, summer, and winter terms of 2010 respectively (see Table 3.1 page 57) are presented and analysed in this chapter.

Chapter Five established the fact that CRL and SRL prompts were effective in enhancing collaborative learning when learning Simple Circuits. This present chapter investigates further whether the introduction of CRL and SRL prompts in a computer based science simulation learning environment will promote the students' usage of CRL behaviours during the learning processes over time. The same 40 Year 7 students that participated in Study 2 also participated in Studies 3 and 4. The students studied two further science topics (Flowering Plants and Blood Circulation) using a computer based science simulation learning environment supported with either CRL and SRL prompts or SRL only prompts. Study 3 data were collected during the Flowering Plants lesson while Study 4 data were collected during the Blood Circulation lesson. All the data collected during Simple Circuits (Study 2), Flowering Plants (Study 3) and Blood Circulation lessons (Study 4) were collated to investigate changes in the learning process over the three topics studied in each of the experimental and the control group.

The Co-regulated Strategies for Learning Questionnaire (CRSLQ) that was used to measure the students co-regulated learning behaviours during collaborative learning during Study 2 was also used in each of Studies 3 and 4. The post-CRSLQ was administered to the students after exposing them to the learning interventions during Studies 3 and 4. Other data collected during Studies 3 and 4 included the post-self-regulated strategies for learning questionnaire (SRSLQ), the knowledge test on Flowering Plants (KTFP) and the knowledge test on Blood Circulation (KTBC). Students' written work in *InterLoc* also formed part of the data. *InterLoc* is a collaborative tool that was used in Studies 3 and 4 (instead of the activity sheets used in Study 2) to provide the students with either CRL and SRL prompts or SRL prompts only. These are referred to as the *InterLoc* chat scripts. Finally there were observational data of the students collected through the use of video cameras/observation notes and audio data. Small group interviews were also carried out after Study 4 with two groups of five students. These groups formed case studies for each of the experimental and the control groups.

This present chapter combines data from Studies 2, 3 and 4 to answer the following research question (RQ 3) which states:

"Does the incorporation of CRL and SRL prompts into a computer based science simulation learning environment improve co-regulated learning behaviours of KS3 (11–12 year old high-school students in the UK) science students over time (from studies 2, 3 and 4)?"

Theories of both co- and self-regulation suggest that 1) the more an individual does something the more they get better at it and 2) that their co- and self-regulation will increase (Schmitz and Wiese, 2006). Additionally Ruspini (2002) suggested that gathering information about the same individuals using the same questions at intervals provides the most reliable data on change in knowledge or attitude. Drawing on this work, the following hypotheses were proposed and investigated in this present chapter:

1. Students' scores on the CRSLQ and SRSLQ measures will increase from Study 2 to Study 4 irrespective of their learning conditions.
2. Supporting students with CRL and SRL prompts will increase their co-regulatory behaviours as measured by the CRSLQ compared to supporting students with SRL prompts only during collaborative learning over time.

3. There will be no significant differences between the two groups on self-regulatory behaviours as measured by the SRSLQ over time.
4. Students in the experimental group will improve their academic performance as measured by the knowledge test on Flowering Plants (KTFP) more than students in the control group.
5. Students in the experimental group will improve in their academic performance as measured by the knowledge test on Blood Circulation (KTBC) more than students in the control group.

This chapter begins with the summary of the procedure used in carrying out the studies presented in this chapter (Section 6.2). Various statistical analyses were used to investigate the students' co-and self-regulatory processes when learning the different science topics in a computer based science simulation learning environment (Section 6.3). Students' academic performances on Flowering Plants and also Blood Circulation were investigated (Section 6.4). Both quantitative and qualitative content analyses employed in investigating learning processes over time are presented in Section 6.5, and this is followed by the presentation of the observational findings in Section 6.6. The chapter continues with a discussion on how the analysis in all the Studies relate to the research questions in Section 6.7. Implications of the findings and the concluding remarks are presented in Section 6.8 and 6.9 respectively.

6.2: Procedure

Studies 3 and 4 were carried out in three separate 50-minute lessons just like Study 2. During the first lesson, students were trained in how to use *InterLoc* in communicating to each other in their groups as they learnt Flowering Plants and Blood Circulation during Studies 3 and 4 respectively. The pre-knowledge test on Flowering Plants (KTFP) and Blood Circulation (KTBC) were handed out to the participating students during the first lesson in each of Studies 3 and 4.

The second lesson for Studies 3 and 4 took place in the same computer suites used for Study 2. Students were introduced to the Sunflower science simulation programme teaching the Flowering Plants and Blood Circulation for Studies 3 and 4 respectively. Students were encouraged to discuss the given task on Flowering Plants and Blood Circulation together as a group using *InterLoc* tool (See Figure 6.1).

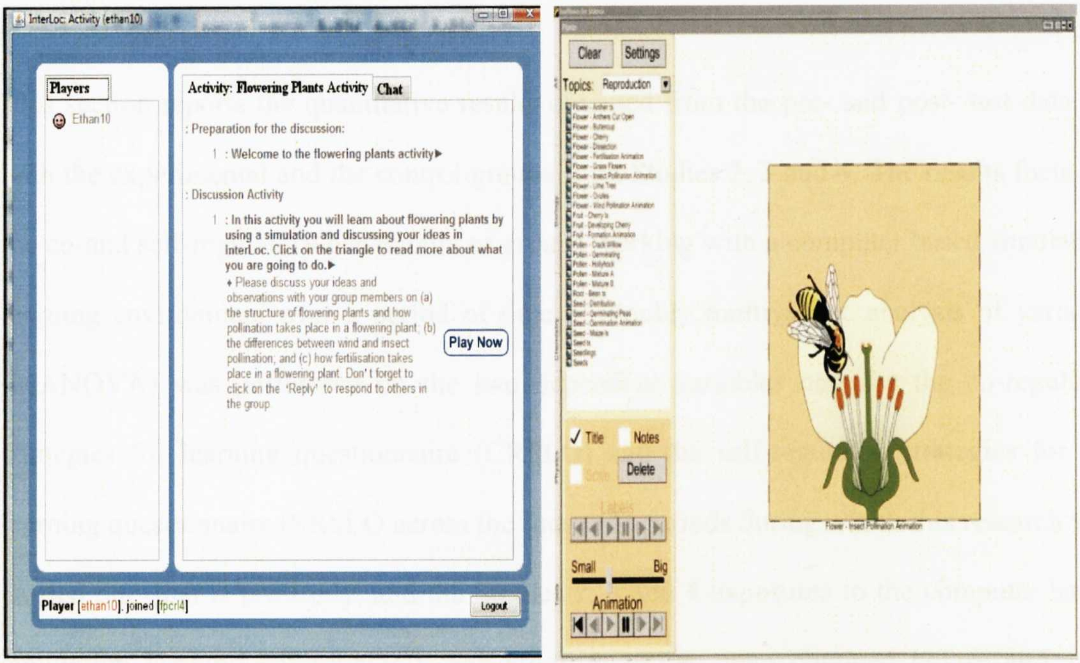


Figure 6.1: Example of how students used InterLoc tool and computer based science simulation during Studies 3 and 4

Prior to both Studies 3 and 4, the researcher had prepared the learning activities for both the experimental and the control groups within *InterLoc* environment. Students in both the experimental and the control group were divided into sub-groups of five and placed in each of the *InterLoc* rooms. The experimental group was provided with the combined CRL and SRL prompts whilst the control group was provided with SRL prompts only. During the lesson students were instructed to work collaboratively using the science simulations on Flowering Plants and Blood Circulation for each of the studies. Thereafter, the students were asked to discuss their learning with other members in their group using *InterLoc*.

Finally, during the third lesson in Studies 3 and 4, the post-CRSLQ, post-SRSLQ and the post-Knowledge tests on the Flowering Plants (KTFP) and Blood Circulation (KTBC) (for

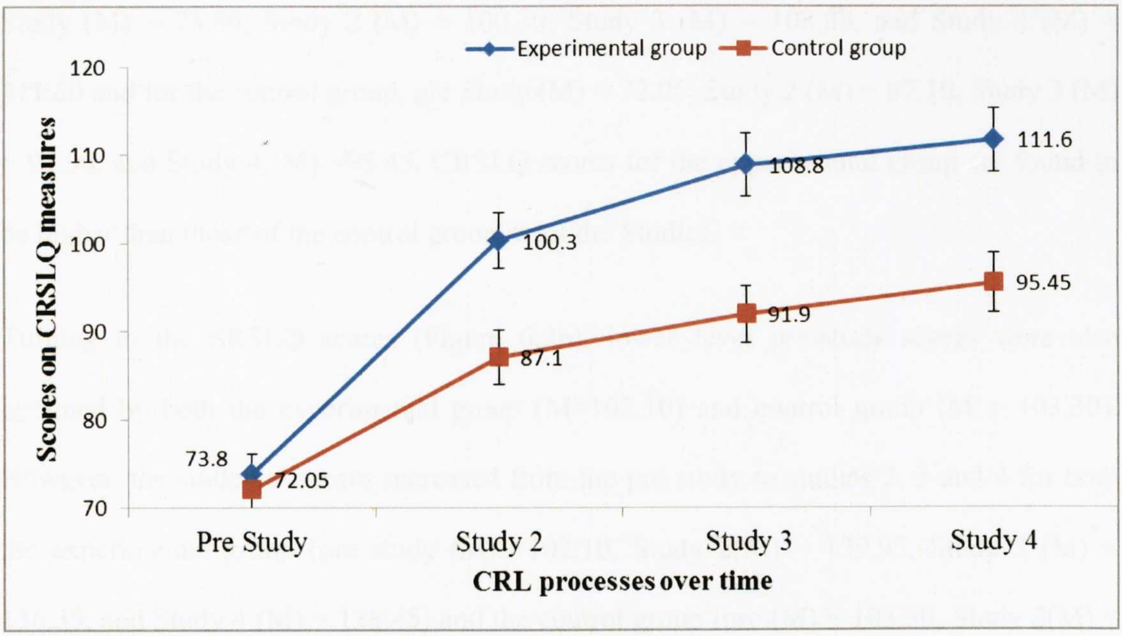
Studies 3 and 4 respectively) were administered to the students. Both the quantitative and qualitative data collected during Studies 3 and 4 were combined with data collected during Study 2 to investigate co-regulation over time. The results of this investigation are presented in the next section.

6.3: Students' Performance on co-and self-regulatory processes over time

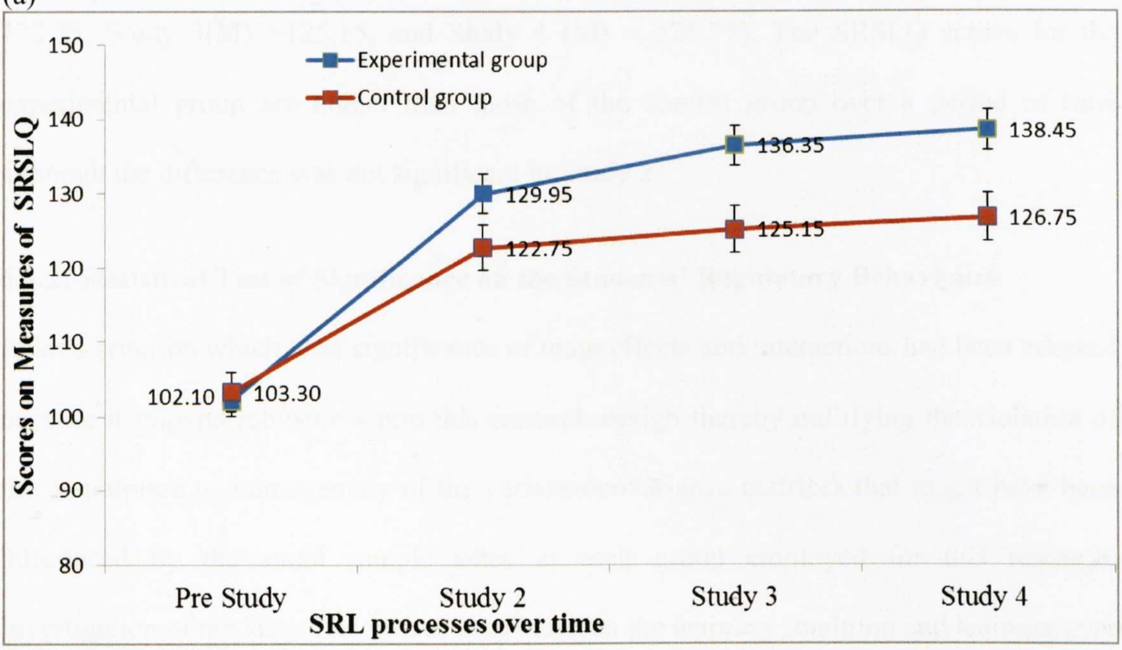
This section reports the quantitative results obtained from the pre- and post- test data for both the experimental and the control groups from Studies 2, 3 and 4. The results focus on the co-and self-regulatory behaviours of groups working with a computer based simulation learning environment over a period of time. A doubly multivariate analysis of variance (MANOVA) was performed on the two dependent variables namely: the co-regulated strategies for learning questionnaire (CRSLQ) and the self-regulated strategies for the learning questionnaire (SRSLQ across the four time periods during which this research was carried out (that is pre-study, and the Studies 2, 3 and 4 exposures to the computer based simulation learning environment). For Study 2, scores were obtained before and after exposure to the computer based simulation learning environment. For Studies 3 and 4 scores were obtained after exposure to the computer based simulation learning. Two types of learning conditions formed the experimental and the control groups.

6.3.1: Descriptive Statistics Results on the Regulatory Behaviours

The mean scores (M) of the dependent measures (CRSLQ and SRSLQ) obtained from the pre- Study and Studies 2, 3 and 4 (Time) for both the experimental group and control group are reported in Figures 6.2a and 6.2b.



(a)



(b)

Figure 6.2: (a) Scores obtained on the CRSLQ measure by both the experimental and control groups before, and after Studies 2 to 4 (b) Scores obtained for SRSLQ measure by both experimental and control groups before, and after Studies 2 to 4

Figure 6.2a shows that both experimental and the control groups' CRL behaviours started at a lower level, as reflected in the mean scores obtained in the pre-Study CRSLQ by the experimental group (Mean, M= 73.80) and the control group (M = 72.05). Looking at the students' mean scores on CRSLQ across pre, Studies 2, 3 and 4 for both groups in Figure 6.2a, it is evident that improvement occurs in students' scores from pre-study, to Studies 2, 3 and 4 for both groups over a period of time. The experimental group's scores were pre

Study (M) = 73.80, Study 2 (M) = 100.30, Study 3 (M) = 108.80, and Study 4 (M) = 111.60 and for the control group, pre Study (M) = 72.05, Study 2 (M) = 87.10, Study 3 (M) = 91.90, and Study 4 (M) =95.45. CRSLQ scores for the experimental group are found to be higher than those of the control group in all the Studies.

Turning to the SRSLQ scores (Figure 6.2b), lower level pre-study scores were also obtained by both the experimental group (M=102.10) and control group (M = 103.30). However, the students' scores increased from the pre study to studies 2, 3 and 4 for both the experimental group (pre study (M) =102.10, Study 2(M) = 129.95, Study 3 (M) = 136.35, and Study 4 (M) = 138.45) and the control group (pre (M) = 103.30, Study 2(M) = 122.75, Study 3(M) =125.15, and Study 4 (M) = 126.75). The SRSLQ scores for the experimental group are higher than those of the control group over a period of time although the difference was not significant in Study 2.

6.3.2: Statistical Test of Significance on the Students' Regulatory Behaviours

Pillai's criterion which tests significance of main effects and interactions had been adopted because it imparts robustness into this research design thereby nullifying the violation of the assumption of homogeneity of the variance-covariance matrices that might have been introduced by the small sample sizes in each group employed for this research. Investigation of the statistical interactions between the learning condition and learning over a period of time (the independent variables) on the students' scores on CRSLQ and SRSLQ measures by the doubly multivariate analysis of variance (MANOVA) revealed some significant results. Specifically, the MANOVA examined whether the effects of varied computer based simulation learning environment (Experimental group and the control group) on the different CRSLQ and SRSLQ measures were the same over time.

The assumption of homogeneity of variance shows that the observed covariance matrices of the dependent variables are equal across the groups. Therefore, assumptions of doubly-multivariate analysis of variance which tests the homogeneity of the variance-covariance matrices were found to be satisfactory as shown in the Box's test. Box's test of equality of covariance matrices showed that the data were robust for multivariate analyses. The test is not significant at $P = 0.05$ (see Table 2 in Appendix L).

Table 6.1 shows a significant interaction between time and learning condition, as illustrated by the value of the Pillai's Trace = 0.21, F (9, 38) = 4.56, p =0.00, partial $\eta 2$ = 0.11 (large effect size). Also, a significant effect of time was found; Pillai's Trace = 0.85, F (9, 38) = 27.83, p = 0.00, partial $\eta 2$ = 0.42 (large effect size).

Table 6.1: Results of multivariate tests (within subjects' effects)

		Value	F	Hypothesis df	Error df	Sig.	partial $\eta 2$
Time	Pillai's Trace	0.85	27.83	6.00	228.00	0.00	0.42
Time * Learning-condition	Pillai's Trace	0.21	4.56	6.00	228.00	0.00	0.11

Moreover, the univariate analysis of variance (Table 6.2) also resulted in an F-ratio that was used to determine whether variations in the students' scores on the CRSLQ and the SRSLQ were affected by time and the various learning conditions (the experimental and the control group). The first within-subject comparison (time) in Table 6.2 confirms that students' scores obtained on CRSLQ ($p < 0.05$) and SRSLQ ($p < 0.05$) measures changed significantly over a period of time irrespective of the groups they belong.

Table 6.2: Tests of Within-Subjects contrast (within subjects comparison)

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig	partial $\eta 2$
Time	CRSLQ	19384.81	1	19384.81	191.79	0.00	0.84
	SRSLQ	17709.62	1	17709.62	152.77	0.00	0.80
Time * Learning-condition	CRSLQ	1099.81	1	1099.81	10.88	0.00	0.22
	SRSLQ	911.65	1	911.645	7.864	0.01	0.17

The second within-subjects comparison (time and learning conditions) shown in Table 6.2 indicates that significant interactions between time and learning conditions exist for both CRSLQ ($p < 0.05$) and SRSLQ ($p < 0.05$) measures.

In Table 6.3, a pairwise comparison of changes in measures of CRSLQ and SRSLQ for the experimental and control groups over a period of time is presented in order to validate hypothesis 1. Pairwise comparison of changes in measures (mean difference of the two groups' scores over time) of CRSLQ, and SRSLQ reveals that test scores for these measures increase through all periods of learning activities irrespective of the learning conditions to which a student belongs during the transition in learning activity from Studies 2 to 4 (Table 6.3).

Table 6.3: Pair wise Comparison of Changes in Measures of CRSLQ and SRSLQ, of the Experimental and Control Groups Over Time

Measures	I (TIME)	J (TIME)	Mean Difference (J –I)	Std. Error	Sig
CRSLQ	Pre Study (72.93)	Study 2 (93.70)	20.78*	2.05	0.00
	Study 2 (93.70)	Study 3 (100.35)	6.65*	1.14	0.00
	Study 3 (100.35)	Study 4 (103.53)	3.18*	0.76	0.00
SRSLQ	Pre Study (102.70)	Study 2 (126.35)	23.65*	2.77	0.00
	Study 2 (126.35)	Study 3 (130.75)	4.40*	1.77	0.01
	Study 3 (130.75)	Study 4 (132.60)	1.85*	0.35	0.00

The analysis presented in Table 6.3 indicates that significant differences exist between the CRSLQ results across the different studies irrespective of the learning conditions to which a student belongs. With respect to SRSLQ, significant differences are also found across the studies irrespective of the learning conditions to which a student belongs. In summary, this result supports research hypothesis number 1 which states that student' scores on CRSLQ and SRSLQ measures will increase from from study 2 to study 4 irrespective of their learning conditions.

Table 6.4: Post-tests comparing the changes across the scores on CRSLQ and SRSLQ in each of the two group and changes in groups in each of the scores on CRSLQ and SRSLQ over a period of time

Measures	Experimental (Mean)	Control (Mean)	Mean Difference between scores of the experimental the control groups	Std. Error	Sig.
CRSLQ					
Pre Study	73.80	72.05	1.75	3.59	1.00
Study 2	100.30	87.10	13.20*	3.59	0.01
Study 3	108.80	91.90	16.90*	3.59	0.00
Study 4	111.60	95.45	16.15*	3.59	0.00
SRSLQ					
Pre Study	102.10	103.30	-1.20	4.14	1.00
Study 2	129.95	122.75	7.20	4.14	1.00
Study 3	136.35	125.15	11.20	4.14	0.21
Study 4	138.45	126.75	11.70	4.14	0.15

Note: Pairwise comparisons were protected against Type I error using a Bonferroni adjustment.

Table 6.4 shows that no significant differences occur in any of the CSRLQ and SRSLQ measures during pre study (i.e. prior to commencement of Study 2) between the experimental and the control groups. This confirms that, overall, students in both the experimental and the control groups are at the same level of CRL and SRL behaviours prior to learning various science topics in a computer based science simulation learning environment. This finding is confirmed by Figures 6.2a and 6.2b. This outcome helps in establishing the treatment effects on the students' regulatory behaviours as they learnt various science topics from Studies 2, 3 and 4. The findings in Table 6.4 are now related to hypotheses 2 to 4 in the subsequent paragraphs.

Hypothesis 2 investigated the effect of supporting students with CRL and SRL prompts on their co-regulatory behaviours as measured by CRSLQ compared to supporting students with SRL prompts when learning various science topics collaboratively in a computer based science simulation learning over time. Table 6.4 shows that significant differences exist among treatment groups over learning periods from Study 2 to 4 on the measure of CSRLQ. Therefore, this result supports hypothesis 2. This result is also supported by

Figure 6.1a which reveals that the experimental group had a higher CRSLQ score when compared with the control group (SRL prompted group) over the different time periods.

Hypothesis 3 states that there will no differences between the experimental group and the control groups on self-regulatory behaviours as measured by SRSLQ over time. Although there was a significant interaction between the effects of group and time (Table 6.2), no group difference at any of the three Studies (Table 6.4).

6.4: Students' academic performance during Studies 3 and 4

In order to determine the influence of CRL and SRL prompts on the students' regulatory behaviours when learning science in a computer based science simulation learning environment, learning outcomes based on the learning content were measured for Studies 3 and 4. Independent-sample t-tests were carried out on the students' pre- and post-Knowledge Test scores on Flowering Plants and Blood Circulation. This analysis helped to test hypotheses 5 and 6. The next two sections present and discuss the independent-sample t-test analysis for Studies 3 and 4.

6.4.1: Students' performance in Knowledge Test on Flowering Plants (KTFP)

Here, it is intended to determine whether different instructional conditions (a computer-based simulation science learning environment with CRL and SRL and SRL only prompts) affect learners' test performance on Flowering Plants in science, indicating a better academic performance.

Table 6.5: Means and standard deviation of pre and post-KTFP scores

	Learning Conditions		Mean(M) Difference in pre- KTFP and post-KTFP	Std. Error Difference
	Experimental (N=20)	Control (N=20)		
Pre- KTFP	8.05	7.45	0.60	0.92
Post - KTFP	10.35	9.85	0.50	0.89

The independent-sample t-test for the means of pre and post KTFP scores presented in Table 6.5 (see details in Tables 1 and 2 in Appendix N) found no significant differences between the experimental and the control groups at the pre KTFP, t (38) = 0.65, P>0.05, also there were no significant differences at post KTFP, t (38) =0.56, P>0.05. The results indicate that there was no difference between the experimental and the control group in academic performance as measured by the knowledge test on Flowering Plants. However it is evident from Table 6.5 that both the experimental and the control groups improved in their Knowledge test from Pre KTFP to post KTFP. This result rejects hypothesis 5 which state that students in the experimental group will improve in their academic performance as measured by the knowledge test on Flowering Plants (KTFP) more than students in the control group.

6.4.2: Students' performance in the Knowledge Test on Blood Circulation (KTBC)

In order to determine the effect of the CRL and SRL prompts on the experimental group's learning task on Blood Circulation, an independent-sample t test was also employed to compare the means for the experimental group and the control group for students' scores in their KTBC. This helped to investigate hypothesis 6 stating that students in the experimental group will improve in their academic performance as measured by knowledge test on Blood Circulation (KTBC) more than students in the control group.

Table 6.6: Means and standard deviation of pre and post-KTBC scores

	Learning Conditions		Mean(M) Difference in pre- KTBC and post-KTBC	Std. Error Difference
	Experimental (N=20)	Control (N=20)		
Pre- KTBC	8.20	7.60	0.60	0.92
Post -KTBC	10.60	10.00	0.60	0.93

The independent-sample t-test for the means of pre and post KTBC scores presented in Table 6.6 (see details in Tables 3 and 4 in Appendix N) found no significant differences between the experimental and the control groups in the pre KTBC, t (38) = 0.65, P>0.05, also there were no significant differences at post KTBC, t (38) =0.65, P>0.05. These results also indicate that there was no significant difference between the experimental and the control groups in academic performance as measured by the knowledge test on Blood Circulation. Table 6.6 shows that both the experimental and the control groups improved in their Knowledge test from pre-KTBC to post-KTBC. This result rejects hypothesis six which states that students in the experimental group will improve in their academic performance as measured by the knowledge test on Blood Circulation (KTBC) more than students in the control group. Table 6.7 below summarises whether each of the hypotheses investigated in this chapter is supported or not by the outcome of this study so far.

Table 6.7: Summary of findings for the six hypotheses

Hypothesis	*Supported (Yes or No)*
1) Students' scores on CRSLQ and SRSLQ measures will increase from study 2 to study 4 irrespective of their learning conditions.	Yes
2) Supporting students with CRL and SRL prompts will increase their co-regulatory behaviours as measured by CRSLQ compared to supporting students with SRL prompts only during collaborative learning over time.	Yes
3) There will be no significant differences between the two groups on self-regulatory behaviours as measured by SRSLQ over time.	Yes
4) Students in the experimental group will improve in their academic performance as measured by the knowledge test on Flowering Plants (KTFP) more than students in the control group.	No
5) Students in the experimental group will improve in their academic performance as measured by knowledge test on Blood Circulation (KTBC) more than students in the control group.	No

In summary, the outcomes from the quantitative analysis carried out so far suggest that CRL and SRL prompts improved students' co-and self-regulated learning processes over time as they learnt various science topics in a computer based science simulation learning environment from Studies 2, 3 and 4. Students' academic performance when learning Flowering Plants and Blood Circulation during Studies 3 and 4 show that there were no differences between the experimental and the control group on KTFP and KTBC respectively. The need to provide further supporting evidence to corroborate the outcomes from the quantitative analysis led to carrying out both quantitative and qualitative content analysis of the data collected in the form of *InterLoc* chat script/ audio data, observational data of the students through the use of video cameras/observation notes. This is discussed in the next section.

6.5: Quantitative and qualitative content analysis

This section presents the quantitative content analysis of the qualitative data collected from Studies 2, 3 and 4 with a view to complementing the findings reported in Section 6.2 to 6.4. The data collected were spoken interactions transcribed from audio recordings and chat scripts containing written expressions of interactions between students within *InterLoc* (the collaborative tool used in this study). The evidence presented in this section will help to establish whether or not the incorporation of CRL and SRL prompts into a computer based science simulation learning environment had an effect on the students' demonstration of CRL behaviour as compared to SRL only prompts over a period of time. This aim was achieved by comparing the qualitative data collected from Studies 2, 3 and 4. The chat scripts (I*nterLoc* transcripts) were analysed using the categories of co-regulation referred to in chapter 5 as adapted from Dettori & Persico, (2008). All the data being analysed were collected during Studies 2, 3 and 4 when participants worked on Simple Circuits, Flowering Plants, and Blood Circulation respectively.

6.5.1: Reliability Analysis of CRL Coding

In this chapter, the coding scheme used to identify indicators of CRL behaviour the students demonstrated in both the experimental and the control groups was the same as the one used for Study 2 (see Section 5.4.1 and Table 2.2). The chosen unit of analysis was a single individual student's contribution to the *InterLoc* chat script messages. These were examined for CRL-indicators which were objectively identifiable and consist of a large but still manageable set of cases. The analysed messages turned out to contain all the indicators proposed in Table 2.2. It is worth pointing out that, several messages also contained more than one occurrence of a CRL-indicator.

Table 6.8 shows that for the experimental group, there were totals of 291 and 312 *InterLoc* messages from the chat script during Studies 3 and 4 respectively. Total messages from *InterLoc* chat script for Studies 3 and 4 were found to consist of 256 and 289 CRL related messages respectively. Both 256 and 289 CRL related messages were then coded into 272 and 365 CRL indicators respectively (see Tables 1 and 7 in Appendix G for details).

For the control group, there were totals of 242 and 275 *InterLoc* messages from the chat script during Studies 3 and 4 respectively. The total CRL related messages obtained for Studies 3 and 4 were found to be 153 and 213 respectively. Finally, both 153 and 213 CRL related messages were then coded into 186 and 269 CRL indicators respectively (see Table 1 and 8 in Appendix G for details).

Table 6.8: Comparison of the frequency of CRL related messages obtained from Studies 2 to 4

	Study 2		Study 3		Study 4	
	Experimental	Control	Experimental	Control	Experimental	Control
Total number of *InterLoc* messages from the chat script.	268	177	291	242	312	275
Number of CRL -related message in InterLoc chat script	217	105	256	153	289	213
Total number of CRL indicators	249	149	272	186	365	269
Holsti reliability (PA_O)	0.85	0.87	0.98	0.96	0.99	0.98
Cohen Kappa reliability (κ)	0.86	0.88	0.95	0.92	0.97	0.96

In order to ensure the validity and the reliability of the coding, two coders (the same who coded the study 2 data presented earlier on in Chapter Five) participated in coding the students' messages in *InterLoc* for studies 3 and 4 (Tables 7 and 8 in Appendix G). (Lombard *et al.*, 2005, Pifarre & Cobos, 2010). The values of the inter-rater reliabilities (Holsti reliability and Cohen Kappa reliability) obtained for studies 3 and 4 are presented in Table 6.8. The values obtained for both Holsti's and Cohen's Kappa coefficients for the inter-rater agreement between two coders 1 and 2 for both groups as they learnt Flowering Plants and Blood Circulation during Studies 3 and 4 respectively show that the coding process was reliable. After the computation of the inter-rater reliability, the coders discussed the controversial cases until they reached 100% agreement as they did for the previous study. The data reported in this section refers to the agreed coding. The values of the inter-rater reliability obtained for this study indicates the replicability of this approach.

Table 6.9: Percentage CRL and non-CRL massages for the experimental and control groups for Study 2 and study 4

	Study 2		Study 3		Study 4	
	Experimental	Control	Experimental	Control	Experimental	Control
CRL-related messages/interaction	81%	59.3%	88%	63.2%	92.60%	77.50%
Non-CRL-related messages/interaction	19%	40.7%	12%	36.8%	7.40%	22.50%

The coding of messages from *InterLoc* chat scripts shown in Table 6.9 for the experimental group indicate that the proportion of CRL related messages in the total messages posted in

InterLoc are 88.00% (256/291) and 92.60% (289/312) during Studies 3 and 4 respectively whereas for the control group, the proportion of CRL related messages are 63.20% (153/242) and 77.50% (213/275).

6.5.2: Students' Verbal and Written Interactions

Table 6.10 summarises the frequency of occurrence of CRL indicators in the spoken interactions (obtained from audio recordings) and written expressions from *InterLoc* chat scripts for both the experimental and control groups in relation to the sub-categories of each of planning, monitoring, task difficulty and demands, help seeking and giving, and motivation (main categories of CRL) for the Studies 2, 3 and 4 during the learning of Simple Circuits, Flowering Plants and Blood Circulation respectively. This analysis helped to investigate the changes in the frequency of students' CRL behaviours over the three Studies (Studies 2, 3 and 4).

Table 6.10: Comparative analysis of the frequencies of usage of categories of the learners' co-regulatory behaviours in a CSCL environment over a period of time

Categories	Study 2		Study 3		Study 4	
	Experimental	Control	Experimental	Control	Experimental	Control
Planning	49	16	55	23	78	45
Monitoring	89	43	96	63	123	88
Task Difficulty and Demands (Evaluating/ Efforts regulation).	3	4	6	10	14	17
Help seeking and help-giving	71	64	74	61	93	76
Motivation	37	22	41	29	57	43
Total	249	149	272	186	365	269

Figures 6.3 and 6.4 illustrate, through bar charts, the changes in the frequency of CRL behaviour over time as measured by counting the numbers of CRL indicators found in the students' spoken interactions (obtained from audio recordings) and the InterLoc chat scripts. Figure 6.3 presents the total number of spoken interactions (obtained from audio recordings) or the *InterLoc* chat script messages during the collaborative learning of Simple Circuits, Flowering Plants, and Blood Circulation obtained for both the

experimental and the control groups. Figure 6.4 suggests that for the experimental and the control groups, the total number of students' messages obtained from either audio recordings or *InterLoc* chat script increases over time. It is also evident from Figure 6.4 that students in both the experimental group and the control group increasingly used CRL skills while learning Simple Circuits, Flowering Circuits, and Blood Circulation within a computer based science simulation learning environment. This supports hypothesis 1. However, students in the experimental condition could be seen to have produced higher number of total messages obtained from either audio recordings or *InterLoc* chat script, and CRL-related messages, than the control group (Figure 6.4).

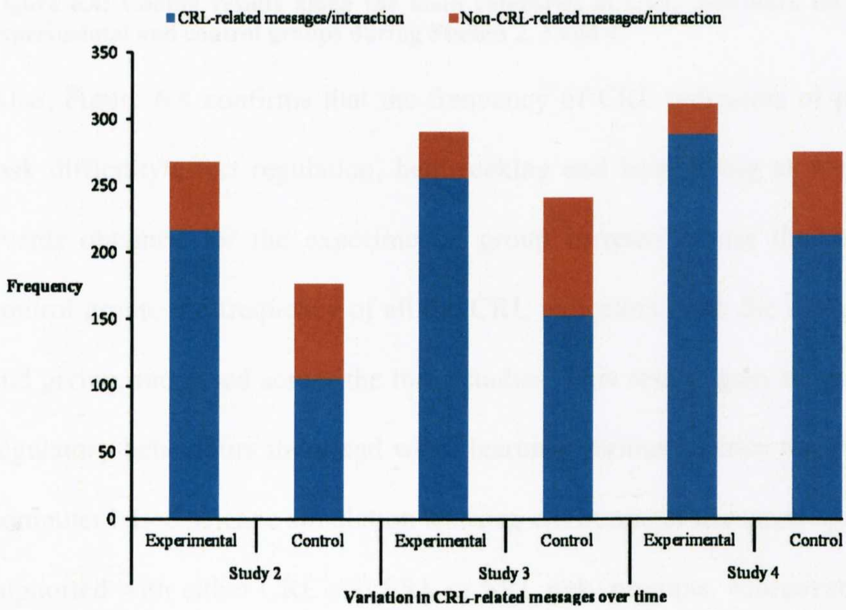


Figure 6.3: Proportion of CRL-related messages in the total number of spoken interactions/written expressions from InterLoc chat scripts by the experimental and the control groups during studies 2, 3 and 4

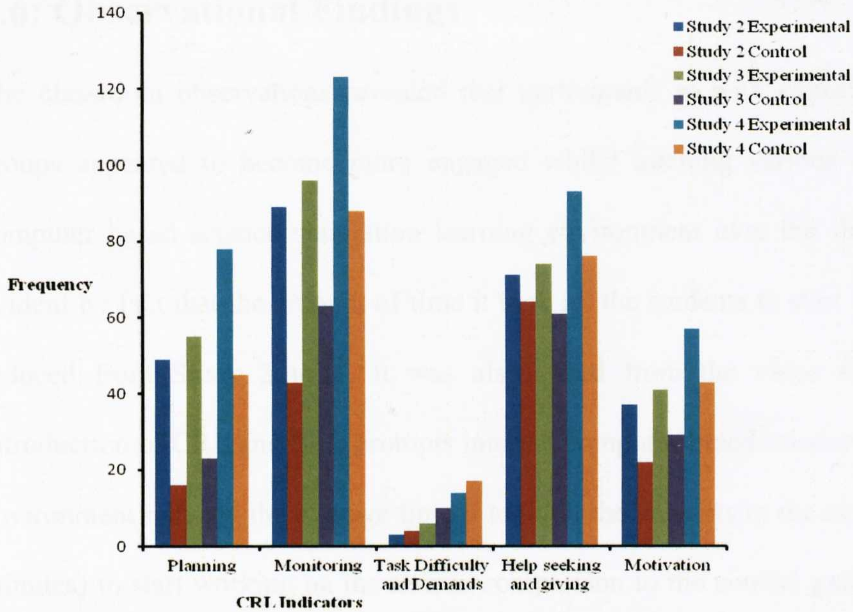


Figure 6.4: Coding results along the main categories of CRL indicators for the interactions of the experimental and control groups during Studies 2, 3 and 4.

Also, Figure 6.4 confirms that the frequency of CRL indicators of planning, monitoring, task difficulty/effort regulation, help-seeking and help-giving as well motivation related events obtained for the experimental group increase across the three studies. For the control group, the frequency of all the CRL indicators, with the exception of help seeking and giving, increased across the three studies. This result again suggests that students' co-regulatory behaviours increased when learning various science topics collaboratively in a computer based science simulation learning environment irrespective of whether they were supported with either CRL and SRL or SRL only prompts. Moreover, experimental group messages from the audio recording and *InterLoc* chat scripts were found to have a greater number of CRL indicators of planning, monitoring, effort regulation, help seeking and giving as well as motivation related events than the control group over the three studies (Figure 6.4).

In the next section, further evidence is provided from the observation notes developed from the classroom observation and video recording in support of research question 3 of this research.

6.6: Observational Findings

The classroom observations revealed that participants in both experimental and control groups appeared to become more engaged whilst learning various science topics in a computer based science simulation learning environment over the three studies. This is evident by fact that the amount of time it took all the students to start working on the task reduced from Study 2 to 4. It was also noted from the video observation that the introduction of CRL and SRL prompts into the computer based science simulation learning environment reduced the average time it took all the students in the experimental group (6 minutes) to start working on the task in comparison to the control group (10 minutes). As students in each group progressed across the learning sessions (comprising Studies 2, 3 and 4) participants in each of the groups were observed discussing how to set clearer lesson aims for each group, when compared to prior sessions. Moreover, during Study 4, students in the control group were seen and heard in their discussions to be progressing from setting personal goals to group goals, which was absent in Study 2. Further, the frequency of this observation in the control group was noted to be less than that of the experimental group as at Study 4.

It was discovered that participants engaged in a greater amount of explanation of concepts relating to Simple Circuits, Flowering Plants, and Blood Circulation. Moreover, it was seen that the amount of negotiation between the participants in each group at the start of the session, coupled with the amount of reflection on their learning at the end of each session increased over a period of time for each group. It was also observed that as learning in the computer based science simulation learning environment progressed, fewer students in the control group sought help from their teachers; therefore, students were seen to be giving help to each other and receiving help from each other.

In effect, reduction in the amount of external intervention from the teacher to the control group was observed to have encouraged students' inter-dependence and autonomy in the control group. This is evident by the fact that students in the control group sought the teacher's interventions for 13, 9, and 4 times during studies 2, 3 and 4 respectively. For the experimental group, the teacher's interventions were noted to have taken place for 5, 2, and 2 times for the same period of time during the session. Many of the students in both groups remarked that they enjoyed using the *InterLoc* and the simulation programme to learn Simple Circuits, Flowering Plants, and Blood Circulation.

6.7: Discussion

This section discusses the implications of the findings reported on the effects of CRL and SRL prompts on the ability of students to co-and self-regulate their learning processes over the three studies carried out in this present research. An experiment design was employed which involved an experimental class and a control class, students in the experimental class were supported with CRL and SRL prompts while students in the control class were supported with SRL prompts only. Overall, the results indicated that supporting students with CRL and SRL prompts has a more positive, gradual effect on the ability of students to regulate their learning processes over time, in comparison to the control class. In addition, it was discovered that both the experimental and control classes increased their demonstration of CRL behaviours over time. Students in both classes had increased scores in their knowledge test in each of the studies but no difference was found between the two classes in terms of the academic performance. These findings are consistent with the theory which suggests that metacognitive behaviours demonstrated by students are unfolding, iterative processes, and within-subjects designs are more likely to detect the effect (Sitzmann *et al.,* 2009; Hadwin *et al.,* 2010). The next two sections present the discussion of the answer to the research question highlighted in Section 6.1 by looking into how the data has shaped the outcome of the investigation of the hypotheses.

6.7.1: Effects of CRL and SRL Prompts on Students' Regulatory Behaviour Over Time

This section provides insight into how different learning conditions influence the extent to which students co-regulate their learning behaviour when learning Simple Circuits, Flowering Plants, and Blood Circulation in a computer based science simulation learning environment. The multivariate analysis of variance (MANOVA) of the CRSLQ scores for different periods of data collection (Studies 2, 3 and 4) confirmed that the experimental group had made greater use of CRL behaviours such as measured by CRSLQ than the control group (Table 6.4, Figures 6.2a and 6.3). With respect to SRL behaviours, students assigned to both the experimental and the control groups improved in their SRL behaviours but no significant difference (Table 6.4 and Figure 6.2b) was observed between the two groups, as measured by the SRSLQ.

Furthermore, the quantitative content analysis of the data obtained from the students' spoken interactions (through audio recording) and *InterLoc* chat scripts suggests that the experimental and the control groups differed in the frequency of demonstrated co-regulatory behaviours while learning Simple Circuits, Flowering Plants, and Blood Circulation over the three studies (Figures 6.3 and 6.4). For instance, it was found that students in the experimental group contributed a greater number of total messages and CRL-related messages through their talk (obtained through audio recording) or through their *InterLoc* chat scripts, in comparison to the control group, as illustrated in Figure 6.3. Also, students in the experimental group exhibited planning and monitoring behaviours at least one and half times as much as the control group across the three Studies (Figures 6.4).

Turning to the task difficulty and demands behaviours, both groups used these behaviours almost equally during Study 2, while the control group employed these behaviours much more than the experimental group during Studies 3 and 4 when learning Flowering Plants and Blood Circulation respectively (see Figure 6.4). Both groups used the help seeking and giving behaviours fairly equally during Studies 2 and 3 (when learning Simple Circuits, and Flowering Plants respectively), while the experimental group employed these behaviours up to 1.25 times as much as the control group during Study 4 (when both groups learnt Blood Circulation). Moreover, the experimental group employed motivational behaviours for collaborative learning activity much more frequently than the SRL group all through the three studies.

Overall, the frequencies of occurrence of the CRL behaviours over the three studies increased for both the experimental and the control groups. These findings highlight the importance of supporting students with CRL and SRL prompts when learning in a computer based science simulation learning environment over a period of time. Moreover, it is likely that the pedagogical use of CRL-prompts was an important part of the continuous development of the students' co-regulatory behaviours. The findings in this study are also supported by the classroom observations reported in Section 6.6.

These findings appear consistent with previous research which examined the development of metacognitive behaviours demonstrated by students in technology rich learning environments, such as CSCL, over time (Sitzmann *et al.,* 2009; Volet *et al.,* 2009; Hadwin *et al.,* 2010; Pifarre & Cobos, 2010). The findings by these CRL researchers suggest that students who are not supported with metacognitive prompts such as CRL and SRL prompts are at risk of being unable to use CRL strategies effectively when learning in a technology rich learning environment. The lower frequencies of occurrence of CRL indicators obtained from the analysis of audio transcripts and the *InterLoc* chat scripts for students in the control group across the sessions (when compared to the to the experimental group) attest to this fact (Figure 6.3). The current results are also consistent with other research which suggests that the metacognitive behaviours demonstrated by students are the result of the unfolding and iterative processes. However, the need to understand how students develop strategies that ultimately determine their ability to regulate their learning behaviour necessitates that these behaviours must be examined over time (Sitzmann *et al.*, 2009; Hadwin *et al.*, 2010). The results highlight the importance of theory in guiding the understanding of the regulation of learning processes and emphasise the criticality of conducting research at the appropriate level of analysis (Sitzmann *et al.*, 2009). By employing a within-subjects design across three studies, it has been affirmed that the incorporation of CRL and SRL prompts into a computer based science simulation learning environment enabled students to improve in their demonstration of CRL behaviours (Tables 6.1 and 6.2). This research also supports the outcome of previous studies suggesting that a within-subjects comparison is more appropriate for understanding whether students' regulation of learning processes changed significantly over a period of time (Tables 6.3 and 6.4) irrespective of which learning condition they were in (Yeo & Neal, 2004; Ilies & Judge, 2005; Vancouver & Kendall, 2006; Sitzmann *et al.*, 2009).

The effect of incorporating SRL prompts only into the computer based science simulation learning environment on the students' ability to co-regulate their studies over a period of time is considered to be relatively small in comparison to that of the experimental group. However, it can be argued on several grounds that these effects are both meaningful and practically significant. Jackson *et al.* (2000) proposed that SRL can be thought of as self-in-social-setting regulation in which individual actions are embedded within the group and that personal goals are inseparable from social goals and are achieved through social interaction. This implies that in co-regulation regulatory processes and products are distributed within the individuals constituting the group. Yowell and Smylie (1999) highlights the developmental processes of SRL using Bronfenbrenner's (1994) ecological theory by applying Dewey's (1963) and Vygotsky's (1978) theories of social cognitive development. Yowell and Smylie posited that many theories of SRL address individual regulatory processes. On this basis, they propose that SRL originates from the product of relationships between and within interpersonal and environmental interactions, as well as through individual processes. Following Yowell and Smylie (1999), SRL can be viewed as a goal-directed process through which learning goals should be adaptable and enhance individual development and social change. Therefore, behaviours of individuals are affected by the opinions, comments, and behaviours of other people within the same collaborative setting. Consequently, these behaviours are socially constructed regardless of whether the learners are aware of the social interaction. On this premise, this study argues that personal goals are inseparable from social goals and are achieved through social interactions. This implies that the effect of SRL prompts producing a small increase in the control group's co-regulatory behaviours may be quite important theoretically. In fact, Sitzmann *et al.* (2009) argued that in theory-testing research small effects may be more informative than large ones if they were predicted by the theory. In the present study, it is suggested that the effects of exposing students to a computer based science simulation learning environment with SRL prompts only on their ability to co-regulate their learning activities may have gradually improved some students' co-regulatory activities. This explanation may account for instances when both experimental and control groups were seen to have demonstrated help seeking and giving behaviours, task difficulty and demand behaviours at an almost equal frequency.

The SRL prompts represent a minimal manipulation when compared to other approaches that have been used to influence students' co-regulation. This perspective which views the social aspects of SRL as holistic interactions suggests that communal regulation has positive effect on learning processes when students are learning in a computer based science simulation learning environment. When students in the control group set goals and take actions toward these goals, their behaviours are not based on individual standards, but on socially accepted goals (Jackson *et al.,* 2000). Even when students in the control group self-regulated their learning over the three studies, they did so in a way that the learning context (i.e. a computer based science simulation learning environment incorporated with

CRL and SRL or SRL only prompts) allowed them to do. The students in the control group referred to other members of their group for guidance and confirmation of appropriate co- and self- regulatory behaviours within the computer based science simulation learning environment in which they were learning. It would seem that Jackson *et al.*'s idea of communal regulation recognises the central part that the learning context plays in the development of co- regulation learning processes. Therefore, while the SRL prompts may produce small increases in improving co-regulatory behaviours of students, these effects may translate into significant gains in work-related outcomes, such as improved academic performance (Jackson *et al.,* 2000).

Finally, a comparison of the CRL behaviours of students in the experimental group supported with CRL and SRL prompts and those in the control group supported with SRL prompts suggests that it is beneficial to support students to co-regulate their learning behaviours through CRL and SRL prompts over time. These results are consistent with Hadwin *et al.* (2010)'s argument that co-regulatory behaviours could be developed in students through continuous training and practice, thereby enabling co-regulatory behaviours to become well-learned. Given that both experimental and control groups possessed almost the same degree of co- and self- regulatory behaviours prior to the conduct of Study 2, students in the control group may have developed self-regulatory skills over a period of time which enabled them to co-regulate without prompting them with CRL strategies. This combined with the fact that the SRL prompts are relatively simple and unobtrusive may have limited the resource conflicts experienced by the participants in the control group, even during the more demanding stages of collaborative learning in a computer based science simulation learning environment. However, it is expected that if further Studies 5 and 6 (for instance) are carried out, the differences between the two groups with regards to their usage of CRL behaviours as shown in Figure 6.2 (page 137) will continue. This outcome is envisaged due to the introduction of different regulatory prompts into the learning environment of each group.

6.7.2: Students' Academic Performance during Studies 3 and 4

This study investigated whether there are differences in students' academic performances when learning Flowering Plants and Blood Circulation in a computer based science simulation learning environment with CRL and SRL and SRL only prompts. The results of this study show that there is no statistically significant difference between the student scores on the means of the KTFP test scores of the experimental and the control groups during Study 3. The independent-samples t-test analysis which failed to support hypothesis 5 of this Study was supported by a non-significance value $P>0.05$. This implies that there is no significant difference between the means of the test scores of the experimental and the control groups. Also, comparing the mean of the post- KTFP scores with the pre-KTFP of the two groups presented in Table 6.5 shows that all students (irrespective of their learning condition) improved in their test scores after learning Flowering Plants in a computer based science simulation learning environment.

The results of the independent-samples t-test obtained for the test scores of the experimental and the control groups during Study 4 show that there is no statistically significant difference between the KTBC test scores of the experimental and the control groups. The independent-samples t-test analysis also failed to support hypothesis 6 of this Study was supported by a non-significance value $P>0.05$. This suggests that there is no significant difference between the means of the test scores of the experimental and the control groups. However, just like Study 3, comparing the mean of the post-KTBC scores with the pre-KTBC of the two groups presented in Table 6.6 shows that all students (irrespective of their learning condition) also improved in their test scores after learning Blood Circulation in a computer based science simulation learning environment.

These findings lend credence to previous research outcomes on the analysis of metacognitive behaviours of learning processes which suggest that students who are provided with either CRL and SRL or SRL supports during collaborative learning in a technology-rich learning environment display learning gains in different domains and scientific tasks (Dettori and Persico 2008; Volet *et al.,* 2009; Sitzmann *et al.,* 2009; Pifarre & Cobos 2010). Moreover, the difference between the average post-test scores of the two groups is noted to be nearly the same in each of the studies when students in both groups learnt Flowering Plant and Blood Circulation. This analysis show that as students learnt in both the experimental and the control groups their knowledge about the given task improved compared to the knowledge they had before their learning sessions in their various groups. In the next section, further insight is provided into why there were no significant differences in the academic performances of the groups under different learning conditions in each of Studies 3 and 4.

Table 6.11 shows further analysis of the raw distribution of the students' knowledge test scores Flowering Plants and Blood Circulation as categorised by the learning context (experimental and the control groups) at pre- and post-test. It provides detailed information about the categorisation of students' academic performances during Studies 3 and 4. Students' scores in all the knowledge tests were categorised as follows: low test scores (0 to 4 marks), intermediate test scores (5 to 9 marks), and high test scores (10 to 13 marks). Table 6.11 confirms that at pre-knowledge test scores for Flowering Plants and Blood Circulation the majority of students (65-80%) in each group could be categorised as having "low" and "intermediate" test scores, with a relatively low percentage (20-35%) of students achieving "high" test scores in each learning context. However, for the Flowering Plants and Blood Circulation topics post-tests, the distribution of high, intermediate and low test scores for both the experimental and the control groups varied noticeably in both Studies.

Table 6.11: Frequency and percentage of students' knowledge test scores as they learnt SC, FP, and BC over a period of time.

Learning contexts	Pre- knowledge test Low	Pre- knowledge test Intermediate	Pre- knowledge test High	Post-knowledge test Low	Post-knowledge test Intermediate	Post-knowledge test High
Experimental	FP = 6 (30%)	FP = 10 (50%)	FP = 4 (20%)	FP = 2 (10%)	FP = 4 (20%)	FP = 14 (70%)
	BC = 5 (25%)	BC = 10 (50%)	BC = 5 (25%)	BC = 3 (15%)	BC = 2 (10%)	BC = 15 (75%)
Control	FP = 4 (20%)	FP = 11 (55%)	FP = 5 (25%)	FP = 3 (15%)	FP = 4 (20%)	FP = 13 (65%)
	BC = 5 (25%)	BC = 10 (50%)	BC = 5 (25%)	BC = 2 (10%)	BC = 4 (20%)	BC = 14 (70%)

To further understand the implication of these results being presented here, the variation in high test scores obtained by students as they learnt Flowering Plants and Blood Circulation was analysed. This approach was adopted because the ultimate aim of learning Flowering Plants and Blood Circulation in a computer based science simulation learning environment incorporated with CRL and SRL prompts is to support learners to attain the highest possible academic performance. Looking through Table 6.11 suggests that there are no noticeable changes in the high post knowledge tests score on Flowering Plants and Blood Circulation for both the experimental (14, 15) and the control groups (13, 14 students) respectively.

The noticeable improvement obtained in the frequency of distribution of the control group's post-test scores as they learnt Flowering Plants and Blood Circulation in each of studies 3 and 4 respectively in comparison to their pre-test scores, could be attributed in part to the effect of the technology-rich learning environment which had been confirmed to promote high academic achievement after long term exposure, irrespective of the regulatory support provided (Jackson *et al.,* 2000; Sitzmann *et al.,* 2009). This analysis further contributes to the research in understanding the role of regulatory prompts incorporated within a computer based science simulation learning environment in order to improve the conceptual understanding of students in different subject domains such as physical and biological sciences.

Overall, contrary to what was expected in this study, there was no statistical significant difference between the experimental and the control groups with regard to their final knowledge test scores. That is, both the experimental and the control group students performed very well in all the knowledge tests from Study 2 to Study 4. This outcome may partly be explained by the activity sheets designed for the purpose of this research. Students in both groups were given detailed and challenging questions on their activity sheets and they were both given the opportunity to ask questions either to their peers or the teachers during the lessons. It could therefore be argued that working together in a group helped members of each group to improve in their academic performance. Consequently, the collaborative effect of working together in a group is assumed to have been one of the factors leading to the non- statistical significant difference reported for the knowledge scores of the two groups. A closer study of Tables 5.5. 6.5 and 6.6 shows that there was a reduction in the mean difference in post-knowledge test scores of SC, FP, and BC between the two groups over Studies 2, 3, and 4. This lends some support to the suggestion that working together over time contributed to the non- statistical significant difference in the knowledge test scores of the two groups. Therefore, this study suggests that introducing either CRL and SRL or SRL only prompts into the students activity sheets may not lead to any statistical significant difference in the academic performance of the two groups because of the collaborative learning processes employed by the students.

It is also suggested that the nature of the knowledge tests used in this research is likely to have contributed to the non-statistical significant difference in the knowledge test scores of the two groups. While the knowledge test questions were derived from past General Certificate of Secondary Education (GCSE) questions, it was found to be less challenging in comparison to the students' activity sheets. Therefore, this could possibly explain why all the students in both groups performed very well such that no statistically significant differences in their knowledge test scores.

6.8: Implications of the Findings from this Study

The results of this study have implications and pose several challenges for the design of the collaborative activity in a computer based science simulation learning environment intended to enhance students' co-regulated learning behaviours and academic performance within different subject domains. As noted earlier on, findings from this study suggest that students supported with CRL and SRL prompts improved in their CRL behaviours more than those in the control group that were supported with SRL prompts only. There were no significant differences between the experimental and the control groups on knowledge tests on Flowering Plants and Blood Circulation during Studies 3 and 4 respectively. This is because continuous exposure of students in the control group to the computer based science simulation learning environments is thought to have eventually helped many students who were in low and intermediate knowledge test scores to progress in their academic achievement. These outcomes establish the need for further investigation in determining whether significant differences would continue to exist between the experimental and control groups given that they learnt scientific concepts within the same subject domains over a period of time in a computer based science simulation learning environments.

6.8: Concluding Remarks

This chapter investigated the effect of CRL and SRL prompts on students' co-regulatory behaviours during collaborative learning activities within a computer based science simulation learning environments over time. Students' academic performance was also investigated in each of Studies 3 and 4. Both quantitative and qualitative data were collected and analysed in order investigate the effect of CRL and SRL prompts over time, (Sections 6.3 to 6.6) and discussed how these results answered the research questions (Section 6.7).

The results showed that supporting students with CRL and SRL prompts in a computer based science simulation learning environments enabled them to improve their co-regulatory behaviours over time. Also, prompting the control group with only SRL-prompts enabled them to develop self-regulatory behaviours over a period of time which eventually aided them to co-regulate. However, supporting students with CRL and SRL prompts enabled them to improve more in their overall co-regulatory behaviours over a period of time in comparison to the control group. With regard to the students' academic performance in each of Studies 3 and 4, it was discovered that there was no significant difference between the experimental and the control groups. This was possibly due to the different pedagogical requirements of the given tasks, which was thought to have influenced the development of their conceptual understanding. In addition, the outcome on the academic performance could also be attributed in part to the effect of the computer based science simulation learning environments on the control group which was thought to have increased the shift from low and intermediate academic achievement to the category of high academic achievement after long term exposure to the computer based science simulation learning environments.

CHAPTER SEVEN: Co-regulatory Behaviours Over Time

7.1: Introduction

Chapter Five (presenting the results of Study 2) of this research used both quantitative and qualitative data to investigate the effect of co- and self-regulated learning prompts (CRL and SRL) on the students' behaviours during collaborative learning in a computer supported collaborative learning environment. The results obtained in Study 2 showed that both CRL and SRL prompts were needed in enabling students to engage in useful interaction during collaborative activities. As it is difficult to conclude from a very short intervention that took place in one science lesson that the incorporation of CRL and SRL prompts into a computer-based simulation environment enhances the demonstration of CRL behaviours all the time, the next step was to investigate what will happen to the students' co-regulatory behaviours as they learnt science over time.

In order to investigate the within-subjects effects of CRL and SRL prompts on the students' regulatory processes during collaborative learning in a computer based science simulation learning environment, both quantitative and qualitative data collected during Studies 3 and 4 were used. The quantitative data and some observational findings reported in Chapter six established that prompting students in the experimental group with CRL and SRL behaviours during collaborative learning enabled them to improve their overall co-regulatory behaviours over time in comparison to the control group. Although the frequency of occurrence of co-regulatory behaviour indicators in both the experimental and the control groups (quantitative content analysis) also provided insight into quantitative differences in the students' co-regulatory behaviours, it fails to capture the details of the nature of the co-regulated learning strategies that students used in their respective groups.

Therefore, in order to investigate the nature of the co-regulated learning behaviours that the students used, this present chapter provides a qualitative description of how students in both the experimental and the control groups demonstrated each of the main categories of CRL behaviours (planning, monitoring, task demand and difficulty, help giving and seeking and motivation behaviours) over time. In order to achieve these aims qualitative data in the form of students' spoken interaction or *InterLoc* chat scripts as well as the students' interview responses collected from one of the subgroup within each of the experimental and the control groups were used to investigate the nature of the co- and self-regulated learning processes that students used when learning in a computer based science simulation learning environment. The analysis examined the strategies that the students used to co- and self-regulate their learning behaviours in their groups. These data were used to answer research question number 4 (i.e. What co-regulated learning behaviours do students use when they learn science collaboratively in a computer based science simulation learning environment incorporated with either CRL and SRL prompts or SRL prompts only?). This is done with the intention of providing insight into the nature of contrasts and similarities existing in the demonstration of CRL behaviours by the experimental and the control groups as they learnt Simple Circuits, Flowering Plants, and Blood Circulation in a computer based science simulation learning environment supported with either CRL and SRL or SRL only prompts over time.

This chapter is organised into several sections. Section 7.2 provides an analysis of the co-regulated learning processes that students used to co-regulate their planning behaviour paying particular attention to patterns that underlying students' planning behaviour when learning science collaboratively in a computer based science simulation learning environment. Examples describing the demonstration of the planning behaviour for each of the experimental and the control groups are given. This analysis consists of an analysis of co-regulated forms of groups' planning regulation strategies. Subsequent sections 7.3 to

7.5 present analyse of the other CRL categories (monitoring, task demand and difficulty, help giving and seeking and motivation behaviours) in the same way. The next section discusses in detail how the experimental and the control groups varied in the ways they regulated planning behaviour. It is important to note that in examining these behaviours one subgroup of students was selected from each of experimental and control group at the beginning of the study and these same groups were followed during subsequent studies. Also, the examples of the *InterLoc* chat scripts presented in this chapter are exactly what the students typed into the communication tool in during the group learning, and some therefore contain errors.

7.2: Planning Behaviours

Planning behaviours are strategies that individuals employ to set the learning goals, activate their prior knowledge about the given task and organise how to achieve the learning goals through time planning. Extending this definition to the group context, a group member can also co-regulate planning behaviours for another group member by setting the learning goals, activating their prior knowledge on the given task as well as organising how to achieve the learning goals through time planning, or multiple group members can share in regulating planning behaviour together. While all the presented examples in this Section are instances of co-regulated planning, in this research, I used the qualitative data from the selected groups to differentiate the type of co-regulated planning demonstrated by both the experimental and the control group.

Here particular attention was paid to whether one individual plans for another group member or the whole group or multiple group members share in co-regulating their planning behaviour over the course of the three different data collection sessions. In the next sub-sections, differences between the two groups are discussed based on goal setting, prior knowledge activation and time planning behaviours, which are the sub-categories of planning behaviour.

7.2.1: Group differences in goal setting

This analysis of the students' spoken interactions/*InterLoc* chat script as well as the interview transcripts of a subgroup of five students in each of the experimental and control reveal that differences existed in the nature of the co-regulated planning behaviour that group members used to define their learning goals in all three tasks. The experimental group co-regulated planning behaviour by having all group members share in setting the group's learning goals and commenting on each other's goals. The experimental group worked in a very distinctive way. All through the three learning tasks, it was evident from their interactions that they were careful to ensure that they negotiated an approach to their task which facilitated the collaborative participation of members. For example, within the process of negotiation the students discussed their personal and group goals (see Example 7.1). In this example, they started their learning task on Flowering Plants by planning together the understanding of what their goals were, and how to achieve those goals.

Example 7.1 (From InterLoc chat scripts)

NICK:	Hello everyone, we need to set our goals here, I will like to learn about plants
DON:	We need to read through the instructions properly
RICHY:	I think we need to write plans and be contributing here, I see
DON:	We will learn the structure of flowering plants, can you see that ?

The group proposed to proceed in their study of Flowering Plants with Nick pointing out the need to set group goals, Don emphasising the need to read instructions properly before proceeding on the given task, and Richy emphasising the need for all members to contribute to the plans on the given task. It is also clear from Example 7.1 that Nick reminded his peers to set both group goals and personal goals. Don and Richy did respond by agreeing on the group goals as well as commenting on the group goals. Furthermore, Don and Richy set group goals while only Nick set a personal goal. This type of co-regulated planning of setting the learning goal together was important for the group in that it resulted in group members developing a shared understanding of the given task as well as how to proceed with their learning in a computer based science simulation learning environment.

There was another equally effective form of co-regulation demonstrated by the members of the control group during Study 3 on the Flowering Plants. It entailed one; more highly regulated individual planning for the other members of her group (see Example 7.2). In the example, Betty proposed how to proceed with the learning process of Flowering plants and what the group's learning goals should be while Nate could not really respond to Betty's proposal. This led Betty to set the group's learning goal and the time they will spend in achieving each component of the task.

Example7. 2 (From InterLoc chat scripts)

BETTY:	How are we going about this task?
BETTY:	What are our learning goals?
NATE:	Umm, I think.....
BETTY:	OK, we will learn about flowering plants from the simulation
ROSE:	Yes that is true
BETTY:	Let us plan how we are spending the remaining time

In response to the question, "did your group members follow the group plan?" it is evident that the experimental group thought they had not done badly in following their group plan as revealed by their answers in Example 7.2a.

Example 7.2a (From Students' Interview data)

DON: I think we 'did plan our work, we did well I think.
NICK: Yeah, I agree with you, we did our best.

Example 7.2b (From Students' Interview data)

BETTY: It was difficult initially to follow the group plan.
NATE: I think we were more co-ordinated as we learnt Flowering Plants and Blood Circulation.

By contrast, the responses given by the control group during the group interview (Example 7.2b) reveal that they found it difficult to follow their plans as a group. Again, Nate pointed out that there was improved co-ordination in following the group plans as the group learnt Flowering Plants and Blood Circulation.

With regard to the degree of contribution by members of each group in setting the group goals, the responses of the experimental group reflect the fact that all members participated in setting the group's learning goals (Example 7.2c).

Example 7.2c (From Students' Interview data)

RICHY: We all tried our best in setting the group's learning goals in all the activities.
NICK: I think all of us were able to set goals.
CATHY: Umm, that's true.

Meanwhile, it is instructive to note the unanimous response of the control group that not every member of the group was able to contribute to goal setting for all the activities (Example 7.2d).

Example 7.2d (From Students' Interview data)

BARRY: Not really.
NATE: I remember everyone contributed during lessons 2 and 3 later on.
BETTY: Yeah, that's true.

For instance, they pointed out that all the participants were able to contribute to the goal setting only when they learnt Flowering Plants and Blood Circulation (i.e. lessons 2 and 3).

7.2.2: Group differences in prior knowledge activation

With regard to linking previous knowledge or experience to the current learning task, members of the experimental group co-regulated their prior knowledge activation. An instance of this was found during Study 2 on Simple Circuits when Don asked a question that prompted the group to link their prior knowledge to the learning task on Simple Circuits together (see Example 7.3). In the example, each of the students contributed relevant everyday knowledge and experience of electricity to the learning process on Simple Circuits.

Example 7.3 (From the spoken interaction)

DON:	What idea have you got about electricity?
NICK:	Electricity is used to watch television, operate a refrigerator, and iron clothes in my home
DON:	Electricity can cause shock
NICK:	Electricity can be used to light up a place
DON	We don't use wet cloth to clean up electrical appliances at home

This type of co-regulated prior knowledge activation was important for the group to be successful in that it resulted in group members sharing what they know about the topic from their everyday experiences. Demonstrating this behaviour enabled the group in establishing relationships between existing knowledge and new information.

The control group did not engage in co-regulated form of prior knowledge activation during Study 2. However this behaviour was observed later during Study 4 when they learnt Blood Circulation collaboratively. Instances of prior knowledge activation demonstrated by Barry and Nate during their discussion on Blood Circulation are evident in Example 7.4.

Example 7.4 (From InterLoc chat scripts)

BETTY:	Blood is red and very thick.
NATE:	Blood is pump from our heart to our body
BETTY:	I don't want to see blood.
BARRY:	I was told that shortage of blood in our body is dangerous
BETTY:	Really! I never knew that. that's interesting
NATE:	I think blood passes through our lungs too to collect oxygen
BARRY:	Oh yes, I remember that now, we were taught in year 6

In the example above, members of the control group recalled relevant prior experience and knowledge about Blood Circulation together. This observed behaviour in the control group supported the notion that students' co-regulated learning behaviours improved over time as they learned in their groups.

The analysis of responses from both the experimental and the control groups established the fact that they were able to link their previous experience or knowledge to their various tasks as confirmed by the testimonials from both groups in Examples 7.4a and 7.4b.

Example 7.4a (From InterLoc chat scripts)

DON: I have knowledge of electricity before; this really helped me with the Simple Circuits work.
NICK: Yes, my experience of injury on the playing ground really helped me to understand Blood Circulation.
CATHY: Ummm! I remember that my daily experience of the flower garden at home helped me in participating in the discussion on Flowering Plants.

Example 7.4b (From InterLoc chat scripts)

BETTY: My experience with butterflies in primary school really helped me during Flowering Plants lesson.
BARRY: Yeah, the same with me, my knowledge of blood gained from year 6 helped greatly in third lesson.

7.2.3: Group differences in time planning

Over the course of the three studies, members of the experimental group were careful with planning their work to make sure that they completed the tasks within the allocated time. Members of the experimental group demonstrated the awareness of the need to allocate time to achieve both personal and group goals. This co-regulated time planning behaviour was observed during Study 4 when they were learning Blood Circulation.

Example 7.5 (From InterLoc chat scripts)

NICK:	I suggest we spend 15 minutes on our personal goals, then, 20 minutes on group goals
NICK:	It will be good if we use 10 minutes to review our work
DON:	I think each of us should spend 10 minutes on personal goals
DON:	25 minutes on group goals and the last 10 minutes to check our answers
RICHY:	Don I think we should go along with Nick's suggestion
DON:	ok, I agree, let us set the ball rolling
RICHY;	that's fine.

In Example 7.5, Don and Nick made different suggestions on how the group should plan their time, however there was disagreement between Don and Nick on the time to allocate to personal and group goals. At this point, Richy mediated and the group agreed on the time spent on the task.

In the control group, members also demonstrated co-regulated form of time planning behaviour over time. Example 7.6 shows an instance during Study 4 when Betty, Nate, and Barry allocated time to achieve different aspects of the given tasks on Blood Circulation.

Example 7.6 (From InterLoc chat scripts)

NATE	10, 15 and 15 minutes on our task.
BETTY	I think we have 40 minutes left, so I suggest 30minutes for the task and 10 minutes for revision.
BARRY	Yes something like that will do , 30 and 10 minutes.

It is evident from Example 7.8 that both Betty and Nate proposed different ideas on how to allocate time towards achieving the group set goals. Barry is seen to have mediated by proposing agreement with Betty and Nate but this was not clear enough in comparison with the experimental group.

In summary, this research showed that students in both the experimental and the control group improved in their time management skills from first study to the last. The research also found evidence to support the idea that continuous exposure of students to either the experimental group or the control group instructions as they learnt in a group over time could foster improved collaborative efforts among learners (Chou, 2002; Burnett, 2003; and Janssen *et al.,* 2007).

In conclusion, based on the findings and discussions in Section 7.2.1 to 7.2.3 the quality of co-regulated planning behaviours for the experimental group could be judged as better than that of the members of control group. In the experimental group it is clear from the first to the last task, that the students made attempts to harmonise and value everyone's participation with students setting group goals, querying their peers to link previous experiences with the given tasks, commenting and agreeing on the set goals and giving feedback on their queries . It may be inferred that these activities which promote negotiation and discussion of what the participants intended to accomplish during each of the learning tasks contributed to the development of well improved co-regulated planning behaviours of the experimental group over the control group. Moreover, following Barron

(2003), it is considered that members of the experimental group successfully engaged in rich collaborative discussion of each task because they were able to affirm, agree, and accept remarks which prolonged their discussion of ideas on the tasks. These characteristics of their CRL behaviour may be considered as the milestones (McConnell, 2006) that helped to define the identity of the experimental group and motivated them to complete each of the given tasks.

The setting of both group and personal goals, linkage of previous experiences to the given tasks as well as engagement in and resolution of conflict on time allocation during Studies 3 and 4 suggests that the quality of the discussions was becoming enriched over time despite the lack of CRL prompts in the computer based science simulation learning environment used by the members of the control group. This could be attributed to the fact that members of the control group were able to improve their participation as they engaged in their various learning tasks during the second and the third lessons (Examples 7.8). Improvement in participation of members of the control group over Studies 3 and 4 could also be partly due to developing familiarity among the group members. This is suggested by the interview responses of control group members (Example 7.6a) who reported that it was really difficult working together during Simple Circuits because they had not been working together on the same table during their normal science lessons as they responded to the question "*What are the things that you did not enjoy about working in your group?*"

Example 7.6a (From Students' Interview data)

BETTY: Not working with my friends.
NATE: I don't like it too
BETTY: I don't like it that all of us working in this group had not been sitting on the same table during past science lessons.

Further analysis of the students' interview suggests that members of the experimental and the control groups demonstrated planning behaviours differently. The response of the experimental group to the question "did you all set learning goals and allocate time for your various activities" confirm that they all engaged in goal setting and time planning activities (sub-categories of planning behaviour) for their group as shown below in Example 7.6b.

Example 7.6b (From Students' Interview data)

DON: Yes, we set our learning goals.
NICK: Yeah, I think we set group goals and each member also set personal goals.
NICKY: We all set goals and allocated time.

However, the responses (see below) given by control group indicate that they improved with time in their goal setting and time allocating behaviours.

Example 7.6c (From Students' Interview data)

NATE: We set goals
BETTY: We set goals and allocated time. But, I think we did this better in Flowering Plants and best in Blood Circulation.

The less frequent appearance of behaviours such as engaging with the task on time through setting of the group's learning goals, commenting and agreeing on the set goals and time allocated to various components of the learning tasks maybe due to the absence of CRL prompts in the learning environment for control group or because they were not used to working together.

In summary, variations were observed in the planning behaviour of both the experimental and the control groups. These variations could be as a result of the CRL and SRL prompts that were present in the experimental group's learning tasks. These prompts led to effective co-regulated planning behaviour accounted for in the experimental group during the course of this study.

7.3: Monitoring behaviours

A study of the spoken interactions/*InterLoc* chat script as well as the interview transcripts of a group of five students in each of the experimental and control groups show that there are marked differences in the nature of monitoring behaviours demonstrated by both groups over time. Monitoring processes result from individual students comparing their performance to their set learning goals, and then generating feedback that can be used to guide further action during the learning processes (Pintrich, 2002). In this research, students monitored how their performances related to the group's learning goals and co- and self-regulated their monitoring behaviours during the learning processes. The nature of the co-regulated monitoring behaviour that occurred during this research involved one student monitoring how another group member's performance related to the group's goals, or multiple group members sharing in monitoring how each other's performance related to the group's goals together.

In order to investigate the differences between the experimental group and the control group in terms of monitoring behaviour, attention was paid to what the group members actually monitored. For example, sometimes group members monitored their process planning; that is, they monitored the status of their given tasks through setting their various learning goals, this monitoring is referred to as monitoring progress toward goals or monitoring task. In co-regulated monitoring, one of the group members would check on what another group member was doing during learning. Task monitoring was identified when a group member acted to make sure that other members of the group were actually doing what they were expected to do during the various science activities.

Students were also engaged in self-questioning, this involved instances when students monitored their own learning through posing questions or re-reading the content of the activity to the group in order to improve understanding of the learning task. Group members monitored their own and each other's ideas and problems related to the content of their tasks. This is referred to as content monitoring in this research. Instances where the students were engaged in co-regulated content monitoring involved either a single group member monitoring another member's idea of problem, or several group members engaged in this process together. In essence, task monitoring refers to monitoring the status of tasks that were created through goal setting at the beginning of each of the learning tasks while content monitoring refers to monitoring the information students gathered in support of their ideas formed during the learning processes in all the three studies.

Another overarching finding that have resulted from the analysis of both the experimental and the control groups' monitoring processes was differences in the way both groups monitored their time during the learning processes from Studies 2 to 4. Finally, differences existed in the quality of students monitoring their understanding of the task. Each of these findings is discussed in detail.

7.3.1: Group differences in monitoring progress toward the set goals

There were examples of all the sub-categories for monitoring progress in the speech or *InterLoc* messages of the experimental group except the feeling of knowing sub-category which was absent during Study 2. In the experimental group the role of monitoring other group members as they work on the given tasks was equally shared among students. This is evident in the examples given below.

Examples 7.7 (Audio data)

NICK:	I'm dragging the wires, one cell, two bulbs, one voltmeter, and one ammeter to construct a circuit
DON:	I think the two bulbs were sharing the same electrical energy before
DON:	See, I'm dragging the ammeter, wires and two battery
NICK:	See, the bulb lights up
DON:	But it appears brighter I think

Examples 7.8 (From InterLoc chat scripts)

NICK:	Yes I 've labelled the parts of a flower, it is easy
DON:	Yes they attract insects
NICK:	Anther for male and ovary for female
DON:	Are you sure Nick, I'm not sure Where are the others?
NICK:	I could see pollen grain in it
RICHY:	Hi, Interesting, I think anther houses pollen. What do you think Don?

Examples 7.9 (From InterLoc chat scripts)

DON:	how are you doing guys, are we going to finish up with our task?
DON:	Thanks How many goals have to achieve now?
RICHY:	Jon, I'm loving it, keep it up I think two more to go
NICK:	how much of our goals are met
DON:	let us check now
CATHY:	Yes we have met all our goals as a group ,
NICK:	Let us check personal goals please
RICHY:	I'm happy with mine
DON:	I'm happy also
NICK:	Working well towards our goals
DON:	I agree with you

Examples 7.7, 7.8, and 7.9 show instances across the three studies on how all the members of the experimental group task monitored their learning progress at various points throughout each of the learning tasks. Students in this group started monitoring each other's learning task right from Study 2 when they were working on the Simple Circuits. Task monitoring played an important role on how the group members co-regulated their learning behaviours. The person who did the task monitoring, benefited from being able to practice monitoring processes which could lead to the refinement of these processes over time. In the experimental group, because all group members monitored other students in their group at various points throughout the three studies, they all had practice refining their monitoring skills. On the other hand, for the individual who was being monitored, it could serve to refocus his or her attention on the given tasks and help in maintaining their on-task behaviour. It could therefore be inferred that the experimental group as a whole benefited from its members checking that everyone in the group were actually doing the tasks. By task monitoring, members of the experimental group took steps to ensure that the tasks established through the set goal during the planning stage were carried out, which has actually contributed to the group's overall success.

Turning to task monitoring in the control group, there were instances in which group members engaged in task monitoring in each of the three studies. Their task monitoring behaviour changed over time, and the most examples of task monitoring occurred during Study 4 which was on Blood Circulation. During the Simple Circuits (Study 2) tasks, it was observed that students started engaging in task monitoring right at the beginning of the lesson before they set their learning goals.

Example 7.10 (Audio data)

BETTY:	Don't do it, it will not work
NATE:	No, we are doing it right,

Students engaged in the interaction given in Example 7.10, this interaction took place before they eventually moved on to set their learning goals. This nature of task monitoring made it difficult for the control group members to contribute to each other's ideas on the tasks. Instead of commenting and agreeing on their contributions, the group just moved on to setting their learning goals. Also, it was observed that the members of the group frequently engaged in a self-regulated form of task monitoring as seen in (Example 7.11).

Example 7.11 (Audio data)

NATE:	I am drawing a simple circuit
NATE:	Let me drag the wires
BETTY:	hold on, I have to look at it again. (Betty *self-monitors)*
NATE:	We need to start again

In essence, the control group demonstrated a lot of self-monitoring compared to the experimental group which engaged more with the co-regulated form of the task monitoring behaviour. One possible explanation for this could be the fact that members of the control group improved as they learnt to work together, even without the CRL prompts. This might have made it difficult for them to engage in task monitoring at group level. However, as the control group members worked together during Studies 3 and 4 on Flowering Plants and Blood Circulation respectively, they tend to improve in their co-regulated task monitoring behaviour (Example 7.12 and Example 7.13)

Examples 7.12 (From InterLoc chat scripts)

BETTY:	How many goals we have not achieved now?
BARRY:	We've only got one goal, let us work harder and faster.
BETTY:	Good stuff today guys! How we are doing with the goals
NATE:	I think we are all getting it

Examples 7.13 (From InterLoc chat scripts)

BETTY:	I think blood goes to the lungs first to collect oxygen and take it round the whole body.
NATE:	Oh.. that is it...oxygen gets to the body through nose and straight to the lungs
BARRY:	'cause oxygen gets to the body through nose *(BARRY elaborates on this monitoring)*

7.3.2: Group differences in content monitoring

Turning to how the experimental and the control groups engaged in content monitoring, the qualitative data in the form of the spoken interactions/*InterLoc* chat script suggested that both groups showed instances of co-regulated content monitoring, while all members in the experimental group shared in co-regulating content monitoring by taking turns to contribute to group task. This meant that all the group members shared in monitoring the group work.

Example 7.14 gives an instance of content monitoring demonstrated by members of the experimental group during Study 3 (Flowering Plants task).

Example 7.14 (From InterLoc chat scripts)

NICK:	Have we found out how insect pollination differs from wind pollination?
RICHY:	Busy bee, I can see some pollens on its body
RICHY:	Insect is beautiful but the wind is not
DON:	Insect ones are very bright
RICHY:	Well we got to look how insect carries pollens again
NICK:	That is true, nice one
DON:	Well, I think the flower smell nicely to attract bees, see that.

The example above shows that when all members of the experimental group took part in content monitoring it benefited the group in several ways. First, each group member was involved in monitoring processes, which led to a greater number of individuals using their own knowledge and experience to examine each other's learning. Nick monitored the group work by asking question such as "*Have we found out how insect pollination differs from wind pollination?*" This question was intended to monitor the group's work. Other group members gave responses such as "*Insect is beautiful but the wind is not*" and "*Insect ones are very bright*" These responses were relevant to the group's learning goals discussed during the planning process. This type of monitoring allowed Nick to be sure other group members were actually on task, and the responses increased his own knowledge of flowering plants and helped him form a more complete understanding of content related to the learning goals.

Secondly, sharing content monitoring processes led to a greater understanding for all group members. By monitoring each other's contributions and ideas, it induced students to expand on and refine their original understanding and this resulted in feedback that improved the overall quality of the students' discussion on the various science topics from Studies 2 to 4. In Example 7.14, Nick's monitoring served as a check for other students in the group, to make sure they understood what they were all working on as a group and helped to ensure their learning of flowering plants was complete. Therefore when group members were all involved in monitoring each other's work it allowed for the identification of inconsistencies or misinterpretations which when addressed, led to a better quality in the students' discussion of the learning tasks.

There were also instances when the control group members co-regulated content monitoring over the three studies. In content monitoring, one group member co-regulated another group member's content monitoring. There were no instances, however, when group members shared in content monitoring simultaneously. There were instances of self-regulated content monitoring, and of co-regulated content monitoring over time. For example, one instance of self-regulated content monitoring is given in Example 7.15.

Example 7.15 (From InterLoc chat scripts)

BETTY: I am just wondering how fertilisation occur in the plants

In this example, Betty's self-monitoring served as a way for her to self-check whether she actually understood how fertilisation occurs in plants and not having any misconceptions about the topic. Self-monitoring benefited Betty by helping her to keep on-task and focused her learning of the Flowering Plants. The self-regulated content monitoring observed in the control group might have been as a result of SRL-prompts that were present in their learning tasks in all the three studies. As this group of students became more comfortable with their learning in the group, they felt more at ease verbalising and demonstrating their SRL behaviours. This in a way might have contributed to their co-regulated learning behaviours.

There were instances of co-regulated content monitoring in the control group over the three studies, and the majority of these instances occurred during Study 4 on Blood Circulation. A typical instance was when both Betty and Nate were monitoring what was happening in the heart simulation in Example 7.16.

Example 7.16 (From InterLoc chat scripts)

NATE	Check from the list of animations/pictures, I will help you now
BETTY	Yes got it now… good.
NATE	Interesting
BETTY	Ok , I can see the dot, is moving and moving…
NATE	Me too, good to see that
BETTY	Which one? Is it the white dot? I am not sure I got that
NATE	Oxygenated blood is red while the deoxygenated is blue?
BETTY	Blue? Can blood be blue?
BARRY	Yes, I think it means less in oxygen
NATE	I agree with that too it means less oxygen in the blood …

At this point, all the group members were able to monitor the content of their learning properly compared to what was observed during Study 2 on Simple Circuits. Therefore, as the control group students learnt together in their group and know each other better, their co-regulation increased in the group. While the students in each of the experimental and the control classes were assigned to the sub-group of five randomly in each class, it was noted from the interview data that students in the control group were not familiar with working together before this research. The experimental group students on the other hand, were familiar with each other and worked together before, so they co-regulated easily from the beginning. While this has occurred just by chance, the findings still suggest that as the control group continues to work together they became familiar with one other over time;

this helped them to be able to monitor each other's ideas on the learning tasks. Their inability to content monitor properly during the first task on Simple Circuit may have affected their performance on the activity sheet during the Simple Circuits task. This also explains why there were differences in the quality of co-regulated learning behaviours of the experimental group and the control group. Also, the control group unlike the experimental group did not engage in explicit efforts to monitor how their learning is connected to the overall goals that were set during the planning stage of their learning. This resulted in learning discussions that was piecemeal and disconnected, which meant that the control group spent considerable time discussing or typing things that were off the task. This might have contributed to their inability to complete the task within the allotted time.

7.3.3: Group differences in time monitoring

Both the experimental and the control groups engaged in the time monitoring behaviours over the course of the three studies. However, the analysis revealed that the experimental group completed their work in all three studies (Examples 7.17 to 7.19).

Example 7.17 (Audio data)

NICK:	Yes and how much time are we left with?
DON:	We've spent nearly 40 minutes already, so around 10 minutes more
DON:	I think we should be rounding up

Example 7.18 (From InterLoc chat scripts)

RICHY:	Oh where is the time? We must finish the work
NICK:	Gggggggg we have five minutes to go
DON:	We are almost there, we will surely finish it

Example 7.19 (From InterLoc chat scripts)

DON:	are we checking time
NICK:	fifteen minutes to go
RICHY:	how time flies
DON:	Finished, that was good.

In examples 7.17 to 7.19, members of the experimental group demonstrated their awareness of time monitoring, they checked on the time and reminded themselves of the time they've spent of the tasks and there was a case of a group member reassuring others that they will surely finish the task. This aspect of time monitoring behaviour was very important to the group success during collaborative learning.

Members of the control group monitored their time during the group tasks but they were unable to complete the tasks in all the Studies (Examples 7.20 to 7.22).

Example 7.20 (Audio data)

NATE:	How many minutes are remaining to complete this task?
BETTY:	22 minutes
NATE:	How many minutes have we spent?
BETTY:	I think the lesson is over

Example 7.21 (From InterLoc chat scripts)

BETTY	We 've spent 13 minutes so far
BETTY	How much time have we left?
NATE	I 've just checked, no more time to complete this work

Example 7.22 (From InterLoc chat scripts)

BETTY	How many minutes do we have more?
NATE	10 mins or so
BETTY	I think we have just less than 10mins, not sure we can finish it

Examples 7.20 to 7.22 show that members of the control group failed to demonstrate that they were able to finish the task within the allocated time but they seem to show time monitoring conversations in all the given examples. The reason for their inability to complete the task on time could be attributed to the fact that they did not plan their work together at the beginning of the tasks. Suddenly in the middle of their discussion they started asking what their aims were and started planning their work the differences in when the two groups planned their work may possibly explain differences in their time monitoring processes which led to inability to complete the task.

7.3.4: Group differences in monitoring understanding

There were differences in how students in the experimental group and the control group monitored understanding while working on the various science tasks. Monitoring understanding involved explicit statements made by one individual to make sure that other group members understood a particular concept or action before moving on or statements made by an individual that suggest he or she understands or does not understand his or her own actions or explanations.

An example of co-regulation for understanding in the experimental group occurred when Nick inquired of his peers if the whole group had found out how insect pollination differs from wind pollination (see Example 7.14. above). There were no instances noted where group members shared in monitoring understanding together. Still when group members did engage in monitoring for understanding it may suggest a high level of commitment from the group members to ensure that there was shared understanding.

In the control group, a member of the group engaged in self-regulated forms of monitoring understanding during Study 2. For instance, self-regulated forms of monitoring understanding refer to statement such as "*I don't understand this*" made by Nate which suggest that she did not understand what she was doing during the Simple Circuits task. The benefit of making this type of explicit statement about their understanding when they were working in the group was that they had access to fellow group members who could provide explanations. There were also co-regulated form of monitoring of understanding as students worked together during Studies 3 and 4. (Example 7. 23).

Example 7.23 (From InterLoc chat scripts)

BETTY: Can you all see how the dot is moving? That is nice
NATE: Yes, it show blood moving round the body
ROSE: Yes got it now... good.
NATE: Interesting

The instance presented in Example 7.23 shows that Betty checked to make sure everyone understood that the dot showed how blood moved round the body. She made sure that all the group members understood the concept before moving on. This nature of monitoring behaviour demonstrated by the control group members helped to ensure that all the group members shared a common understanding of the learning task on Blood Circulation.

Responses from both the experimental and the control groups during the interview indicate that only some of the (five) members in each group participated in the discussions on various tasks as shown in Examples 7.23a and 7.23b.

Example 7.23a (From Students' Interview data)

NICK: Not all my group members participated in the activities.

Example 7.23b (From Students' Interview data)

NATE: Not everyone in our group participated in the task.

BETTY: I think only three of us were very active in discussing the tasks, others couldn't log on to the InterLoc thing on time.

Further responses to the interview question "what made people that participated in the activity do so very well?" by the experimental group showed that friendship among the peers, as well as, the instructions placed in the InterLoc did promote active participation among the three students who contributed most messages in this group.

Example 7.23c (From Students' Interview data)

NICK: The three of us are friends and we were placed in the same group, this really helped us in getting on well with all the activities.
RICHY: I think you are right, the three of us did very well in the activities.
RICHY: and we do play together, don't we?
DON: Yeah! That's true.
NICK: I think the instructions in the InterLoc thing helped us to participate much better.
DON: Truly, when you asked us to agree on our goals, I think we did, and it was really helpful.

However, it could be inferred from the responses (Example 7. 23d) of the control group members that working together over time also helped the members who participated actively in the discussions on various tasks.

Example 7.23d (From Students' Interview data)

NATE: I think we were able to participate much better during the flower and the blood lessons.
BETTY: I agree with you, our participation was better off during the Blood Circulation lesson.
BARRY: that's true.

In conclusion, members of the experimental group, unlike members of the control group, demonstrated in-depth work of reflection to which all the members contributed, not only about the given task, but also about their own learning, thereby decisively contributing to the participants' CRL behaviours of knowledge construction on each of the tasks (Jeong & Chi, 2007). As a result, the participants in the experimental group were able to demonstrate more CRL behaviours and shared knowledge (Weinberger *et al.*, 2007), contributing to the development of the participants' knowledge construction.

7.4: Task difficulty and demand behaviours/ Evaluation Processes

Task difficulty and demand/evaluation refer to how hard or simple a given task was. The evaluation aspects refer to appraisals, corrections, or assessments students made about their own performance or that of other group members. When students evaluated their own performance, they appraised, corrected, or assessed their own work and therefore generated feedback that could be used to correct their own errors and misunderstandings. In this research both the experimental and the control group members co-regulated task difficulty and demand /evaluation activities. Overall, there were fewer instances of task difficulty /evaluation processes statements made by both the experimental and the control groups compared to their planning and monitoring statements in this research. Both groups engaged in co-regulated efforts to evaluate each other's work; however, the experimental group also engaged in co-regulated evaluation that was shared among the group members simultaneously. Co-regulation in the control group involved one group member evaluated another group member's work. In order to investigate the differences between the experimental group and the control group in terms of task difficulty and demand/evaluation processes, attention was paid to how the students evaluated the learning process and content, the learning processes and the context as well as effort regulation. Each of these findings is discussed below.

7.4.1: Learning process and content

The experimental group made statements aimed at evaluating the learning process and content over the course of the three studies. Example 7.24 provides instances of this nature showing the evolution of the regulation process demonstrated by this group during Study 3.

Example 7.24 (From InterLoc chat scripts)

NICK:	Does ventricle sends blood low in oxygen to the lungs?
CATHY:	Is it not the auricle?
DON:	That is wrong Cathy let us check the simulation carefully again
NICK:	ok
RICHY :	Yeah, look the animation shows that right auricle send blood low in oxygen to the lungs
NICK:	Let me check too,

Example 7.24 was an instance of an example of shared co-regulation in that multiple group members engaged in evaluation processes simultaneously on their collaborative task. There were several benefits to the group members when they shared evaluation processes together. First, because multiple group members were involved in evaluation processes it resulted in a greater number of individuals using their own knowledge and experience to assess and correct each other's work. This made it more likely that errors would be identified because more group members were checking on each other's contributions. Also, when multiple group members shared in evaluation processes, they built on and refined each other's evaluations which in the case of the experimental group resulted in feedback that improved the overall quality of their discussion on various tasks.

It is also important to note that when group members in the experimental group evaluated each other's work, their evaluations were specific. In Example 7.24 above, Don did not simply tell Richy and Cathy the right answers. Instead, Don studied the simulation together with Richy and Cathy in order to employ their joint observations to clarify their misconceptions. Evaluation processes that were specific at clarifying a particular learning misconception on the assigned task benefited the group members more than those that were not targeted at specific learning difficulty encountered by students. This was because they give the rationale behind why the correction of someone's idea on the task was needed. In the example presented here, it called for revisiting the simulation in order to have proper understanding of whether it is ventricle or auricle that sends blood low in oxygen to the lungs. It is possible that when students understand why they need to correct their ideas or misconceptions, they may be more capable of evaluating their own work in their future learning. The experimental group evaluated both content related to their various learning tasks across the three studies as well as corrected their own and each other's idea on the tasks. In both groups students co-regulate evaluation processes more during the last study on Blood Circulation. In the case of the control group, the instances of co-regulated evaluation processes involved one group member evaluated the learning processes in another group member's work. One of these instances is presented in Example 7.25 below.

Example 7.25 (From InterLoc chat scripts)

BETTY	Where is the heart simulation? I can't find it?
NATE	Check from the list of animations/pictures, I will help you now
BETTY	Yes got it now... good.

In the example, when Nate said to Betty "*Check from the list of animations/pictures, I will help you now*" she was referring to the topics under the Blood Circulation simulation. Because Betty could not locate the heart simulation, she was confused and didn't know what to do. However, instead of working with Betty to fix the simulation properly, Nate just took over responsibility for re-adjusting it on Betty's computer. While perhaps there was little for Betty to learn from Nate in this particular instance, Nate's vague evaluation definitely did not benefit Betty in any way, since Nate could not have guided Betty by giving her step-by-step instructions on what she was supposed to do exactly should the same difficulty have arisen again during future learning processes.

It is worth noting that revisiting the content may have helped to solidify the individual's understanding or could possibly have exposed inconsistencies and misconceptions which could then be corrected during collaborative learning. It is important to note that in the experimental group there was no single individual who always evaluated the other group member's work. All group members engaged in co-regulated efforts to evaluate each other's work, this role was assumed by all group members throughout the three studies. In contrast, Betty assumed responsibility for evaluating her fellow group member's work in the control group.

7.4.2: Learning processes and the context

The students in the experimental group made statements about evaluating both the learning processes and the learning context during the collaborative learning. There were instances where individuals made statements evaluating the content of their own work. An example of self-regulated context evaluation occurred when Don contributed during the Blood Circulation tasks (Example 7.26).

Example 7. 26 (From InterLoc chat scripts)

DON	let me feel my pulse to see if my heart pumps blood like this
DON	I see, this simulation is correct, my heart beats just like that

Example 7.26 is an instance of self-regulated context evaluation because Don confirmed what he thought to be his assumption that his heart beat like the one in the simulation. His confirmation resulted in feedback that "*I see, this simulation is correct, my heart beats just like that*". Therefore, similar to monitoring processes the benefit of a student evaluating his or her own work was that it resulted in feedback that could improve the quality of the group's discussion on the given tasks. Being evaluated may require the individual to reiterate his or her thought process related to the context.

There were also instances of the co-regulated form of context evaluation observed for the experimental group but none was observed for the control group. Example 7.27 shows how the group of students in the experimental group co-regulated their learning context.

Example 7.27 (Audio data)

NICK:	But why is it brighter now?
RICHY:	I've got no idea, Do you?
DON :	I think the two bulbs were sharing the same electrical energy before
DON:	Then they dim
RICHY:	The same energy is now for one bulb, I get it now.
RICHY:	That means one bulb now get more energy than before to power it
NICK:	That sounds reasonable, it's a bit tricky

In this example they demonstrated this behaviour until they came to the point of expressing the level of the difficulty of the task when Nick said "*that sounds reasonable, it's a bit tricky*". This type of evaluation made by Nick benefited the whole group in that they knew what they were doing with the simulation was reasonable. This in a way might have helped to improve the quality of the group's discussion on the Simple Circuits task.

7.4.3: Effort regulation

Turning now to evaluations aimed at effort regulation in terms of the ways that the students assessed and corrected one's own and each other's work, there were instances of these evaluation processes over the course of the three studies. One type of co-regulated effort evaluation demonstrated by the experimental group was when one group member evaluated another group member's contribution during the Blood Circulation task. Example 7.28 illustrates the co-regulated type of evaluation as Don inquired from Richy if he understood the concept of how oxygen is transferred round the body to give us energy.

Example 7.28 (From InterLoc chat scripts)

DON:	Do you understand how oxygen moves round the body Richy?
RICHY:	Don, I don't know, let me remember
DON:	This shows how the blood takes oxygen from our hearts and the food we eat around our bodies to give us energy
NICK:	That is fine, go on with your explanation, I'm enjoying it
NICK:	Ummm! And what happen to the blood when it is low in oxygen?

Richy replied that "*Don I don't know*" Don then proceeded to co-regulate Richy by explaining that "*the blood takes oxygen from our hearts and the food we eat around our bodies to give us energy*". This led Richy to overcome his ignorance about how the blood takes oxygen from our hearts and the food we eat around our bodies to give us energy and also helped Nick to gain confidence to ask Don about "*what happens to the blood when it* *is low in oxygen?*" in order to clarify his ignorance or confusion. The benefit of co-regulating for Richy and Nick was that they were able to correct their misconceptions on the task.

Finally, in co-regulating task difficulty/evaluation processes across the three studies in this present research, the person being evaluated benefited from receiving feedback on their work. This led to overall improvement in the quality of the students' discussion during collaborative learning processes. The dilemma of when only one group member assumed responsibility for all other group members' work was that (a) the student might overlook an error/misconception in learning, (b) he might provide incorrect feedback that no one else evaluated or double checked, and/or (c) he might not provide an explanation for the correction or adjustment made to the learning content and context, and as such the group member would not learn from his or her mistake.

These findings may be accounted for by the agreement (Example 7.28a) between members of both groups (the experimental and the control) that they found the given tasks on Blood Circulation to be the easiest because it was related to their bodies in response to the interview question *"Can you say a bit about how easy or difficult you found the task?"* This implies that the degree of relevance of a task to the students' every day or personal experience may determine the nature of students' interest on the task's discussion which also influence the quantity of discussions engaged in by students.

Example 7.28a (From the students' interview data)

NICK: I find Flowering Plants easy, Simple Circuits easier, and Blood Circulation easiest.
DON: That's true, I think our group had highest number of discussion during Blood Circulation.
RICHY: I think Blood Circulation task is related to our body.
CATHY: Yeah, you are right.
DON: I think those instructions in the box in the InterLoc also made it easier to work through the tasks.
NICK: I agree with you, ---- (referring to DON).

Example 7.28b (From the students' interview data)

BETTY: I was able to help others especially during the tasks on Blood Circulation.
ROSE: I enjoyed receiving help from my group members.
NATE: Setting goals and achieving it together as a group is what I really enjoyed here, we did this well during the last lesson.
BETTY: I'm happy with our discussion too during the task on Blood Circulation.
NATE: I learnt the skill of how to manage time during any given task.
BETTY: I learnt that with time, members of a group can work together as friends to achieve goals.

Moreover, the largest number of turns of discussion reported for Blood Circulation in Chapter six for both groups may also be attributed to conduct of the task at a later stage in the study. According to the testimonial from the students' interview (Example 7.28c) in response to the question "*What skills did your group use in working to achieve success on the given task*?", students in both groups identified goal setting, helping peers, time management, monitoring the contribution made towards achieving goals, and having sufficient time to work together, as skills which helped members of both groups to achieve success in their collaborative learning processes of various scientific concepts (Example 7.28c and 7.28d).

Example 7.28c (From the students' interview data)

NICK: I enjoyed the help given to me by Don when learning Simple Circuits. It helped me to develop confidence to offer help to other members of my group.
DON: I enjoyed working with my friends, it helped to discuss freely with them. I'm happy giving helping hands to Nick during the task on Simple Circuits.
RICHY: We were able to manage our time properly. , I think.

Example 7.28d (From Interview data)

BETTY: Yeah! Blood Circulation is the easiest of all the tasks. I really enjoyed it.
NATE: You are right, -I think it's easy because it is similar to how our hearts work.
ROSE: Yes, I joined in during the Blood Circulation lesson and I enjoyed it.

7.5: Help-seeking and help-giving behaviours

Help-seeking and giving behaviour as observed in this present study shows that the less-capable student learnt from the more-capable student. By receiving help, the less-skilled individual can correct misconceptions, fill in gaps in his or her understanding, strengthen connections between new information and previous learning, and develop new idea and knowledge of the learning tasks. Also, explaining one's own thinking and understanding constitutes part of the process through which the less-capable person constructs her knowledge. Therefore, when a less-skilled student gives explanations, it serves to clarify and transform her own thinking rather than help the more-capable person.

In order to understand the nature of help-seeking and giving behaviour over the course of the present study, an attempt was made to distinguish between the help given by one student trying to help another student and explanations offered by a student needing help as a way of demonstrating her thinking. However, most observations of help-giving seem to imply the former situation (a more-knowledgeable student giving an explanation to a less-knowledgeable student). Note that the evidence of who were the less and the more capable students was obtained from the science teacher's response to one of the interview questions "*Do you think any student in particular benefited from the study?*"

Example 7.29 (From the teacher's interview data)

Yes I think so; some of our students who are grouped as students with the low academic ability did participate very well during the lessons. And I can even see that they did very well in all the post-tests carried out.

Knowing who was giving help and who was receiving help during the collaborative tasks enabled me to explain the nature of this behaviour as demonstrated by students during collaborative learning. Help-seeking and giving behaviour for the experimental and the control groups was more equally distributed across the three studies, and it was noted that the behaviour increased in both groups over time. Both groups used co-regulated form of help-seeking and giving. Co-regulating help-seeking and giving behaviour benefited both groups by (1) engaging students, (2) re-engaging students after they start talking off-task, and (3) helping students to sustain effort and attention on the given tasks. There were not big differences in how members in the experimental and control groups regulated their help-seeking and giving behaviour when working on various science tasks. Students were able to request and gave help when needed in all the studies. These qualitative findings were consistent with the patterns of help seeking and giving behaviour observed in the quantitative content analysis described in Chapter Six of this thesis.

The data analysis showed that students in both groups disclosed their lack of knowledge or their confusion about the tasks being learnt over the three studies. Members of the control group were seen to have requested help from the teacher and peers when they learnt Simple Circuits. However, as the group progressed to learning Flowering Plants and Blood Circulation, members requested help from one another. The experimental group members continued to engage in help seeking and giving from each other during collaborative learning as they learnt Blood Circulation.

The instance of help seeking presented in Example 7.28 (in section 7.4.3) shows that Don might have perceived that Richy was having problems in understanding the concepts on Blood Circulation. Don is then seen to have sought from Richy whether he understood the concept of how_"*the blood takes oxygen from our hearts and the food we eat round the body to give us energy.*" Richy then disclosed his lack of knowledge as he tried to remember. Don then proceeded to explain the concept to his peers while Nick encouraged and provided emotional support to Don by commenting "*that is fine, go on with your explanation, I'm enjoying it*". It may be inferred from this interaction that the discovery by Nick that Don understood the concepts on Blood Circulation might have propelled him to ask his own question: "*What happen to the blood when it is low in oxygen?*" Again, Don is seen to have provided an explanation in response to Nick's query.

In both groups, both the help seeker and the help giver were responsible for explanations concerning the given tasks. In most cases, the help seeker first expressed a need for help that clearly conveyed his or her area of difficulty or lack of understanding (see Examples 7.30a and 7.30b).

Example 7.30a (From InterLoc chat scripts)

DON: How do the anthers hang outside the flower? I'm not sure

Example 7.30b (From InterLoc chat scripts)

BETTY: Where is the heart simulation? I can't find it

In the experimental group an example of this was found when Don said "*How do the anthers hang outside the flower? I'm not sure*". Also in the control group Betty asked

"*Where is the heart simulation? I can't find it*" In both examples above, the students asked direct questions in order to address their difficulties on the task during both the Flowering Plants and the Blood Circulation lessons. These data suggested that students Don and Betty sought help in an effective way. They realised that they needed help and they willingly sought help; one of them even identified someone in the group who provided help among the group members. They both used effective strategies to elicit help (e.g., asking explicit, precise, and direct questions).

The relative success of being specific with the help requested made it easier for both groups' members to understand the nature of a student's confusion or uncertainty regarding the tasks and to formulate an appropriate and precise response. These specific requests exemplified several characteristics of the help-seeker in this present analysis. It means that the help-seeker wanted to learn more about Simple Circuits, Flowering Plants and Blood Circulation, that they already have at least some understanding of the task in which they were able to pinpoint a specific area that they were not clear with. The help-seeker also benefited from the explanations given to their query.

By contrast, Mastergeorge *et al.* (2000) found that general requests for help, particularly if asked before a student attempted the given task, typically elicited low-level help. The group members seemed to interpret this help-seeking behaviour as an indication of the help seeker's lack of motivation, lack of ability, or both. For instance, some help seekers may simply want to avoid expending effort on the task. That is, they ask questions with the intention of having others complete the work, sometimes called "dependency-oriented" help seeking. Note that the help-seeking behaviours demonstrated by the participants in both the experimental and the control group in this research were specific in all the learning tasks.

Another important point noted in the way students in both groups demonstrated help-seeking and giving behaviour was the fact that the help-seekers were persistent in asking specific questions in both groups (see example 7.31).

Example 7.31 (From InterLoc chat scripts)

NATE: Can you see how the dot is moving? That is nice
BETTY: How did you get the dots
BETTY: So where did you get that dots from

This behaviour is very important in that, on the part of the help-seeker, it provided an opportunity to obtain understandable help from their group members. Only students who persistently asked precise questions had a significant chance of receiving explanations that helped them to learn more about the given tasks. Some students repeated the same specific question ("*How did you get the dots?*" and "*So where did you get that dots from?*") but either asked a different student each time or asked the teacher. Other students modified their questions, becoming increasingly specific.

Turning now to help - givers, the willingness of help-givers to expend the effort to provide relevant and elaborated explanations provided another key to whether help-seekers obtained understandable answers to their queries on the learning task. Nearly all group members responded to help-seeking attempts within the experimental group whilst they were working on Blood Circulation. However, this was not the case for Simple Circuits and the Flowering Plants. This might have resulted from the increasing occurrence of specific questions as opposed to the general questions that students asked during the Simple Circuits task. However, the students claimed that they were able to respond to each other's queries during the Blood Circulation lesson because the topic was very relevant to what was going on in their body (see Examples 7.28a and b).

Finally, students who received help from peers during collaborative learning are expected to also apply the help received to deal with the subsequent queries in their future learning without assistance. Carrying out further learning activity after receiving help from the group members may benefit the help-seeker in several ways. First, while using the idea received to solve another problem, students may generate self-explanations that help them to internalise principles and construct specific inference rules (Chi *et al.* 1989). Secondly, attempting to try things out themselves may help students to monitor their own understanding and help to them realise their misunderstandings/misconceptions about the given task or lack of understanding. Unless students attempt to try things out for themselves without assistance during the learning processes, they may falsely assume that they understand how to employ certain scientific concept to solve the problems, especially if they observe other students answering questions correctly. Attempting to apply explanations received about the tasks may also help the group monitor the help seeker's level of understanding and make it easier for peers to formulate additional explanations. Groups that rely on students' own admissions of understanding of scientific concepts (e.g., ''I get it''), which may be inaccurate may miss opportunities to help others. This finding is also confirmed by the finding of the quantitative analysis that co-regulated help seeking and giving behaviours increase over time.

Responses from the interviews of both groups, (Examples 7.31a and 7.31b) when asked: "did you help other group members who had difficulty in understanding the group task?" confirmed that students received help from one another and they also rendered help in return to other members of their group. It should be noted that members of the control group did request for help from their teacher at the beginning of the task on Simple Circuits. The members of the control group also reported that they worked independently of the teacher's help with time especially as they learnt about Blood Circulation.

Example 7.31a (From the students' interview data)

RICHY: During the first task, I received help, but during the last lesson, I helped (referring to Cathy) who finds it difficult to understand the Blood Circulation simulation. I'm happy I was able to help.
DON: Yes, I helped others and I received help from others during the activities.

Example 7.31b (From the students' interview data)

BETTY: Yes, I explained what blue blood meant in the simulation on third task. But we did request help from the teacher during the task on Simple Circuits.
NATE: Umm, I can remember that our group worked independently of the teacher, especially as we learnt Blood Circulation.
ROSE: That's true; Betty explained the blue blood in the third task.
BETTY: I'm happy to help as I received help during the task. The group work was nice, I think.

7.6: Motivational behaviour

Students in both the experimental and the control groups engaged in a variety of strategies to regulate motivation in their groups over time as they learnt Simple Circuits, Flowering Plants and Blood Circulation. This section explores co-regulation in which one group member regulated another group member's motivation. The trend over time, when students attempted to regulate motivation, suggested that the instances occurred more often during the Blood Circulation lesson than the other two lessons. The members made statements to express how interesting or "cool" an aspect of the task was as shown in Example 7.32

Example 7.32 (From InterLoc chat scripts)

DON: *Yeah, you are a star!!!, Cathy. Loving your explanation Cathy.*

In Example 7.32 during Study 4 on Blood Circulation, Cathy contributed to the group's discussion saying that she thought that the valves which pumped blood were located between the upper auricles and lower auricles, to which Don Replied, "*Yeah, you are a star!!!, Cathy. Loving your explanation Cathy.*" This encouraged Cathy to continue describing her idea about different parts of the heart and their functions. Don's statement therefore served to regulate Cathy's motivation in that it promoted her continued engagement with the content and reinforced the idea that her contributions to the discussion were valuable to the group members.

What if Don had suggested to Cathy that her idea was not interesting during the group discussion? This may have conveyed to Cathy that her idea had little or no value to the group, and as a result Cathy may have ceased participating in the group discussion. Therefore, when a group member (X) engaged in an activity and turned to another group member (Y) for their feedback, the initial judgments of group member (Y)'s interest could potentially determine group member (X)'s persistence or termination within that task. This is because statements that show interest in another group member's contributions suggest that the contribution was valued (Hidi & Ainley, 2008).

As such, in this study, statements that suggested to another group member that her contributions were interesting or cool were important in that they had the potential to increase participation and persistence in the task. Similarly, attempts to praise/encourage another group member or foster his or her self-efficacy also served to sustain that group member's participation and persistence in the task.

During the Simple Circuits lesson, Nick said that his two bulbs were not glowing brightly enough. This contribution showed that he was not too happy with his learning processes because he thought he was not getting what he supposed to get. Don replied to him to say: "*Oh don't worry...lets remove one bulb and see what happens .... See it is glowing brighter, you've done it!*" This statement conveyed to Nick that Don had confidence in his ability to make the bulb glow brighter. When group members received feedback that indicated confidence in their abilities, it had the potential to increase their self-efficacy. In this example, Nick finally said that it was really fun.

Furthermore, an increase in the students' self-efficacy could result in increased persistence and engagement in the task if students adopted these beliefs. This was the case in the example above in that Don's confidence in Nick's ability to make the bulb glow brighter by removing one of the bulbs from the circuit board resulted in Nick showing more interest in the learning content and context. Also, when a group praise/encourage another group during the learning processes it may increase persistence and engagement in the task as well. This was confirmed during the group interview (Example 7.32a) when Don said that he always liked how they moved on from the beginning of the lesson to the end.

Example 7.32a (From Students' Interview)

DON: We managed our time very well; I liked our discussion from the beginning of the lesson to the end.
NICK: We achieved all our goals for each task.
NICK: And we were able to monitor our progress as we worked on our task as a group.

It is worth noting that, when a group member made explicit statements that he agreed with/understood another group member's contribution, this is an example of co-regulated motivation because it is an expression of a sense of shared understanding and communication that the contribution was valued by all the group members. Furthermore, when group members believed that their contributions were valued; it was likely to increase persistence and sustained engagement in the task. There was one instance during the Simple Circuits lesson when Nick suggested that they should try one more thing before the end of the lesson. He said "*...With three batteries and two bulbs, what will happen to the amount of current in the circuit*? Don replied, "*Ha-ha it goes very bright again*" which served to convey to Nick that his contribution was clearly understood and valued. It showed that Don actually did what Nick suggested that they should try out in the group. In turn, Nick further elaborated on this idea that two bulbs were sharing more current from three cells rather than one. This idea eventually became a very important contribution to the group's learning about Simple Circuits. Because all of these strategies were effective in that they increased participation, persistence and/or engagement in the task for members of the experimental group, I have defined them as productive strategies. Furthermore, after reviewing the data, it was observed that all group members demonstrated the behaviour equally: all group members made statements that served to regulate each other's motivation over the course of the three studies.

A careful investigation of how the control group members regulated their motivation over the three studies showed that the instances in which the students used various strategies to regulate motivation over the course of the three studies increased across Studies 2, 3 and 4. The difference between the control group and the experimental group was not in the type or quantity of strategies they used to regulate motivation; rather, it was that these strategies were directed primarily at increasing the motivation of one group member, Barry, who showed low interest in the task and rarely participated in the task (Example 7.33). When he did participate it was only after explicit probing by one of the other group members. The other group members tried a number of strategies to increase Barry's engagement in the task, many of which were similar to the strategies used by the experimental group members to regulate their motivation. Some of these strategies were forms of positive reinforcement such as praise and encouragement.

Example 7.33 (Audio data)

BARRY:	This is a bit tricky not sure of what I am doing.
NATE:	Come on, you are doing well
BETTY:	Yes, you are, well done
BARRY:	So, how do we get to the simulation now? So, where is this now? Can someone help please?

Unlike the experimental group, none of these strategies worked to increase Barry's participation or motivation in the task. For instance, during the Flowering Plant lesson Barry said that the lesson was really tricky and that he was not sure of what he was doing again. The other group members quickly replied including Nate *"Come on, you are doing well"* and Betty "*Yes, you are, well done*" (Example 7.33). They all attempted to encourage Barry not to give up on his participation in the discussion. These encouraging statements by Nate and Betty were not successful because Barry still expressed more worries regarding his learning like "*So, how do we get to the simulation now?" "So, where is this now? Can someone help please?"* Therefore, the strategies to co-regulate Barry's motivation were unproductive, as they did not really increase his persistence in the task. Later on in the task, Barry's participation just decreased as he lost interest in the learning processes. One potential explanation for why these strategies were unproductive in co-regulating Barry's motivation could be that when Nate said *"Come on,.... you are doing well"* it may have had a critical tone that Barry potentially interpreted as attacking him. If this was the case, it could explain why Barry's participation with the task decreased towards the end of the lesson. This observation was supported by the fact that there were few instances when Barry participated in group discussions, even during the Blood Circulation lesson.

Finally, members of the control group made statements to express interest in another group member's contributions. As previously noted, these statements were important because they had the potential to increase a group member's persistence and engagement in the task. In the experimental group this was the strategy group members used most often to co-regulate motivation. During the Flowering Plants lesson, Betty suggested that they should find out how fertilisation occurs in the plants. Nate accepted this proposed idea, "*Oh, yeah that would be cool! Alright let's do that i have open it here*". Similar to the interpretation for the experimental group, feedback indicated by a member's level of interest in another group member's work was important because it could determine whether that group member engaged and persisted within that task. In this example, Nate's statement potentially helped to sustain Betty's engagement and persistence in the task As such, when members of the control group provided feedback that suggested to another group member that his or her contributions were interesting or cool, this had a similar effect on persistence and engagement as it did in the experimental group.

In conclusion, one common strategy that members in both groups used to regulate motivation was to make statements to express interest in another group member's contributions. These statements were important because they had the potential to increase a group member's persistence and engagement in the task. Group members also used praise/encouragement to motivate each other's participation and persistence in a task. In the experimental group, praise/encouragement was a productive strategy to regulate the group members' motivation, while in the control there was at least an example that group it had the opposite effect. Nevertheless, it was not possible to classify certain statements of praise/encouragement as productive or unproductive without considering the context in which they occurred.

7.7: Conclusion

This chapter employed the qualitative data to investigate co-regulated learning behaviours of both experimental and the control group. The data analysis showed that there were both within-group and between-group differences in the nature of co-regulated learning behaviours demonstrated by both groups. These findings suggested a possible trend over time in co-regulatory processes in both the experimental and the control groups.

The quality of CRL planning behaviours for the experimental group was better than that of the control group members. It is suggested that this is because members of the experimental group harmonised and valued everyone's participation by setting group goals, encouraged their peers to relate previous experiences to the given tasks, commented and agreed on the set goals and gave feedback on their queries from the first to the last task unlike the control group. In addition, the experimental group, unlike the control group, demonstrated in-depth work of reflection to which all the members contributed, not only about the given task, but also about their own learning, thereby decisively contributing to the participants' CRL behaviours of knowledge construction on each of the tasks. Consequently, participants in experimental group were able to demonstrate more CRL behaviours and shared knowledge.

All members of the experimental group co-regulated one another with regard to task difficulty/evaluation processes with the person being evaluated benefiting from receiving feedback on their work. It is suggested that this led to an overall improvement in the quality of the collaborative learning processes of the experimental group in comparison to the control group where only one member assumed responsibility for co-regulating the task difficulty/evaluation processes of all other group members' work. Furthermore, it was discovered that there was no major difference in the help-seeking and giving behaviour of the experimental and the control groups. It increased over time for both groups, with both groups demonstrating co-regulated form of help-seeking and giving behaviours, thereby benefiting members of both groups. It was also discovered that members of both groups engaged in a variety of strategies to regulate their motivation over time, such that students attempted to regulate their motivation more often during the Blood Circulation lesson than during the first two lessons. Finally, members in both groups adopted the strategy of making statements that expressed interest in another group member's contributions, resulting in an increase in the group member's persistence and engagement in the task. It is concluded in this chapter that the introduction of CRL and SRL prompts into the computer based science simulation learning environment enriched the collaborative discussion of scientific concepts and contributed to the development of improved co-regulated behaviours of the experimental group over those of the control group.

CHAPTER EIGHT: Discussion, Conclusions, and Recommendations

8.1: Introduction

In this thesis, I have examined the co- and self-regulation learning strategies that students used as they worked together in their various groups when learning science collaboratively by employing a computer based science simulation learning environment. Specifically, the research addressed the following questions:

1. Is the Co-regulated Strategies for Learning Questionnaire (CRSLQ) developed as part of this research fit for purpose of measuring the CRL behaviours of Key Stage 3 science students?

2. a) Does the computer based science simulation learning environment with both co- and self-regulated learning prompts support Key Stage 3 students to regulate their learning behaviour more effectively than using self-regulated learning prompts only?

   b) Does the computer based science simulation learning environment with both co- and self-regulated learning prompts result in a greater improvement in Key Stage 3 students' academic performance when learning scientific concepts than when using self-regulated learning prompts only?

3. Does the incorporation of CRL and SRL prompts into a computer based science simulation learning environment improve co-regulated learning behaviours of Key Stage 3 students over time (from Studies 2, 3 and 4)?

4. What co-regulated learning behaviours do Key Stage 3 students use when they learn science collaboratively in a computer based science simulation learning environment incorporated with either CRL and SRL prompts or SRL-prompts only?

In the following section, I will summarise the major findings related to each research question, and how these findings support, extend, or challenge the current literature. Then I will discuss the limitations of this study, highlighting the methodological and theoretical issues. Finally, I will reflect on the significance of this work for both theory and practice.

8.2: Summary of Research Findings

8.2.1: Research Question 1

The first research question asked, "Is the Co-regulated Strategies for Learning Questionnaire (CRSLQ) developed as part of this research fit for purpose of measuring the CRL behaviours of Key Stage 3 students?" The aim of Study 1 was to develop and validate a questionnaire that measured the co-regulated learning behaviours that students used when learning science collaboratively in a computer based science simulation learning environment. The questionnaire was completed by key stage three students who are used to working in groups during science classes. The items of the CRSLQ were derived from theories on self-regulated learning (SRL) and co-regulated learning (CRL). It contained items on seven regulatory behaviours: Planning, Monitoring, Evaluating, Effort regulation, Peer learning, Time management, Help-seeking.

The questionnaire was validated by means of principal axis factoring (PAF) analysis with direct oblimin. The factors (e.g. Planning, monitoring, efforts regulation and help seeking and giving behaviours) underlying the questionnaire were confirmed by the data in a linear structural analysis of the data. Although a total of 22 statements assessing co-regulated learning behaviours were included in the questionnaire, not all the statements represented a factor structure or assumptions that are valid or reliable. The factors were extracted based on eigenvalues, percentage of variance explained, and examination of scree plots. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was measured as 0.78; this suggested that the statements were very suitable for factor analysis (Kaiser, 1974). The PAF results indicated a four-factor structure, and a total of 21 statements were kept. The total explained variance was 66.80% in relation to the four factors. Table 4.1 shows details of the factor loadings of the 21 statements relative to the four factors on the co-regulated learning behaviours.

With regard to the inter-correlation of statements, the reliability coefficient of the Cronbach's alpha model on internal consistency was used for estimating the internal consistency of co-regulated learning statements and for measuring the extent to which statements' responses that were obtained at the same time correlated highly with each other. The total 21-statement scale had an excellent internal consistency reliability of 0.82. In short, the PAF and the Cronbach's alpha analysis show that the constructed CRSLQ is a scale with more than reasonable validity and internal consistency reliability.

Finally, the results of the analysis provided evidence for the validity, reliability and the theoretical use of the CRSLQ when used to measure co-regulated learning behaviours that students used in collaborative learning settings. The results of the PAF indicated that a four factor model comprising 21 items fits the data well. These four regulatory factors can provide tips for students and teachers to encourage co-regulatory behaviour during collaborative learning. It also provides teachers with the guidelines to assess and adjust the co-regulatory process in order to improve this interaction process during group work. Moreover, the questionnaire seems applicable not only to key stage three students learning science collaboratively, but also to any group where the members have shared learning goals.

8.2. 2: Research Question 2

The second research question asked, "a) Does the computer based science simulation learning environment with both co- and self-regulated learning prompts support Key Stage 3 students to regulate their learning behaviour more effectively than using self-regulated learning prompts only? And b) Does the computer based science simulation learning environment with both co- and self-regulated learning prompts result in a greater improvement in Key Stage 3 students' academic performance when learning scientific concepts than when using self-regulated learning prompts only?" These research questions were addressed in Study 2 (presented in Chapter 5). Students were randomly assigned to either the experimental (CRL and SRL prompted) or the control (SRL prompted) group. MANOVA was used to investigate the effect of a computer based science simulations learning environment with CRL and SRL prompts on students' co-regulated learning behaviour and academic performance as compared to a computer based science simulations learning environment with SRL prompts only.

The findings from Study 2 showed that students in the experimental group demonstrated more co-regulatory behaviours than the students in the control group. This was indicated by the experimental group's high scores on CRSLQ measures compared to the control group's scores. For the scores on the SRSLQ (Self-Regulated Strategies for Learning Questionnaire) measure, the result of Study 2 showed no significant difference between the experimental and the control groups in their usage of self-regulated learning behaviour during collaborative science learning in a computer based science simulation learning environment. This outcome was also expected as stated in one of the study's hypotheses. Students in both the experimental and the control groups were prompted to use self-regulated learning behaviour; therefore, there was increase from their pre- to post- SRSLQ scores but no significant difference was found between the groups on SRSLQ scores.

Similarly, the study also investigated whether there were differences in the students' academic performances when learning in a computer based science simulations learning environment with CRL and SRL or SRL prompts. The results show that all students irrespective of their group improve from the pre-test to post- test on Simple Circuit knowledge test. However, no significant difference was found between the two groups.

This failed to support one of the study's hypotheses that; there will be a significant difference between the means of the test scores of the experiment group and control group.

Further investigation of the students' score on the activity sheets which also assessed performance on Simple Circuits showed that there was a significant difference between the experimental and the control groups' performance on their answers in the activity sheet. One implication for this finding was that when the experimental group co-regulated well during the group work, both individual and group regulatory behaviours also increased. This finding suggests that doing well on the group's work corresponds to an improvement in group members' performance on the given task as well. Therefore, supporting students with co-regulated learning behaviours during collaborative learning in a computer based science simulation learning environment helped students to improve their regulatory behaviour and performance in the activity sheet. This finding is supported by previous research outcomes on metacognitive behaviours during solo and collaborative learning processes which suggest that students who are supported with CRL-prompts display significant learning gains in different domains and scientific tasks (Dettori and Persico, 2008; Volet *et al.,* 2009; Kirschner *et al.* 2009; Pifarre & Cobos, 2010). The findings by these CRL researchers suggest that students who are not prompted with CRL behaviours when learning in a computer based science simulation learning environment are at the risk of being unable to use CRL strategies effectively. The benefit of deploying CRL prompts into a computer based science simulation learning environment is reinforced with the resultant improvement in the construction of social knowledge by students in another study by Kreijns *et al.,* (2004). It is also important to note that the success of incorporating CRL and SRL prompts into a computer based science simulation learning environment for enhancing co-regulation could be ascribed to the fact that the designed CRL prompts did not impose the burden of additional information processing that may interfere with the students' aim of concentrating on the to-be-learned information. Furthermore, because the designed CRL prompts were pedagogically integrated into the learning resources, it helped the students to work towards achieving their target goals within the allocated time.

The findings obtained from Study 2 of this research also have implications and pose several challenges for the design of learning activities intended to enhance students' CRL behaviours and academic performance in technology-rich dynamic science classrooms. Students in the experimental group used more effective CRL behaviours such as planning and monitoring, were more motivated when compared to students prompted with SRL behaviours only. These outcomes led to further investigation on how CRL prompts can influence CRL behaviours over a period of time in a computer based science simulation learning environment. Study 2 also led to investigating the nature of co-regulatory behaviours in both the experimental and the control group over a period of time in this present research.

Finally, the outcomes of this study suggest that the CRL behaviours demonstrated by students working together collaboratively in a computer based science simulation learning environment can be a predictor of the improvement they made in their conceptual understanding of the science topics they studied, as evident shown by the experimental group's significantly higher scores on their activity sheets. Although not supported by knowledge test scores, this finding is indicative of the fact that how well groups co-regulate each other when learning scientific concepts in a computer based science simulation learning environment can be related to how successful they are on improving their conceptual understanding of the given task. Effective co-regulation of learning processes may lead to improved conceptual understanding and it will be beneficial for CRL and SRL prompts to be incorporated into a computer based science simulation learning environment in order to support the learning processes of scientific concepts.

8.2. 3: Research Question 3

Research question 3 asked, "Does the incorporation of CRL and SRL prompts into a computer based science simulation learning environment improve co-regulated learning behaviours of KS3 science students over time (from Studies 2, 3 and 4)?". In order to answer this research question, quantitative data from the CRSLQ and the SRSLQ and content analysis of transcriptions from the audio and *InterLoc* chat scripts were employed to investigate the overall co-regulation processes over time when students learnt in a computer based science simulation learning environment. The findings from this investigation showed both within-group and between-group differences in co- regulated learning behaviours by students when learning in collaborative settings over time. Results from post hoc tests comparing the changes across the scores on the CRSLQ and the SRSLQ, in the experimental and the control groups over a period of time shows that no significant differences occurred in any of the CSRLQ and SRSLQ measures during pre-study test (i.e. prior to starting Study 2) between the two groups. This confirms that, overall, students showed the same level of CRL and SRL behaviours prior to learning Simple Circuits, Flowering Plants, and Blood Circulation, regardless of which group they were assigned to.

Investigation of the statistical interactions between the learning condition and learning over a period time (the independent variables) on the students' scores on CRSLQ and SRSLQ measures by the doubly multivariate analysis of variance (MANOVA) revealed some significant results. The MANOVA results presented in Table 6.1 and Figure 6.2 showed that there was interaction between time and learning conditions. A significant effect of time was found also found.

Further univariate analysis of variance was used to determine whether variations in the students' scores on CRSLQ, and SRSLQ, were affected by the interaction between the time and the various learning conditions (a computer based science simulation learning environment with CRL and SRL prompts or SRL only). The finding showed that students' scores on CRSLQ and SRSLQ measures changed significantly over a period of time irrespective of whether they were in the experimental group or the control group during the collaborative science learning over the three Studies. Findings also showed that significant differences existed among treatment groups between Studies 2 and 4 on the CRSLQ measure, whereas with respect to the SRSLQ measure, students in both experimental and the control groups improved in their SRL behaviours but no significant difference was found between the two groups. The result of the quantitative content analysis suggested that co-regulatory behaviours increased from Studies 2 to 4. The experimental group had made greater use of CRL behaviours; such as planning, monitoring, effort regulation, and help seeking and giving, than the control group. The students in the experimental group also had a higher number of total messages obtained from either audio recordings or *InterLoc* chat scripts, and CRL-related messages, than the control group.

The findings showed that the frequencies of occurrence of the CRL behaviours over the three studies increased for both the experimental and the control groups. These findings highlighted the importance of supporting students with CRL and SRL prompts when learning in a computer based science simulation learning environment over a period of time. This has enhanced the students' demonstration of co-regulatory behaviours.

Furthermore, the outcomes of the investigation of research question 3 also confirmed that prompting the control group with only SRL prompts enabled them to possess well-developed self-regulatory behaviours over a period of time that eventually aided them to co-regulate. Figure 6.1b confirmed that the control group's scores on SRSLQ measure increase from Pre Study to Study 4. This finding has implications and poses several challenges for the design of learning activities intended to enhance students' co-regulated learning behaviours and academic performance in a computer based science simulation learning environment when learning in different subject domains. Findings from Chapter six suggest that students prompted with CRL and SRL behaviours tend to improve in CRL behaviours and are likely to attain higher level of academic performance faster than the control group prompted with SRL behaviours only in a computer based science simulation learning environment. However, when different subject domains were investigated successively there was no significant difference between the differences in the groups' post test scores over a period of time. This could be attributed to the continued exposure of students in the control group to the regulatory prompts. These findings highlight the importance of the continued use of CRL and SRL prompts in the computer based science simulation learning environment over a period of time with a view to enhancing students' demonstration of co-regulatory behaviours. This is thought to have eventually helped many students who are of low and intermediate academic ability to move to a higher category of academic achievement. Since counting the number of instances of CRL indicators in both the experimental and the control groups provided insight into quantitative differences in the students' CRL behaviours but fails to capture the details of the nature of co-regulated learning strategies that students used in the various groups, further investigation looked at the data qualitatively in order to address the research question 4 presented in Chapter seven. The question explored the nature of CRL behaviours that students demonstrated when learning in a computer based science simulation learning environment supported with either CRL and SRL prompts or SRL prompts only.

8.2. 4: Research Question 4

Research question 4 asked, "What co-regulated learning behaviours do students use when they learn science collaboratively in a computer based science simulation learning environment incorporated with either CRL and SRL prompts or SRL-prompts only?" While research questions 3 focused on overall co - regulation processes over time quantitatively, research question 4 examined the sub-process and strategies that students used to co-regulate their learning behaviours qualitatively over time. Therefore, research question 4 extended other studies that have collected qualitative data rather than self-report questionnaires (Dweck & Leggett, 1988; Pintrich, 2000) in that it examined co-regulatory processes over a relatively long-term time period in which students worked collaboratively in a computer based science simulation learning environment.

These analyses showed that there were both within-group and between-group differences in the nature of co-regulated learning behaviours demonstrated by students when learning in collaborative settings over time. The results of this Study suggest that students in the experimental group that were supported with CRL and SRL prompts engaged in a deeper level of collaborative activity and used more metacognitive strategies such as planning compared to students in the control group that were supported with SRL prompts only. Students in both experimental and the control groups demonstrated the following co-regulated learning behaviours: one group member with higher regulation skills co-regulating another group member(s), the role of the more able being alternated among group members, or several group members shared in regulating each other's regulatory activities simultaneously. Because the control group members demonstrated co-regulation as well, there was no evidence to suggest one form of co-regulation was better than the other.

The experimental group co-regulated both task and content monitoring to ensure that process planning tasks were accomplished. In addition, they made explicit efforts to monitor how group members' ideas and knowledge about the task related to the overall goals of their learning in each of Studies 2, 3, and 4. This served to keep the group on task and focused on their shared goals. In terms of evaluation processes, the findings showed that the experimental group engaged co-regulated evaluation processes, in which only one group member evaluated another group member's contribution during learning. As noted earlier on, the demonstration of evaluation processes were low in both experimental and the control group. They also engaged in productive motivational strategies, in that these strategies increased their participation, persistence, and engagement in the various tasks over time. Finally, both students in the experimental and the control groups they made statements to increase each other's effort and attention throughout the three studies.

However, supporting the students with CRL and SRL prompts when learning helped in promoting effective co-regulation of learning processes by students which eventually lead to improvement in an individual member's SRL. While theoretically researchers have hypothesised a relationship between students' co-regulation and self-regulatory processes (e.g., Corno & Mandinach, 2004; Hadwin & Oshige, 2007; McCaslin& Hickey, 2001), this present research added empirical support to this claim. It also lends support to qualitative findings (e.g., Järvela & Järvenoja, 2007) that suggested the existence of co-regulatory processes when students worked on collaborative tasks.

8.3: Reflection on the Research process

There were several lessons learnt during this research which are outlined in this section. The lessons cover my experience right from the beginning (e.g. gaining access to the school) to the end (e.g. data analysis) of this research process.

8.3.1: Access to school

After obtaining permission from the Open University Human Research Ethics Committee (HREC) to carry out this research, there remained the big issue of the school to use for this research. Letters were sent out to most of the school within the locality requesting them to participate in this PhD research. This was further followed up with various telephone calls and visit to the local schools. This was however, taking more time than planned for this research as I was not able to secure any schools to participate at this point. Finally after several months and through my supervisors' intervention as well as other members of the Open University, a school agreed to participate in the research. Perhaps the most important lesson learnt from that experience was that the negotiating process can be prolonged and initial hindrances can be overcome with persistence through provision of all the necessary arguments as well as materials to the interested participants. Also at this point I had to reduce the number of lessons that I was requesting from the school which was five lessons per term to three lessons per term because the school could only allow me use three science lessons.

This experience also highlights the importance of planning well in advance for receiving permissions in the schools. In this research, my initial two visits to the school were helpful in that it enabled me to talk to the science teachers about my research. These informal visits were the key to obtaining final consent to carry out my research in the school.

8.3.2: Developing and testing the CRSLQ

After the initial literature review, I discovered the need to design an instrument that would be used to measure students' co-regulated learning behaviours when learning science collaboratively with others in a small group. The development and validation of the CRSLQ was the very first study in this research. Without having developed the instrument it would have been impossible to measure co-regulatory behaviour quantitatively. The available literature on co-regulation has made use of qualitative data to investigate co-regulation, therefore designing and testing the questionnaire with 214 key stage three students was one of the main achievements in this research.

8.3.3: The knowledge tests

The knowledge tests, although taken from past GCSEs were observed not to be rich enough and adequate enough to examine students' academic performance. Moreover, the activity sheets also worked well as it was able to examine wider areas of knowledge gained by the participants learning in the CSCL environment. Therefore, one important lesson or reflection is that some much more extensive testing of the knowledge tests to ensure they were fit for purpose will be carried out if I were to re-conduct this research work.

8.3.4: Statistical Analysis

This research made use of a number of MANOVA tests to investigate the research questions addressed in this research. This was a problem because the tests were not the same for Studies 2, 3, and 4, so there was no rationale for the overtime effect on the knowledge test. Changing the statistics to using independent- samples t-tests to analyse knowledge tests during Studies 2, 3 and 4 provided a different, interesting way of looking at the data and led to a simpler interpretation.

8.4: Educational Significance

8.4.1: Theoretical Significance of this Study

Theoretically, this research extends individual models of SRL that focus on individual differences to examine social forms of regulation. Rather than considering interpersonal, social, and/or cultural influences as separate variables that affected students' regulatory processes, this research argued that SRL is fostered, developed, and maintained (1) within social contexts and (2) as a result of interactions with peers. On this premise, the development of SRL is conceptualised as a social as well as individual process. Second, this research offers empirical evidence for the nature of co-regulation that is present in collaborative group interactions. Specifically, I presented evidence that supported co-regulation as follows:

1. A single more regulated group member co-regulated other group member(s).
2. The role of more able group members alternated among group members, depending on whose regulatory processes were better suited for a particular task.
3. Several group members shared in regulating each other's regulatory activities simultaneously.

This research has drawn on both social cognitive and sociocultural theories and offers an integrative approach to conceptualise regulation that may serve to further understand CRL and SRL processes within a computer based science simulation learning environment. As pointed out earlier on, the outcomes from the quantitative analysis present the evidence that CRL is a significant predictor of change in SRL over time. The quantitative content analysis showed that the experimental and the control groups differed in the frequency in which they co-regulated their learning processes over the three Studies. Analysis from the qualitative data established that the experimental and the control groups also differed in the nature of co-regulated learning they engaged in. These findings are consistent with sociocultural theories that suggest co-regulatory processes were present within collaborative group contexts and that groups employ these processes in order to regulate their own and each other's regulatory behaviours. The present research therefore has extended the current literature by investigating social models of SRL and offering empirical support for various types of co-regulated learning behaviours that students demonstrate when learning in a computer based science simulation learning environment. Therefore, this is an original contribution of this research to the body of knowledge on co-regulated learning.

8.4.2: Practical Significance of this Study

First, because teaching in small groups and its associated benefits is an instructional approach teachers are already familiar with, the incorporation of the CRL and SRL prompts into a computer based science simulation learning environment capitalises on existing classroom practices. Therefore, this approach reduces the need to implement new instructional methods, which may require substantial time, effort, and resources, when students could benefit from an existing method which incorporates CRL and SRL prompts into a computer based science simulation learning environment for the enhancement of students' CRL behaviours. Incorporating CRL and SRL prompts into a computer based science simulation learning environment is consistent with students' efforts to use ICT tools to communicate scientific information and contribute to presentations and discussions in accordance with the UK educational standards that call for developing essential skill and processes during science learning. This includes encouraging students to engage in discussions with one another about scientific issues during collaborative learning. These curriculum standards are expected to help students develop regulatory skills and group collaboration as a means of increasing their learning and academic performance. Therefore, enhancing students' demonstration of CRL behaviour with the ultimate goal of promoting their SRL is consistent with existing classroom instructional methods and the requirements of the England educational curriculum standards.

Secondly, the increasing student-tutor ratio in the UK is making the implementation of traditional approaches for helping students to cultivate SRL strategies more difficult. The prospect of using CRL and SRL prompts to develop students' SRL processes means that the practical problem of having few science teachers and many students could be partly solved by having students serve as more knowledgeable peers to each other. In these circumstances, it is expected that expertise will be shared among students and group members will assume a collective responsibility for helping each other develop regulatory skills. As interactions among students are enhanced by the incorporation of the CRL and SRL prompts into a computer based science simulation learning environment, opportunities abound for students to learn new strategies as they work collaboratively with their peers on joint tasks. Therefore, employing CRL and SRL prompts to help science students develop SRL skills is expected to alleviate resource demands as well as capitalise on students' modelling and explaining processes.

8.5: Scope and Limitations

This research focused on key stage three students learning science in a computer supported collaborative learning (CSCL) environment supported (computer based science simulation learning environment) with either CRL and SRL prompts or SRL prompts only. The findings showed that supporting students with co-regulatory behaviours during collaborative learning is very important as this can help students to learn effectively in the group setting. This will affect their performance on the given tasks. This present research made use of three science topics in the area of physics and biology (Simple Circuits, Flowering Plants and Blood Circulation); the procedure should be extended to other science topics in chemistry in order to ascertain the effectiveness of CRL and SRL prompts.

Also, the cultural background influenced students' regulatory behaviours in the classroom. The samples used in this research are from an English school, where the National curriculum is taught to the students. The school Ofsted's report judged the school to be outstanding in terms of the students' performance as well as the students' attendance in the school. Previous studies on self-regulated learning suggested that cultural backgrounds are a differentiating factor in the degree of SRL skills that student demonstrate during learning (Chye *et al.,* 1997; Pillay *et al.,* 2000; Matthews *et al.,* 2000, Turingan, & Yang, 2009). It is however unclear whether the findings of this research could generalise to students in other countries following other curricula. Although many developing world have modelled their school education and teaching system on the British system, this may make the results of this research to be representative of the students in the developing educational system.

Furthermore, there are also limitations regarding the role of the researcher as participant. The nature of the design research methodology used in this research is that the experiment is set up and implemented by the researcher. To overcome this limitation Bereiter (2002) suggested that research design methodology requires on-going collaboration with teachers involved in the research. He emphasised the need for the practitioners (teachers) to be the ones who are receptive to the innovation and willing to experiment with unproven methods which are part of the requirements for a willing participant. A good rapport was established between the researcher, head of science department in the school, the science teacher in charge of the class and the participating students. The science teacher in this research approved all the topics and all the activities; he also provided information about the classes used for this research.

A promising means to increase student's co-and self-regulated learning strategy use are prompts. Prompts are questions or hints that are designed to encourage productive learning strategies. Prompts have proved to be effective with regard to enhance strategy use and learning outcomes in various contexts (Makitalo *et al.,* 2005, Bannert *et al.,* 2009). According to Young (1993), Dabbagh & Kitsantas (2004) and Saadawi *et al.* (2010) prompts are temporary supports which are supposed to be withdrawn gradually as the group's competence in terms of co-regulatory behaviours increases. Ideally these would have been withdrawn but this was not possible in this relatively short research. The next section gives some recommendations for further research.

8.6: Recommendations for further research

Further research needs to theorise the role of underlying co- and self-regulated learning prompts. The prompts used in this research were derived from previous research on self-regulation studies. However, during the course of the study, I noted limitations in the prompts compared to some of the emerging behaviours demonstrated by the students. For example, there were no motivation prompts, but this was one of the behaviours that students demonstrated during the collaborative learning. This behaviour might have been as a result of the theories on which the present prompts were based on.

Further research should examine the extent to which students continue to co-regulate in future science tasks that do not include CRL and SRL prompts and the extent to which students become desensitised to prompts over time. It is possible that incorporating the prompts in one task is sufficient for improving students' co-regulatory skills and the students will be able to apply these skills in future tasks. However, there is also research evidence indicating that students' regulatory ability varies greatly across tasks and situations (Weaver & Kelemen, 2002). This suggests that the prompts may need to be incorporated in all tasks to continuously remind students to co- and self-regulate or the prompts may not be effective in all tasks.

The students' discussion that leads to co-regulation needs to have an element of criticality and reflection. For example, if there are too many members of a group who tend to agree with each other too easily, without being critical of others' contributions to the discussion, the quality of the co-regulatory process is likely to be low. This scenario is likely to be demonstrated when most of the group members don't express their opinion freely but only echo the views of other participants. However, taking a critical but positive approach, may not be easily achieved. Indeed Mercer *et al.* (2004) argue that students need to be trained on how to take part in productive group discussion in learning about Science. It would be valuable to explore how such reasoning methods might interact with the development of regulatory skills.

Another area to follow up is the teacher's approach and response to introducing co-regulation in the classroom. Although the teacher in this study was very supportive, and as reported in chapter 3, he was involved in the process of designing the activities, the response of the teacher, and any changes in his attitude towards teaching science was not explored. This aspect of investigating teachers' approaches to science teaching in the context of children's developing co-regulation would be an interesting and important topic for further study.

In addition, although it was possible to carry out this study over three terms which is longer than many studies, it would be interesting to see what would happen over a longer period of time, especially if the prompts were removed. One question to be developed is whether co-regulation would be applied to a new context without further training and prompting, and a second issue is whether the difference between the groups would be maintained.

A final interesting direction for further work is investigating whether there might be cultural differences in how students respond to co-regulation. This study was carried out in the UK in the context of the English national curriculum. One possibility therefore would be to carry out a similar study in Nigeria, the researcher's home country. This would be an interesting comparison as Nigeria's curriculum is very influenced by that in the UK and so the Science KS3 curriculum is similar. However, the pedagogic approach is rather different, with much more emphasis on imparting information, and less on a student led critical reflective approach. Arguably, such an approach would not sit as comfortably with developing co and self-regulation, if the student does not view managing her or his learning as her responsibility. Clearly there is also an implication here for the teachers' role.

Finally, in this present research, the control group served as an interesting comparison group because of their ineffective co-regulation processes; future research should investigate the effect of excessive regulation on the group's regulatory processes. It is possible that over-regulation may disrupt flow; for example, an extended discussion is discontinued so that the group continues to move forward. It is possible that students could engage in co-regulation but they are regulating toward a negative goal. Therefore, in the future I would like to explore these issues.

8.7: Concluding Remarks

This chapter outlines a number of achievements of this research. Investigating co-and self-regulated learning behaviours within a computer supported collaborative learning environment has provided a number of other interesting research outcomes, in particular the development and validation of CRSLQ .and the analytical framework.

In section 8.2, the research questions were revisited and the major findings and implications were discussed. These findings were also related to the available literature. The reflective discussion on the research process in section 8.3 highlighted in particular the challenges of gaining access to a school. The rest of the section reiterated the challenges associated with statistical analysis.

The main educational significance of this study in that the incorporation of CRL and SRL prompts into a computer based science simulation learning environment help science students develop their CRL and SRL behaviours and its alleviation of resource demands have been established in section 8.4. The limitations of the research were addressed in Section 8.5. Whilst the limitations in some cases were unavoidable such as not being able to investigate possible knowledge increases over time because of the different topic areas, using independent- samples t-test gave another opportunity to explain my findings. To round off this chapter, further research is suggested in section 8.6.

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List of Appendices

Appendix A: Self-Regulated Strategies for Learning Questionnaire (SRSLQ)

Name---
Gender: Male / Female (Please circle the appropriate one)

Instructions: This questionnaire has a number of questions which seeks to find out about the way you learn. Using the scale below, please answer the following questions. There are no right or wrong answers. Just answer as accurately as possible. If you think the statement is very true of you, circle 6; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 6 that best describes you.		**Not at all true of me**	**Untrue of me**	**Somewhat untrue of me**	**Moderately true of me**	**Somewhat true of me**	**Very true of me**
1	During science lessons, I often miss important points because I'm thinking of other things.	1	2	3	4	5	6
2	When preparing for science lessons, I make up questions to help me focus my reading.	1	2	3	4	5	6
3	When I become confused about something during science lessons, I go back and try to figure it out.	1	2	3	4	5	6
4	If the science topics are difficult to understand, I change the way I prepare for the lesson.	1	2	3	4	5	6
5	Before I start a new science activity, I often skim it to see how it is organised.	1	2	3	4	5	6
6	I ask myself questions to make sure I understand the science activity.	1	2	3	4	5	6
7	I try to change the way I do my work during science lessons in order to fit the requirements and the teacher's instructions.	1	2	3	4	5	6
8	I often find that I don't know what the science activity was all about.	1	2	3	4	5	6

9	I try to think through the science activity and decide what I am supposed to learn from it.	1	2	3	4	5	6
10	During science lessons, I try to determine which concepts I don't understand well.	1	2	3	4	5	6
11	During science lessons, I set goals for myself in order to direct my activity in the class.	1	2	3	4	5	6
12	If I get confused when I am taking notes during science lessons, I make sure I sort it out afterwards.	1	2	3	4	5	6
13	During science lessons, I usually try to concentrate on my work.	1	2	3	4	5	6
14	During science lessons, I make good use of my time.	1	2	3	4	5	6
15	During science lessons, I find it hard to stick to the time allocated for various parts of the given activity.	1	2	3	4	5	6
16	I make sure that I complete my work during science lessons.	1	2	3	4	5	6
17	I make sure I attend science lessons regularly.	1	2	3	4	5	6
18	I often find that I don't spend very much time on my work during science lessons because of other things I do in the class.	1	2	3	4	5	6
19	I rarely find time to revise my science notes before an exam.	1	2	3	4	5	6
20	I often feel so lazy or bored when I am doing a science activity that I quit before I finish what I planned to do.	1	2	3	4	5	6
21	I work hard to do well in science lessons, even if I don't like what we are doing.	1	2	3	4	5	6
22	When the science activity is difficult, I either give up or only do the easy parts.	1	2	3	4	5	6
23	Even when the science activity is dull and uninteresting, I manage to keep doing it until I finish.	1	2	3	4	5	6

		Not at all true of me	Untrue of me	Somewhat untrue of me	Moderately true of me	Somewhat true of me	Very true of me
24	During science lessons, I often try to explain the activity to my classmates.	1	2	3	4	5	6
25	I try to work with others in the science class to complete the given activity.	1	2	3	4	5	6
26	Even if I have trouble with my learning during science lessons, I try to do the work on my own, without help from anyone in my class.	1	2	3	4	5	6
27	I ask my science teacher to clarify concepts I don't understand well.	1	2	3	4	5	6
28	When I can't understand the science activity, I ask other students in the class for help.	1	2	3	4	5	6
29	I try to identify students in science lessons whom I can ask for help if necessary.	1	2	3	4	5	6

Appendix B: Co-Regulated Strategies for Learning Questionnaire (CRSLQ) (Final)

Name---

Gender: Male / Female (Please circle the appropriate one)

Instructions: This questionnaire has a number of questions which seeks to find out about the way you learn together with other students during science lessons. Using the scale below, please answer the following questions. There are no right or wrong answers. Just answer as accurately as possible. If you think the statement is very true of you, circle 6; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 6 that best describes you.		**Not at all true of me**	**Untrue of me**	**Somewhat untrue of me**	**Moderately true of me**	**Somewhat true of me**	**Very true of me**
1	When working in our science group, I often ask myself questions to find out whether I've learnt what I want to learn.	1	2	3	4	5	6
2	When working in our science group, I try to make sure we all make efforts to achieve our set goals.	1	2	3	4	5	6
3	When working in our science group, I often feel pleased if others remind me of the time remaining to finish our work.	1	2	3	4	5	6
4	When working in our science group, I often try to work with others to complete our task.	1	2	3	4	5	6
5	When working in our science group, I work hard to do well even if I don't like what we are doing.	1	2	3	4	5	6
6	When working in our science group, I often give feedback to contributions made by others.	1	2	3	4	5	6
7	When our science group's task is difficult, I either give up or do other things.	1	2	3	4	5	6
8	When working in our science group, I try to make sure we set learning goals and allocate time for various activities.	1	2	3	4	5	6
9	When working in our science group, I often help others who have difficulties in understanding the group task.	1	2	3	4	5	6

		Not at all true of me	Untrue of me	Somewhat untrue of me	Moderately true of me	Somewhat true of me	Very true of me
10	I often think through our group's science task and decide what I am supposed to learn from it.	1	2	3	4	5	6
11	When working in our science group I often ask for clarification if I do not understand something.	1	2	3	4	5	6
12	When working in our science group, I often try to participate in the group discussions.	1	2	3	4	5	6
13	When working in our science group and the task is not interesting, I often manage to keep on contributing my ideas until we finish the task.	1	2	3	4	5	6
14	When working in our science group, I often read quickly through the activities to see how they are organised.	1	2	3	4	5	6
15	When working in our science group, I often try to remind others of the time remaining to finish our work.	1	2	3	4	5	6
16	During our science group task, I often fail to contribute to the task because I'm thinking of other things.	1	2	3	4	5	6
17	When working in our science group, I often try to explain the task to others.	1	2	3	4	5	6
18	When working in our science group, I often remind others to contribute their ideas.	1	2	3	4	5	6
19	When we are doing science group work, I make up questions to ask our group members to help find out whether we have understood the work	1	2	3	4	5	6
20	When working in our science group, I ask others to explain concepts I don't understand well.	1	2	3	4	5	6
21	When there is disagreement in our science group, I either give up or do other things.	1	2	3	4	5	6

Appendix C: Knowledge tests: (on a Simple Circuits (KTSC), Flowering Plants (KTFP) and Blood Circulation (KTBC)

Appendix C1: Simple Circuits Quiz

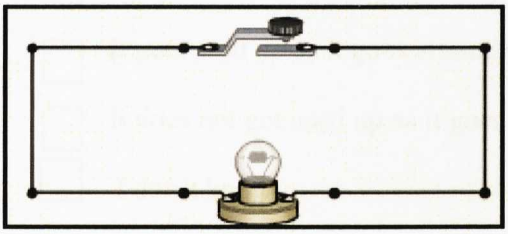
Name: ____

Gender: Male/Female (Please circle the appropriate one).

<u>**Instructions:**</u> This test consists of two sections. In the first section, Pleases choose the correct answers from the given options by placing a tick in the box next to your chosen answer. In the second section, write the components of the circuit in the spaces provided please.

<u>**Section 1**</u>

(1) What needs to be done to this circuit so that the lamp lights up?



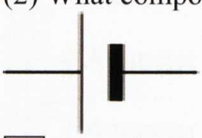
☐ Close the switch

☐ Add another bulb/ lamp

☐ Add a cell/battery and close the switch

☐ I don't know

(2) What component does this circuit symbol represent?



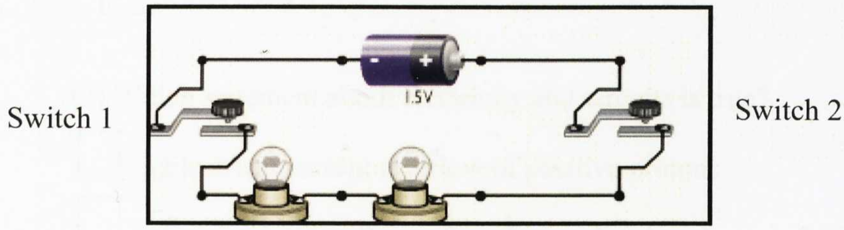
☐ Capacitor

☐ Cell

☐ Switch

☐ I don't know

(3) Which switch or switches must be closed to make the lamps light?

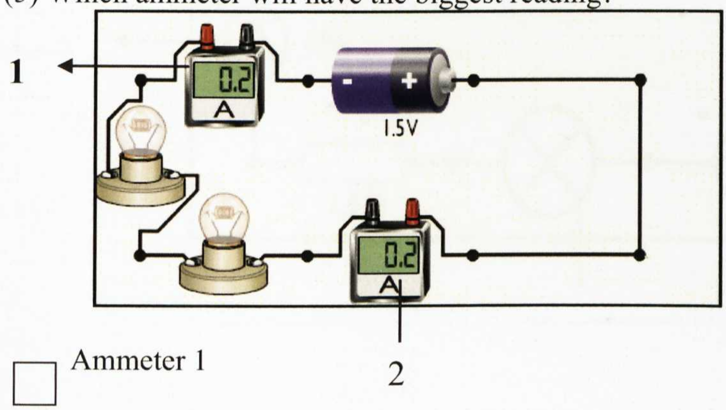


- [ ] Only switch 1
- [ ] Only switch 2
- [ ] Switches 1 and 2
- [ ] I don't know

(4) Which statement about electric current is correct?

- [ ] It always flows clockwise
- [ ] It gets used up as it goes around the circuit
- [ ] It does not get used up as it goes around the circuit
- [ ] I don't know

(5) Which ammeter will have the biggest reading?



- [ ] Ammeter 1
- [ ] Ammeter 2
- [ ] They will read the same
- [ ] I don't know

(6) The amount of electricity flowing around a circuit is called

- [ ] Voltage
- [ ] Mileage
- [ ] Current

☐ I don't know

(7) Which statement about electricity and circuits is true?

☐ Electrical current is a flow of positive protons

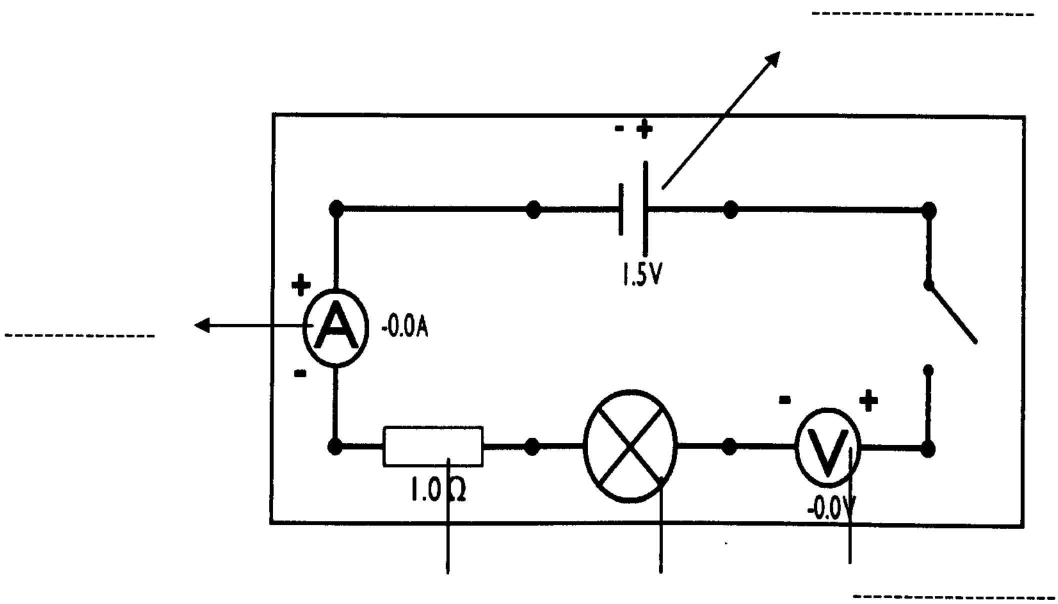
☐ For a current to flow a switch must be closed

☐ A battery or cell is a supply of heat energy

☐ I don't know

Section B

This circuit has components in it. Please name the components.



Appendix C2: Flowering Plants Quiz

Name: ____

Gender: Boy/Girl (Please circle the appropriate one).

Instructions: This test consists of two sections. In the first section, please choose the correct answers from the given options by placing a tick in the box next to your chosen answer. In the second section, label the reproductive organs of the flower please.

Section A

(1) What is the reproductive structure of a flowering plant?

☐ Root

☐ Stem

☐ Flower

☐ I don't know

(2) What are the female parts of a flower called?

☐ The sepal and the stalk

☐ The anther, the filament and the petal

☐ The stigma, the style and the ovary

☐ I don't know

(3) What is the function of the anther in a flower?

☐ It attracts insects

☐ It contains pollen grains

☐ It provides food for insects

☐ I don't know

(4) The movement of pollen from the anthers of a flower to the stigma of the same flower or of another flower is called -------------------------

☐ Pollination

☐ Fertilisation

☐ Germination

☐ I don't know

(5) Which of the following is true?

☐ Insect pollinated flowers usually have bright coloured petals

☐ All flowers are pollinated by insects

☐ Insect pollinated flowers produce much more pollen than wind-pollinated flowers

☐ I don't know

(6) What is the main job of the petals?

☐ To attract insects

☐ To make pollen

☐ To provide food for insects

☐ I don't know

(7) Which part of the plant receives pollen when the insect visits another flower?

☐ Filament

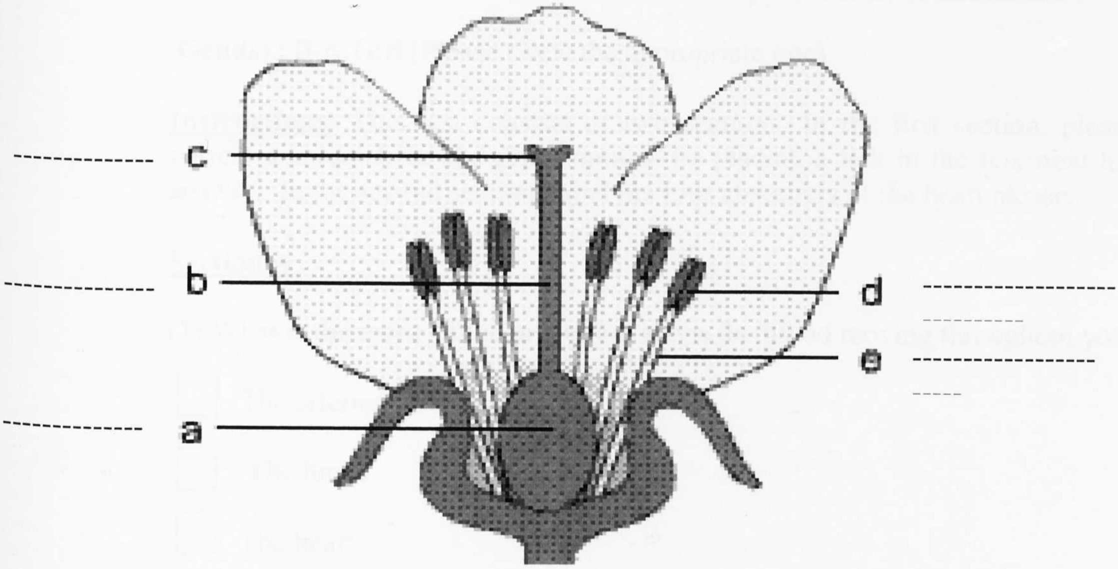
☐ Stigma

☐ Style

☐ I don't know

Section B

Please label the reproductive organs of this flower.



Appendix C3: Blood Circulation Quiz

Name: ____

Gender: Boy/Girl (Please circle the appropriate one).

__**Instructions:**__ This test consists of two sections. In the first section, please choose the correct answers from the given options by placing a tick in the box next to your chosen answer. In the second section, label the four chambers of the heart please.

__**Section A**__

(1) What is the name of the organ that keeps the blood moving throughout your body?

☐ The arteries

☐ The lungs

☐ The heart

☐ I don't know

(2) Which blood vessels carry blood from the heart to various parts of the body?

☐ Veins

☐ Capillaries

☐ Arteries

☐ I don't know

(3) Due to presence of _______ , back flow of blood is prevented in veins.

☐ Valves

☐ Septa

☐ Arteries

☐ I don't know

(4) The _______ of the heart pumps the blood up to the lungs only.

☐ left ventricle

☐ right ventricle

☐ left auricle

☐ I don't know

(5) What does the blood release at the cells?

☐ Carbon Dioxide and nutrients

☐ Nutrients only

☐ Oxygen and nutrient

☐ I don't know

(6) Which of the three blood vessels has the thinnest walls?

☐ Capillary

☐ Vein

☐ Artery

☐ I don't know

(7) Which type of blood vessel carries blood back to the heart from the body?

☐ Artery

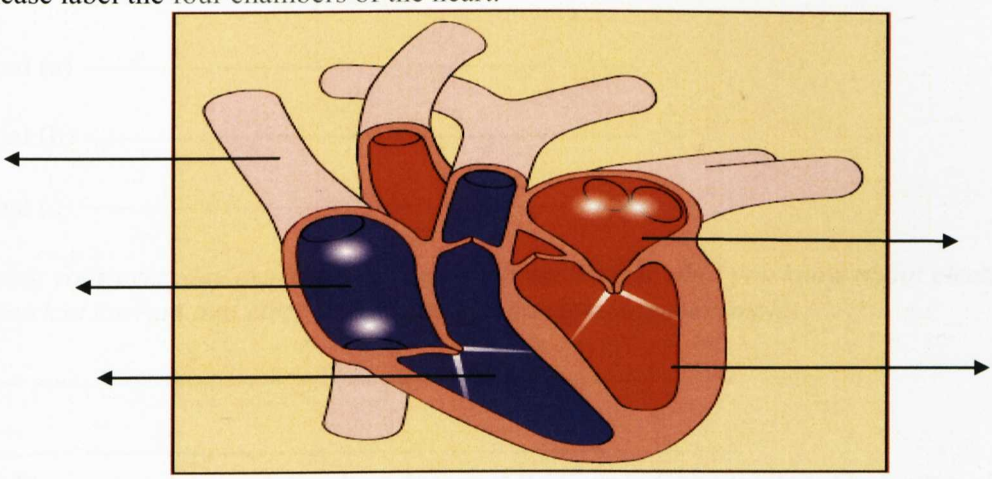
☐ Vein

☐ Capillary

☐ I don't know

Section B

Please label the four chambers of the heart.



Appendix D: Activity sheets for the experimental and the control groups

Appendix D1: Electric Circuits Activity for the Experimental Group

Name____

Introduction: In this activity you will learn about electrical circuits by using a simulation and discussing your ideas with others in your group. You will discuss how to represent simple circuits using symbols and describe the flow of electrons in a circuit. Also, we would expect you to be able to draw diagrams of electric circuits and explain when the path of an electric circuit is complete using the tools provided for you in the simulation.

Time allowed: 50 minutes
Aims of the lesson
(1) To learn how to represent simple circuits using symbols.
(2) To learn the flow of electrons in a simple electric circuit consisting of a cell/battery, a switch and a light bulb.
Learning Activity
Please set three specific learning goals that you want to achieve in this electric circuits activity.

Can you all look through the whole activity before starting to see how they are organised?

Please try and comment on goals of others in your group. It will also be good if you can all agree on three goals here.

Can you all agree on the time you would like to spend on each goal? Note that you have just 50 minutes for the whole activity.

Goal (a) ---

Goal (b) ---

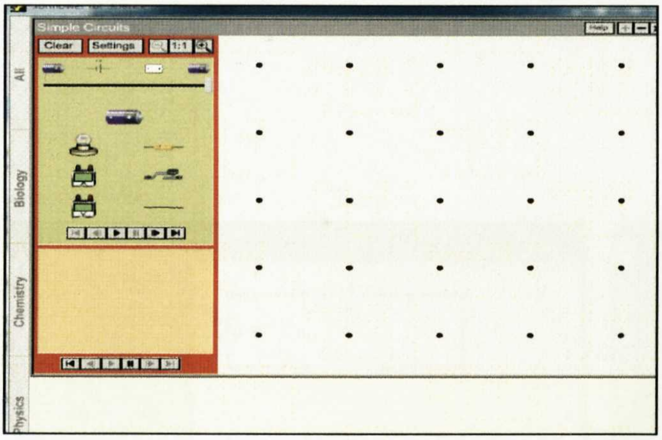
Goal (c) ---

Using your everyday experiences, please tell each other what you know about electricity, electrical current and electric circuits. You can give some examples.

----

(4) Please start the simulation by selecting All / Simple Circuits/ Run. On the top of the left hand side, you will see a cell/battery and under these you will also see a slider that allows

you to view electric circuit in pictures, symbols and electrons modes (Figure A). You will also see some other tools like bulb, resistor, meters (Ammeter and Voltmeter), switch and wire (line) for making your circuit.

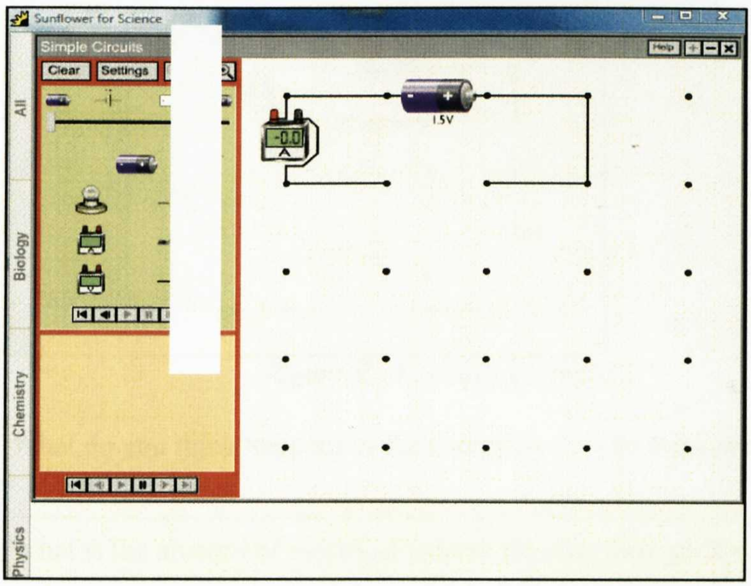


Please take note of the concepts you do not understand in the activity and ask for help from others.

Figure A: Tools and drawing board

On the right side (of the simulation window) you will see a board with some dots. These dots will help you in drawing your circuit. Just drag the tools into the board to construct your circuit.

Now try and use the tools to draw an incomplete circuit. Drag the wire into the board followed by another wire (all should be on a straight line). Drag another wire on both edges, drag two more wires to make a rectangle but leave the centre open. Drag meter (A) on the vertical line. Drag a cell/battery on the upper horizontal line. You should have an incomplete circuit now as shown below in Figure B.



Please write down your conversation with others in your group

Figure B: Incomplete circuit

Drag the slider on top of the left hand side slightly to replace the pictures with symbols as shown below in Figure C. Drag the slider further to see what the electrons are doing in the wires as shown in Figure D below. The red glow around the electrons shows that they have extra energy.

Please check the time and remind others of the time remaining to complete the task.

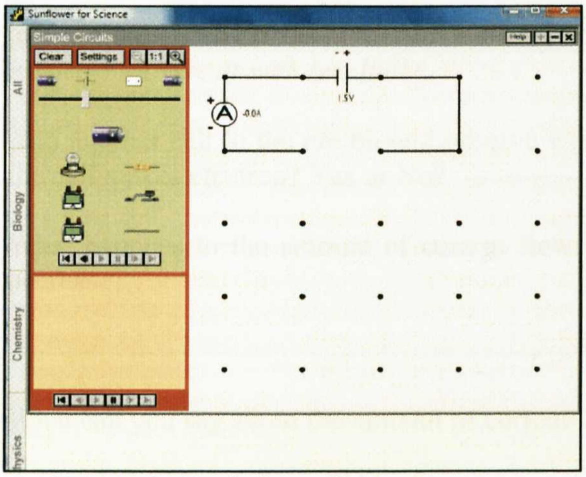


Figure C: Symbols mode

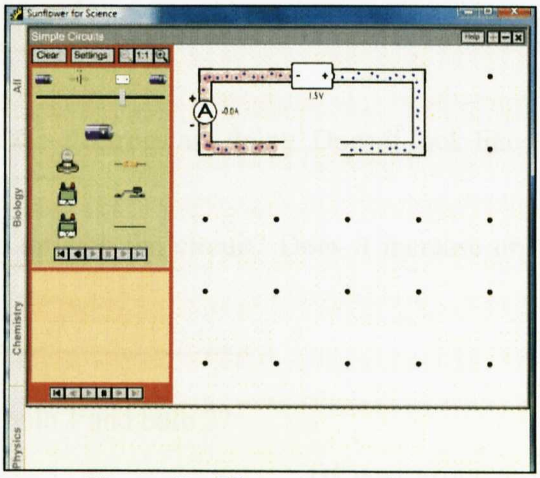


Figure D: Electrons mode

Now drag the slider back to the picture mode as shown in Figure E. Add a bulb to complete the circuit. Return to the electron mode and watch the electrons as you did earlier.

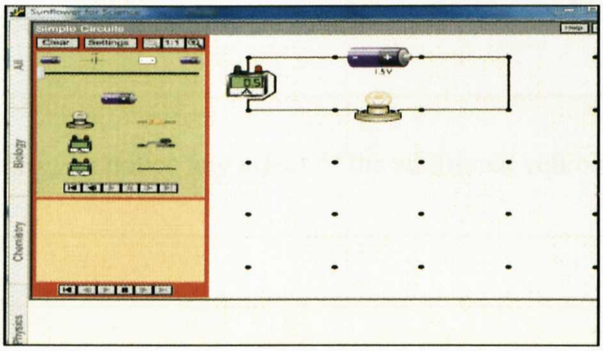


Figure E: A complete circuit

You have spent more than half of your time

What do you think happens to the energy as the electrons pass through the bulb?

What is the amount of electrical current flowing through the circuit?

Please check your answers with other group members.

Now drag another bulb into your circuit diagram as shown in Figure F, drag the slider to see what the electrons are doing in the wires.

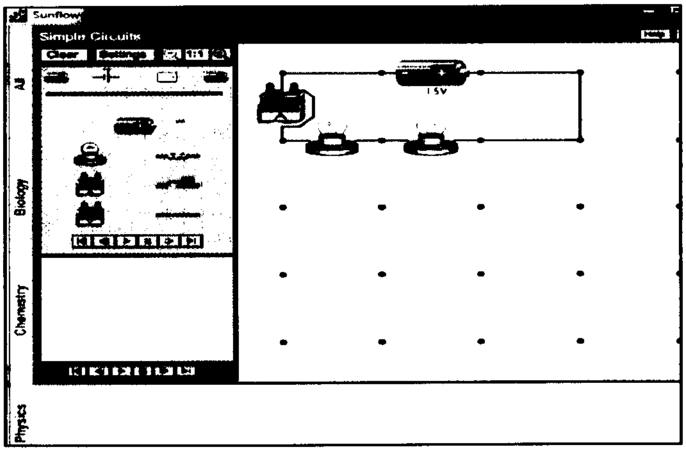


Figure F: A circuit with two bulbs.

Please make sure you remind others to write down their observations.

Add another cell to the circuit and observe what the electrons are doing. Does it look like the cell makes electron? Yes or No? --------------------

What happens to the amount of current flowing through the circuit? Does it increase or decrease?

What can you say about the amount of current in bulb 1 and bulb 2?

Ask your group members if they need help with the group activity and try to respond to them.

Add another cell to the circuit and observe what the electrons are doing.

What happens to the amount of current flowing through the circuit? Does it increase, decrease or remain the same?

If you have any questions, please ask others.

Do you notice any effect of the additional cell/battery into the circuit?

If you have any questions at this stage, please write them here.

Appendix D1A: Sample of Completed Activity Sheet for the Experimental Group.

Introduction: In this activity you will learn about electrical circuits by using a simulation and discussing your ideas with others in your group. You will discuss how to represent simple circuits using symbols and describe the flow of electrons in a circuit. Also, we would expect you to be able to draw ...s of electric circuits and explain when the path of an electric circuit is complete using the tools provided for you in the simulation.

Time allowed: 50 minutes

Aims of the lesson

(1) To learn how to represent simple circuits using symbols.

(2) To learn the flow of electrons in a simple electric circuit consisting of a cell/battery, a switch and a light bulb.

Learning Activity

Please set three specific learning goals that you want to achieve in this electric circuits activity.

To revise our Skills

To find out different Symbols

To learn about different circuits

Can you all look through the whole activity before starting to see how they are organised?

Please try and comment on goals of others in your group. It will also ... good if you can all agree on three goals here.

How much voltage a bulb can hold, To revise most of our Skills, To learn about parallel and series circu

Can you all agree on the time you would like to spend on each goal? Note that you have just 50 minutes for the whole activity.

Goal (a) ---------10 mins---------

Goal (b) ---------25 mins---------

Goal(c) ---------10 mins---------

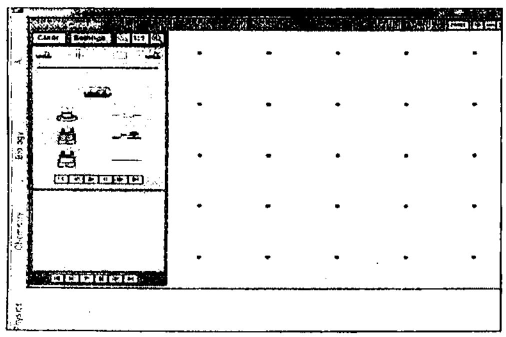
Using your everyday experiences, please tell each other what you know about electricity, electrical current and electric circuits. You can give some examples.

There has to be a Complete Circuit.

The Switch has to be Closed.

(4) Please start the simulation by selecting All / Simple Ci... Run... the top of the left hand side, you will see a cell/battery and under these you will also see a slider that allows you to view electric circuit in pictures, symbols and electrons modes (Figure A). You will also see

some other tools like bulb, resistor, meters (Ammeter and Voltmeter), switch and wire (line) for making your circuit.

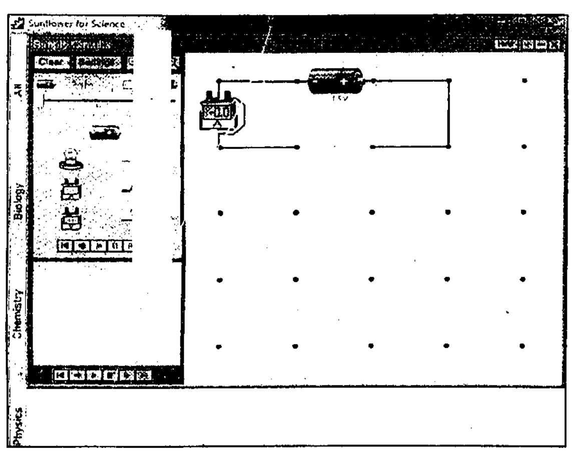


Please take note of the concepts you do not understand in the activity and ask for help from others.

Figure A: Tools and drawing board

On the right side (of the simulation window) you will see a board with some dots. These dots will help you in drawing your circuit. Just drag the tools into the board to construct your circuit.

Now try and use the tools to draw an incomplete circuit. Drag the wire into the board followed by another wire (all should be on a straight line). Drag another wire on both edges, drag two more wires to make a rectangle but leave the centre open. Drag meter (A) on the vertical line. Drag a cell/battery on the upper horizontal line. You should have an incomplete circuit now as shown below in Figure B.



Please write down your conversation with others in your group

Figure B: Incomplete circuit

I think it will be easier

to the instruction on the screen

Drag the slider on top of the left hand side slightly to replace the pictures with symbols as shown below in Figure C. Drag the slider further to see what the electrons are doing in the wires as shown in Figure D below. The red glow around the electrons shows that they have extra energy.

Please check the time and remind others of the time remaining to complete the task.

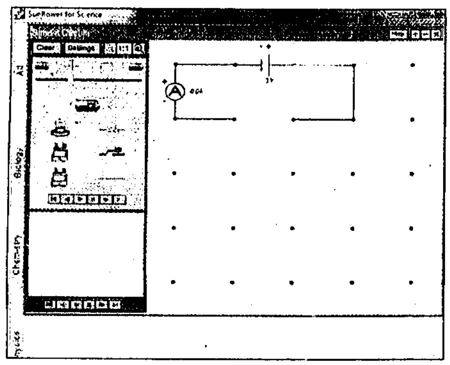


Figure C: Symbols mode

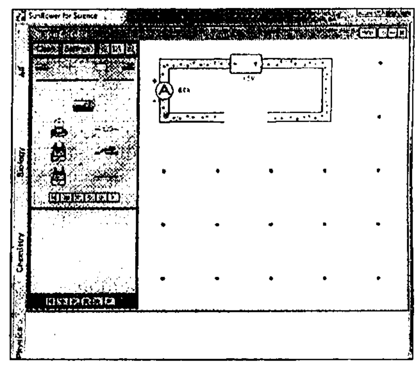


Figure D: Electrons mode

Now drag the slider back to the picture mode as shown in Figure E. Add a bulb to complete the circuit. Return to the electron mode and watch the electrons as you did earlier.

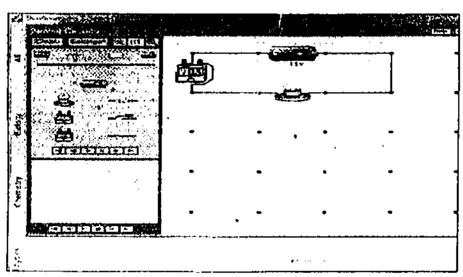


Figure E: A complete circuit

You have spent more than half of your time

What do you think happens to the energy as the electrons pass through the bulb?

Its component collects energy and then releases it

What is the amount of electrical current flowing through the circuit?

Please check your answers with other group members.

Appendix D2: Electric Circuits Activity for the Control Group

Name____

Introduction: In this activity you will learn about electrical circuits by using a simulation and discussing your ideas with others in your group. You will discuss how to represent simple circuits using symbols and describe the flow of electrons in a circuit. Also, we would expect you to be able to draw diagrams of electric circuits and explain when the path of an electric circuit is complete using the tools provided for you in the simulation.

Time allowed: 50 minutes

Aims of the lesson

To learn how to represent simple circuits using symbols.

To learn the flow of electrons in a simple electric circuit consisting of a cell/battery, a switch and a light bulb.

Learning Activity

Please set three specific learning goals that you want to achieve in this electric circuits activity.

Can you look through the whole activity before starting to see how they are organised?

Please indicate how much time you intend to spend on each goal? Note that you have just only 50 minutes for the whole activity.

Goal (a) --

Goal (b) --

Goal(c) ---

Using your everyday experiences, please write what you know about electricity, electrical current and electric circuits. You can give some examples.

Please start the simulation by selecting All / Simple Circuits/ Run. On the top of the left hand side, you will see a cell/battery and under these you will also see a slider that allows you to view electric circuit in pictures, symbols and electrons modes (Figure A). You will also see some other tools like bulb, resistor, meters (Ammeter and Voltmeter), switch and wire (line) for making your circuit.

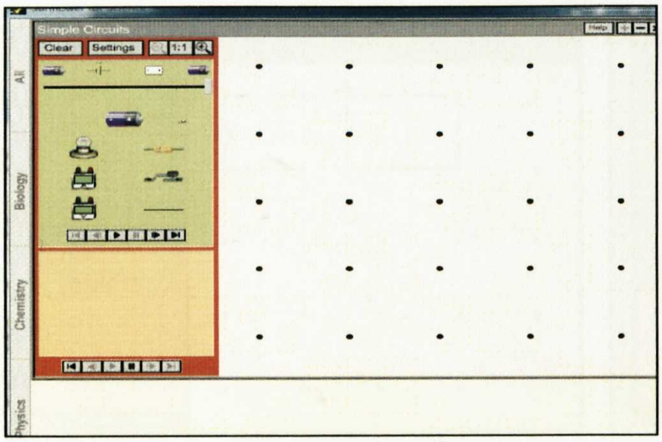


Figure A: Tools and drawing board

It is ok to ask the teacher if you need any help.

On the right side (of the simulation window) you will see a board with some dots. These dots will help you in drawing your circuit. Just drag the tools into the board to construct your circuit.

Now try and use the tools to draw an incomplete circuit. Drag the wire into the board followed by another wire (all should be on a straight line). Drag another wire on both edges, drag two more wires to make a rectangle but leave the centre open. Drag meter (A) on the vertical line. Drag a cell/battery on the upper horizontal line. You should have an incomplete circuit now as shown below in Figure B.

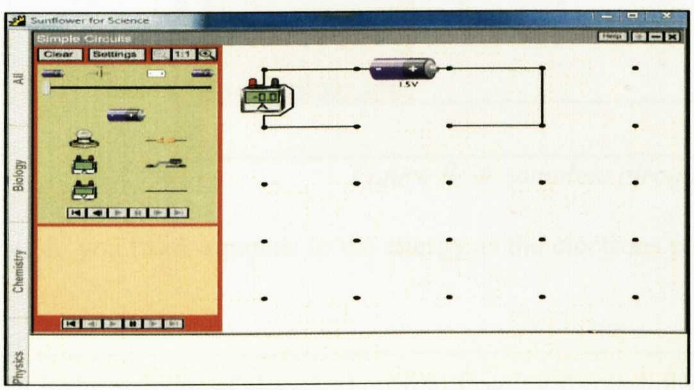


Figure B: Incomplete circuit

Please make sure you write down your observations.

Please check the time remaining to complete the activity.

Drag the slider on top of the left hand side slightly to replace the pictures with symbols as shown below in Figure C. Drag the slider further to see what the electrons are doing in the wires as shown in Figure D below. The red glow around the electrons shows that they have extra energy.

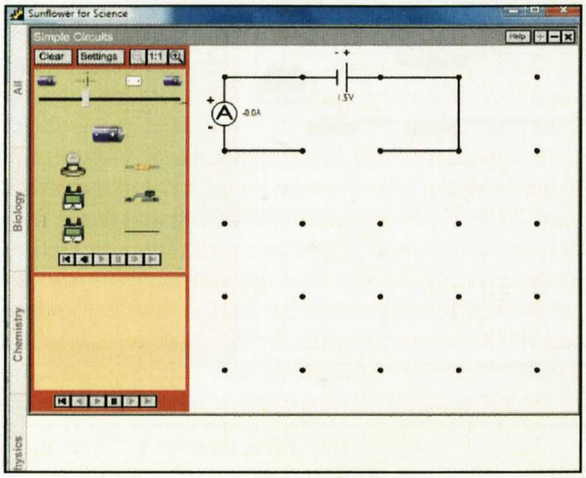


Figure C: Symbols mode

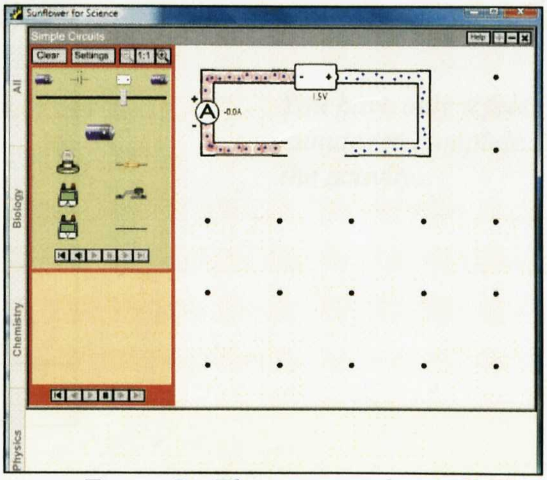


Figure D: Electrons mode

Now drag the slider back to the picture mode as shown in Figure E. Add a bulb to complete the circuit. Return to the electron mode and watch the electrons as you did earlier.

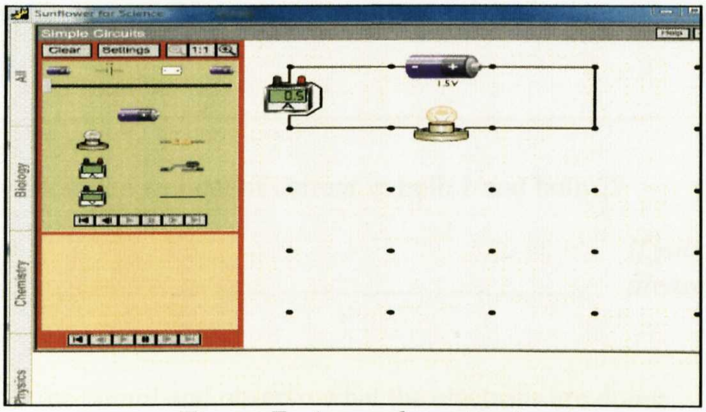


Figure E: A complete circuit

What do you think happens to the energy as the electrons pass through the bulb?

What is the amount of electrical current flowing through the circuit?

If you have questions at this stage, please write them here.

Now drag another bulb into your circuit diagram as shown in Figure F, drag the slider to see what the electrons are doing in the wires.

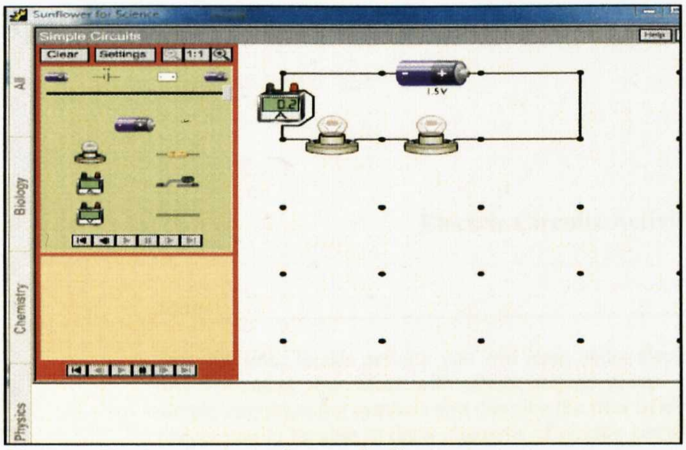


Figure F: A circuit with two bulbs.

You have only a few minutes to complete the activity.

Add another cell to the circuit and observe what the electrons are doing. Does it look like the cell makes electron? Yes or No? ---------------------

What happens to the amount of current flowing through the circuit? Does it increase or decrease?

What can you say about the amount of current in bulb 1 and bulb 2?

If you need help, please ask.

Add another cell to the circuit and observe what the electrons are doing.

What happens to the amount of current flowing through the circuit? Does it increase, decrease or remain the same?

Do you notice any effect of the additional cell/battery into the circuit?

If you have more questions write them here

Appendix D2A: Sample of Completed Activity Sheet for the Control Group.

Electric Circuits Activity

Name_______________________________________

Introduction: In this activity you will learn about electrical circuits by using a simulation and discussing your ideas with others in your group. You will discuss how to represent simple circuits using symbols and describe the flow of electrons in a circuit. Also, we would expect you to be able to draw diagrams of electric circuits and explain when the path of an electric circuit is complete using the tools provided for you in the simulation.

Time allowed: 50 minutes

Aims of the lesson

To learn how to represent simple circuits using symbols.

To learn the flow of electrons in a simple electric circuit consisting of a cell/battery, a switch and a light bulb.

Learning Activity

Please set three specific learning goals that you want to achieve in this electric circuits activity.

To figure out all the scientific sign *Can you look through the whole activity before starting to see how they are organised?*

To be able to set a simple circuit easily

To be able to set hard circuits

Please indicate how much time you intend to spend on each goal? Note that you have just only 50 minutes for the whole activity.

Goal (a) 10 mins

Goal (b) 15 mins

Goal(c) --

Using your everyday experiences, please write what you know about electricity, electrical current and electric circuits. You can give some example

It doesn't react well with water and can start fire.

Please start the simulation by selecting All / Simple Circuits/ Run. On the top of the left hand side, you will see a cell/battery and under these you will also see a slider that allows you to view electric circuit in pictures, symbols and electrons modes (Figure A). You will also see some other tools like bulb, resistor, meters (Ammeter and Voltmeter), switch and wire (line) for making your circuit.

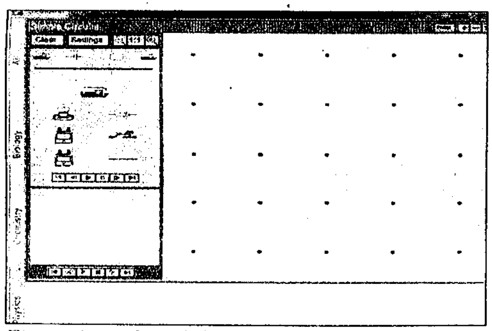


Figure A: Tools and drawing board

It is ok to ask the teacher if you need any help.

On the right side (of the simulation window) you will see a board with some dots. These dots will help you in drawing your circuit. Just drag the tools into the board to construct your circuit.

Now try and use the tools to draw an incomplete circuit. Drag the wire into the board followed by another wire (all should be on a straight line). Drag another wire on both edges, drag two more wires to make a rectangle but leave the centre open. Drag meter (A) on the vertical line. Drag a cell/battery on the upper horizontal line. You should have an incomplete circuit now as shown below in Figure B.

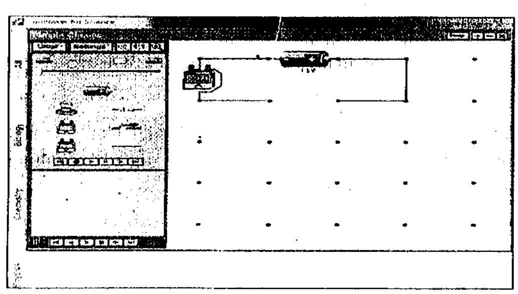


Figure B: Incomplete circuit

Please make sure you write down your observations.

Please check the time remaining to complete the activity.

Drag the slider on top of the left hand side slightly to replace the pictures with symbols as shown below in Figure C. Drag the slider further to see what the electrons are doing in the wires as shown in Figure D below. The red glow around the electrons shows that they have extra energy.

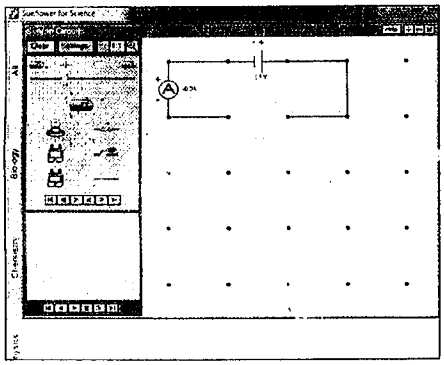


Figure C: Symbols mode

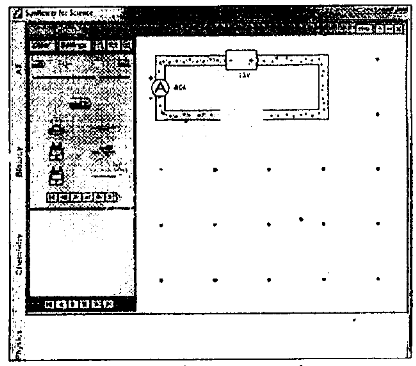


Figure D: Electrons mode

Now drag the slider back to the picture mode as shown in Figure E. Add a bulb to complete the circuit. Return to the electron mode and watch the electrons as you did earlier.

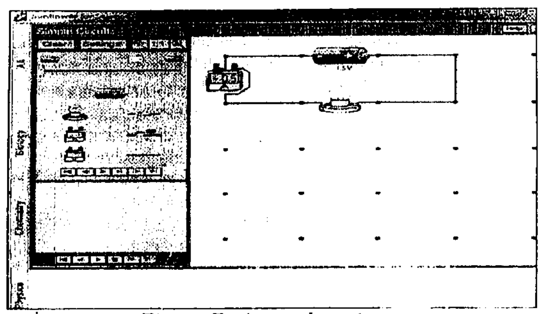


Figure E: A complete circuit

What do you think happens to the energy as the electrons pass through the bulb?

They get used up

What is the amount of electrical current flowing through the circuit?

0 · 5amps

No questions

If you have questions at this stage, please write them here.

Now drag another bulb into your circuit diagram as shown in Figure F, drag the slider to see what the electrons are doing in the wires.

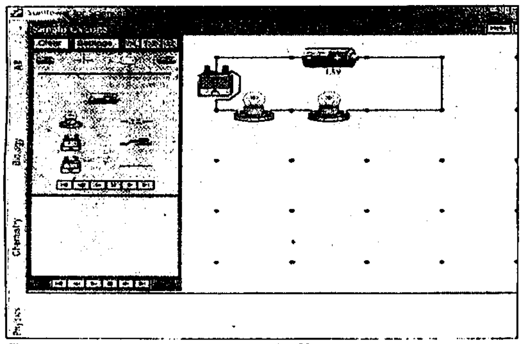


Figure F: A circuit with two bulbs.

You have only a few minutes to complete the activity.

Add another cell to the circuit and observe what the electrons are doing. Does it look like the cell makes electron? Yes or No? -----------NO ✗ (1)

What happens to the amount of current flowing through the circuit? Does it increase or decrease?

Stays the same because it is 0.5 amps ✗ (1)

What can you say about the amount of current in bulb 1 and bulb 2?

I don't know ✗ (1)

If you need help, please ask.

Add another cell to the circuit and observe what the electrons are doing.

What happens to the amount of current flowing through the circuit? Does it increase, decrease or remain the same? (2)

Increase ✓

Do you notice any effect of the additional cell/battery into the circuit? (1)

NO ✗

If you have more questions write them here

8/17

Appendix D3: Flowering Plants Activity for the Experimental Group

Name____

Introduction: In this activity you will learn about reproduction in plants by using a simulation and discussing your ideas with others in your group. You will discuss the functions of different parts of flowering plants and explain how pollination takes place in plants. Also, we would expect you to be able to differentiate between wind and insect pollination.

Time allowed: 50 minutes

Aims of the lesson

To learn about the structure of flowering plants.

To learn how pollination takes place in a flowering plant.

To differentiate between wind and insect pollination.

To learn how fertilisation takes place in a flowering plant.

Learning Activity

Please set three specific learning goals that you want to achieve in this activity.

Can you all look through the whole activity before starting to see how it is organised?

(a)---

(b)---

(c) ---

Please try and comment on the goals of others in your group. It will also be good if you can all agree on three goals here.

Can you all agree on the time you would like to spend on each goal? Note that you have only 50 minutes for the whole activity.

Goal (a) ---

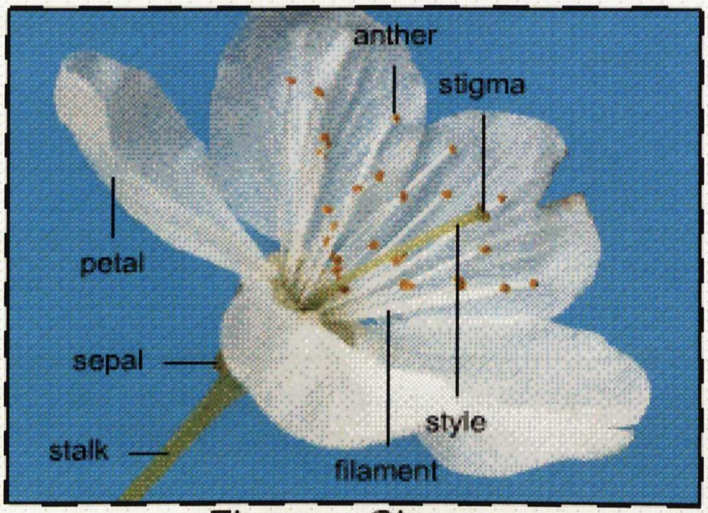
Goal (b) ---

Goal(c) ---

Using your everyday experiences, please tell each other what you know about flowering plants. You can give some examples of flowering plants you have in your garden.

Please start the simulation by selecting All / Plants/ Run new. On the top of the left hand side, you will see 'Clear' and 'Settings' buttons. Click on the 'Settings' and click on 'Show all labels' button. The 'Topics' button allows you to choose what you would like to learn. In this lesson, you will be learning about plant reproduction. Set the topics to 'Reproduction'.

Please click on 'Flower-Cherry' from the lists. Try and learn different parts of the flower.



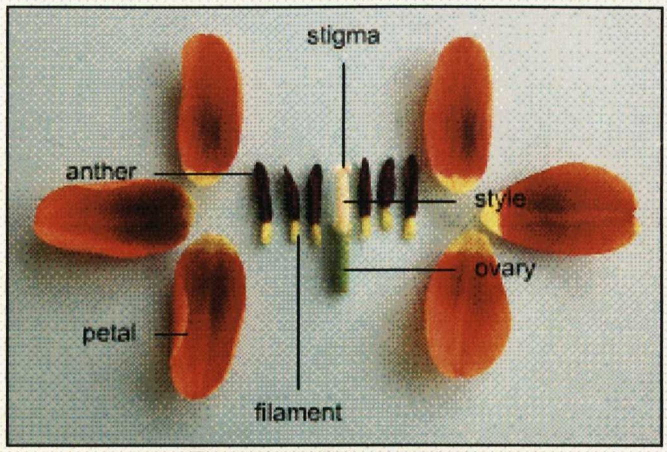
Flower - Cherry

Do you think the flower is important in a plant? Yes/ No.

If yes, what is the main function of the flower?

Please take note of the concepts you do not understand in the activity and ask for help from others.

Please clear your screen and bring up the picture of 'Flower-Dissection'.



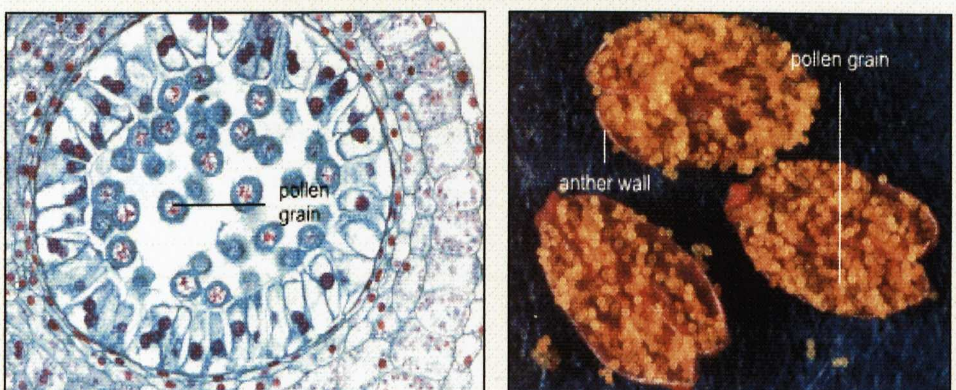
Flower - Dissection

Which parts are male organs and which are female organs?

Male:------------, ---------------------

Female:--------------,----------------------, and ------------------------

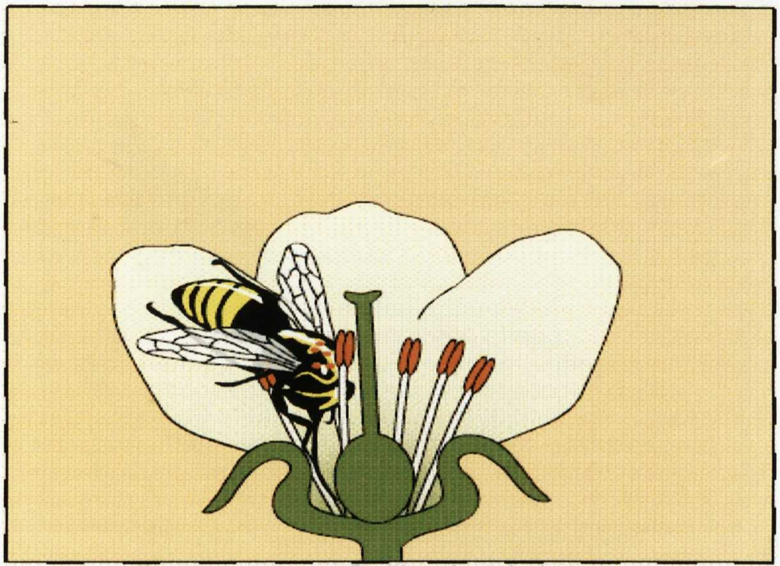
Click on 'Flower-Anther ts'; try to locate pollen grain in the picture. Also click on the 'Flower-Anthers Cut Open picture'. This shows how a pollen grain looks like inside the anther.



Flower - Anther ts   Flower - Anthers Cut Open

What is the function of the anther in a flowering plant?

Now clear your screen and bring up the animation 'Flower- Insect Pollination'. Watch how a bee might help pollinate a typical flower.


Flower - Insect Pollination Animation

Why does the insect reach down into the flower?

What happens to the pollen from the first flower while the insect is there?

Ask your group members if they need help with the group activity and try to respond to them.

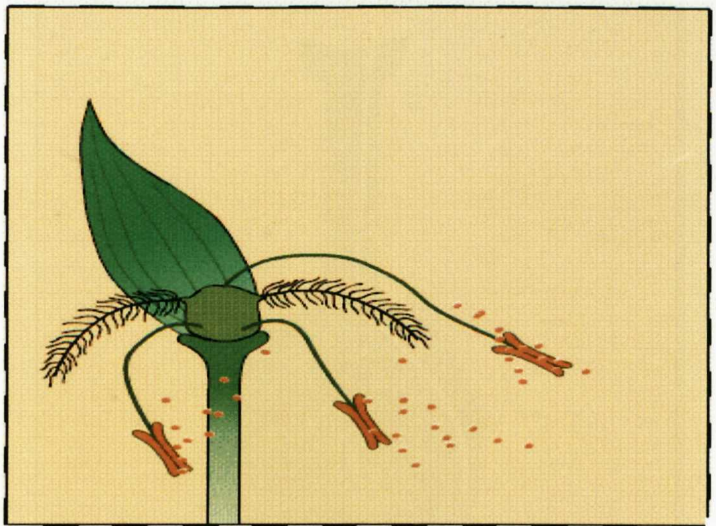
Where does the insect leave the pollen in the second flower?

What methods do you think flowers use to attract attracting insects to them?

Please check the time and remind others of the time remaining to complete the task.

Clear your screen and bring up the animation 'Flower-Wind Pollination'. Watch how wind pollination takes place in the flower.

Please make sure you remind others to write down their observations.



Flower - Wind Pollination Animation

Please check your answers with other group members.

Why do you think the anthers hang outside the flower?

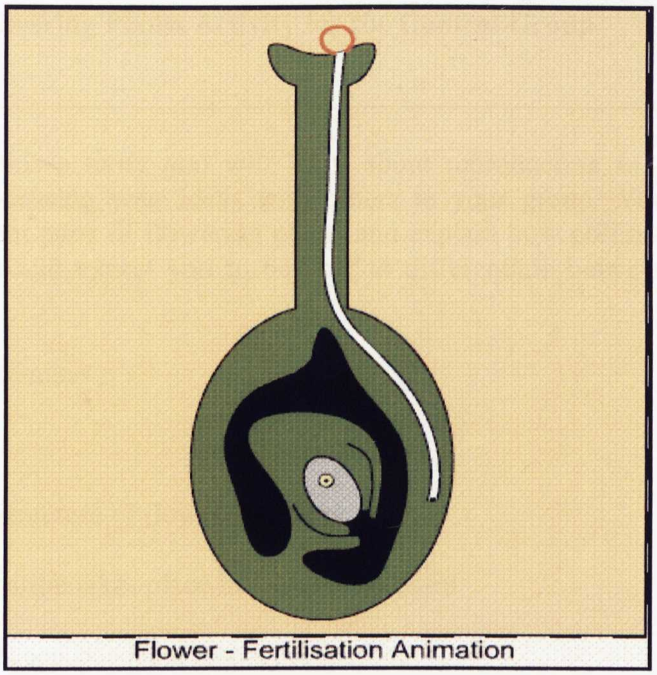
Why are the stigmas so big and feathery?

Why do you think a wind pollinated flower produces lots of pollen?

Please write two differences between insect–pollinated flowers and wind-pollinated flowers.

If you have any questions, please ask others.

Clear your screen and bring up the fertilisation animation. Watch how fertilisation takes place in the flower. The animation shows a flower after pollination. When a pollen grain lands on a stigma, a pollen tube grows down to the ovary and then into it.



What are the names of the **two cells** that are involved in the plant fertilisation?

Please ask questions from your group members to be sure you are right.

Appendix D4: Flowering Plants Activity for the Control Group

Name____

Introduction: In this activity you will learn about reproduction in plants by using a simulation and discussing your ideas with others in your group. You will discuss the functions of different parts of flowering plants and explain how pollination takes place in plants. Also, we would expect you to be able to differentiate between wind and insect pollination.

Time allowed: 50 minutes

Aims of the lesson

To learn about the structure of flowering plants.

To learn how pollination takes place in a flowering plant.

To differentiate between wind and insect pollination.

To learn how fertilisation takes place in a flowering plant.

Learning Activity

Please set three specific learning goals that you want to achieve in this activity.

Can you look through the whole activity before starting to see how it is organised?

(a)--

(b)--

(c) --

Please indicate how much time you intend to spend on each goal? Note that you have 50 minutes for the whole activity.

Goal (a) --

Goal (b) --

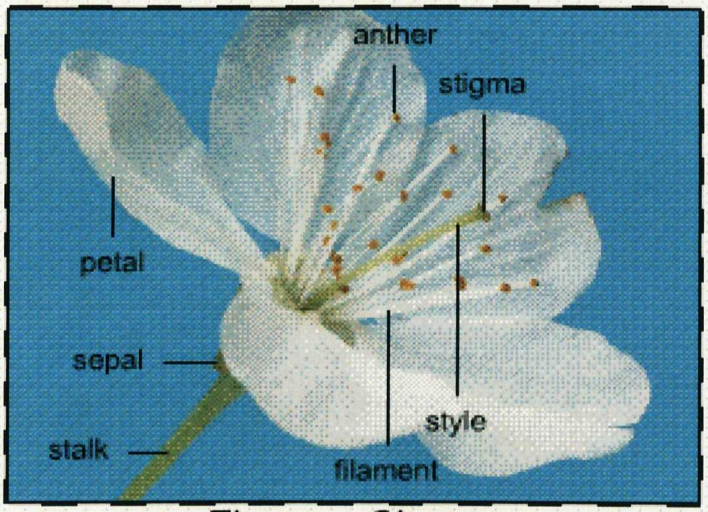
Goal(c) --

Using your everyday experiences, please write what you know about flowering plants. You can give some examples of flowering plants you have in your garden. .

Please start the simulation by selecting All / Plants/ Run new. On the top of the left hand side, you will see 'Clear' and 'Settings' buttons. Click on the 'Settings' and click on 'Show all labels' button. The 'Topics' button allows you to choose what you would like to learn.

In this lesson, you will be learning about plant reproduction. Set the topics to 'Reproduction'.

Please click on 'Flower-Cherry' from the lists. Try and learn different parts of the flower.



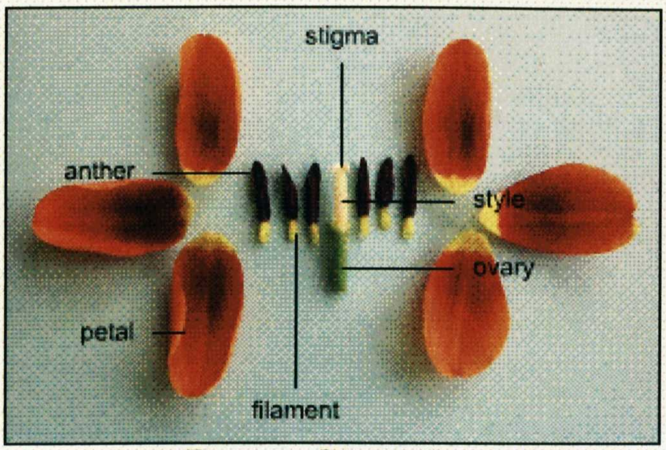
Flower - Cherry

Do you think the flower is important in a plant? Yes/ No.

If yes, what is the main function of the flower?

Please take note of the concepts you do not understand in the activity and write them down.

Please clear your screen and bring up the picture of 'Flower-Dissection'.



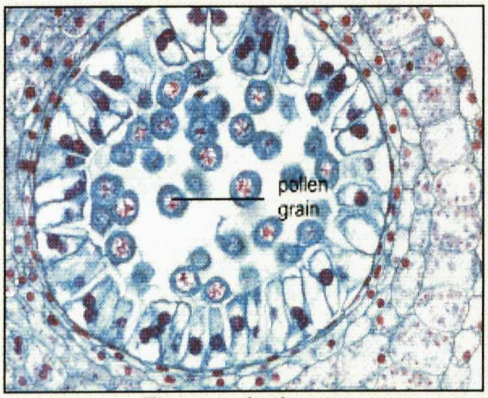
Flower - Dissection

Which parts are male organs and which are female organs?

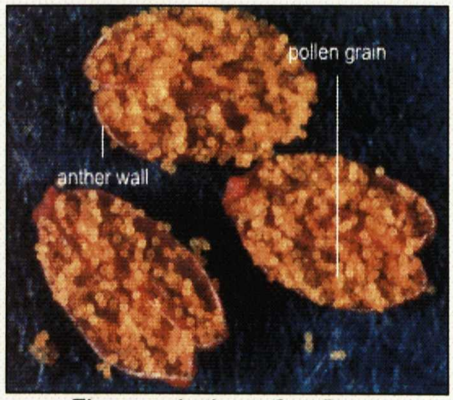
Male:-------------, -----------------------

Female:---------------,-----------------------, and --------------------------

Click on 'Flower-Anther ts'; try to locate pollen grain in the picture. Also click on the 'Flower-Anthers Cut Open picture'. This shows how a pollen grain looks like inside the anther.



Flower - Anther ts



Flower - Anthers Cut Open

What is the function of the anther in a flowering plant?

Now clear your screen and bring up the animation 'Flower- Insect Pollination'. Watch how a bee might help pollinate a typical flower.

Flower - Insect Pollination Animation

Why does the insect reach down into the flower?

What happens to the pollen from the first flower while the insect is there?

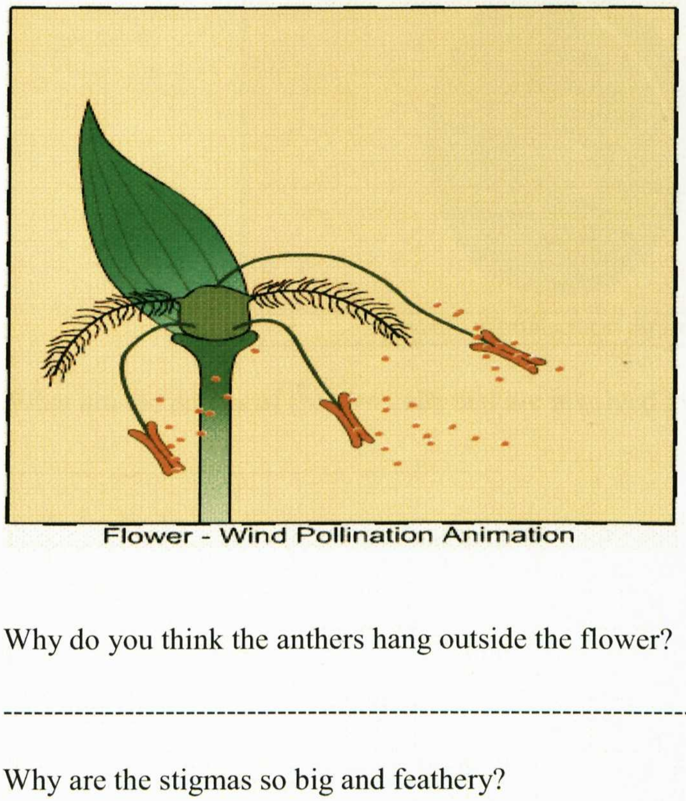
Please raise your hand if you need any help at any point during the activity.

Where does the insect leave the pollen in the second flower?

What methods do you think flowers use to attract attracting insects to them?

You have spent more than half of your time.

Clear your screen and bring up the animation 'Flower-Wind Pollination'. Watch how wind pollination takes place in the flower.



Flower - Wind Pollination Animation

Please raise your hand if you need any help at any point during the activity.

Why do you think the anthers hang outside the flower?

If you need help, please ask.

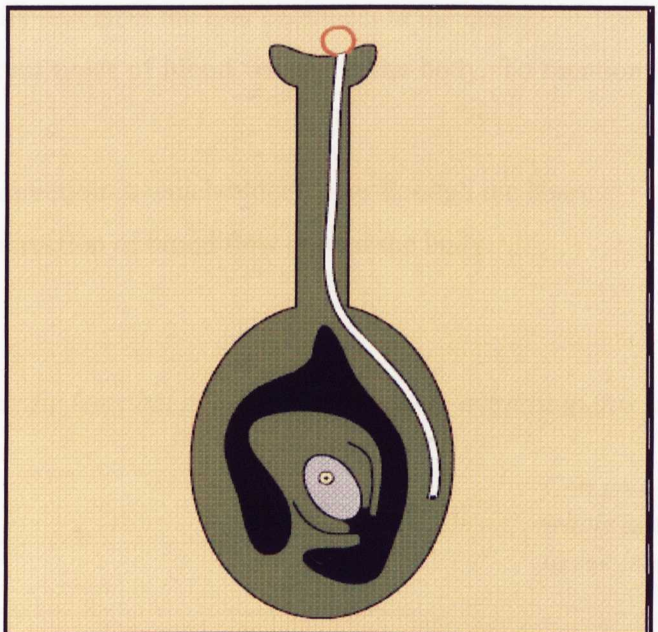
Why are the stigmas so big and feathery?

Why do you think a wind pollinated flower produces lots of pollen?

Please write two differences between insect–pollinated flowers and wind-pollinated flowers.

If you have any questions, please ask.

Clear your screen and bring up the fertilisation animation. Watch how fertilisation takes place in the flower. The animation shows a flower after pollination. When a pollen grain lands on a stigma, a pollen tube grows down to the ovary and then into it.



Flower - Fertilisation Animation

What are the names of the **two cells** that are involved in the plant fertilisation?

If you have more questions write them here

Appendix D5: Blood circulation Activity for the experimental Group

Name____

Introduction: In this activity you will learn about heart, blood vessels, and blood circulation in the body. You will use the circulation simulation to learn how blood flows around the body and you will discuss your ideas with others in your group.

Time allowed: 50 minutes

Aims of the lesson

To be able to identify and label the four chambers in the heart.

To name the different types of blood vessels in the body. To mention their functions and their differences.

To understand the direction in which blood flows through the heart.

To understand the direction of blood flow around the body.

Learning Activity

Please set three specific learning goals that you want to achieve in this activity.

(a)--

(b)--

(c) ---

Can you all look through the whole activity before starting, to see how it is organised?

Please try and comment on the goals of others in your group. It will also be good if you can all agree on three goals here.

Can you all agree on the time you would like to spend on each goal? Note that you have only 50 minutes for the whole activity.

Goal (a) ---

Goal (b) ---

Goal(c) --

Please indicate how much time you intend to spend on each goal? Note that you have 50 minutes for the whole activity.

Goal (a) --

Goal (b) --

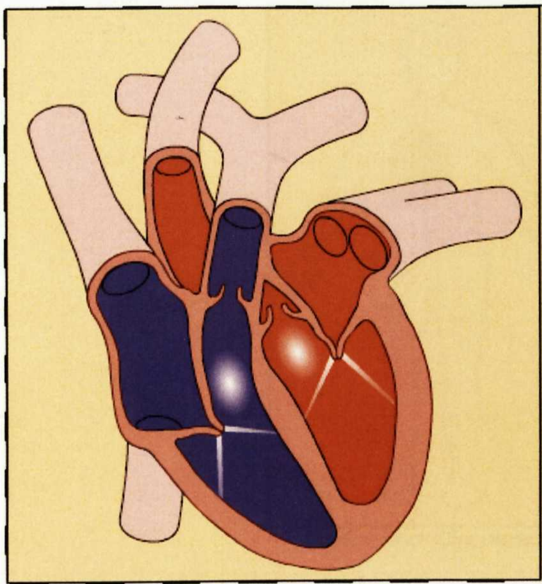
Goal(c) ---

Using your everyday experiences, please write what you know about blood circulation.

Please start the simulation by selecting All / Circulation/ Run new. On the top of the left hand side, you will see 'Clear' and 'Settings' buttons. Click on the 'Settings' and place a tick in the box next to 'Notes' then click OK button at the bottom.

At the left hand side of the simulation screen, you will see pictures and animations on blood circulation, please bring up the animation of 'Heart (Close UP)' from the list of animations/pictures. The heart animation shows what happens more closely in the heart. The heart is similar to two pumps working together.

Blood flows from the heart taking dissolved food and oxygen to the tissues (represented by the colour red in the heart simulation). It returns to the heart low in oxygen (represented by the colour blue in the heart simulation) and is then pumped to the lung to collect more oxygen. It returns to the heart again and is then pumped around the body. Note that the movement of blood (in the 'Heart (Close Up)') is represented by the white dot moving from the top chambers to the bottom.



Heart (Close Up)

Please take note of the concepts you do not understand in the task and ask for help from others.

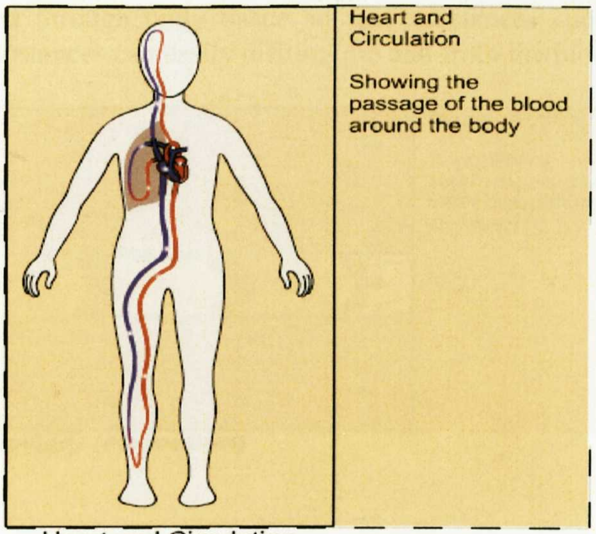
Looking at the 'Heart (Close Up)' animation, what can you say about oxygenated and deoxygenated blood?

There are four chambers in the heart. The upper part of the heart is made up of two chambers, the right (blue) and left (red) atria. The right and left atria receive the blood entering the heart. The bottom part of the heart is divided into two chambers called the right and left ventricles, which pump blood out of the heart.This pumping action creates pressure in the heart which makes blood flow through the arteries.

Note that the valves (*the pink strips that connect the auricle and the ventricle*) ensure that blood only flows in one direction through the heart. Please try and follow the movement of blood (white dot) in the in the "Heart (Close Up)" animation. Which chamber of the heart sends blood low in oxygen to the lungs where it is given much more oxygen?

Please make sure you remind others to write down their observations.

Clear your screen by clicking on the "Clear button" and bring up the animation of "Heart and Circulation". The simulation shows the movement of the blood around the body. You will observe that the right side of the heart pumps blood to the lungs where it collects oxygen (this is the left side on the drawing with purple blood going out via double blood vessels) while the left side of the heart pumps blood rich in oxygen around the body.



Heart and Circulation

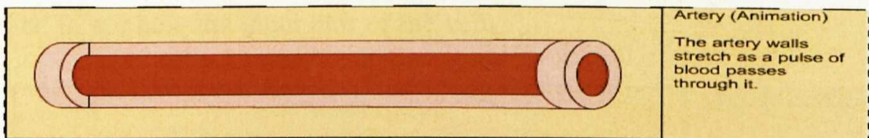
Ask questions from your group members to be sure you are on the right track.

Also, try and follow the path of blood around the body.

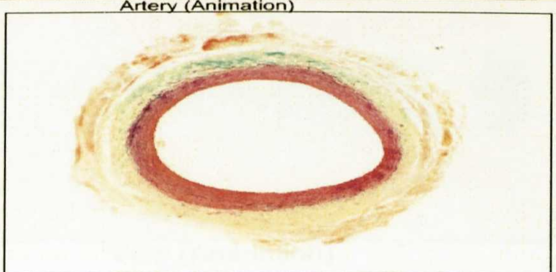
Blood is not blue. What do the blue and red colours represent in the animation?

Why do you think blood goes to the lungs before it goes to the rest of the body?

There are three types of blood vessels in the body. Now you will learn about them, their functions and their differences. Please clear your screen, and then click on the "Artery (Animation)" from the list. Observe carefully how the blood is pumped through the arteries.



Artery (Animation)



Artery ts

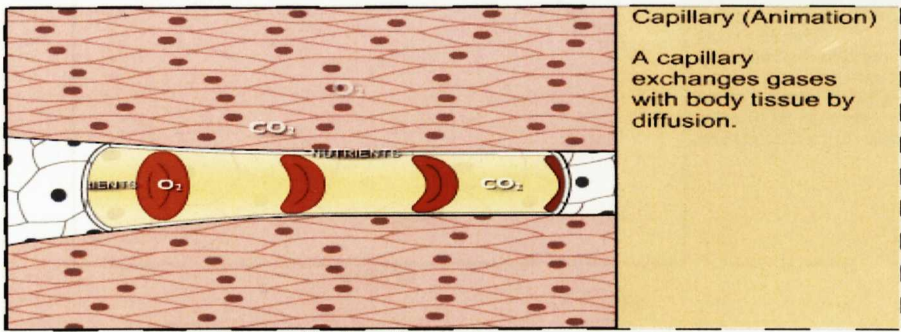
Now select "Artery ts" from the list of the animations to see the inner part of the artery.

What makes blood flow through arteries?

Please check the time and remind others of the time remaining to complete the task.

Please clear your screen and bring up the 'Capillary (Animation)'. Capillaries are small blood vessels that join arteries to the veins. Capillary walls are only one cell thick.

Capillaries are spread through body tissue so that substances such as dissolved food, oxygen, and waste substances can easily diffuse into and from the blood.



Capillary (Animation)

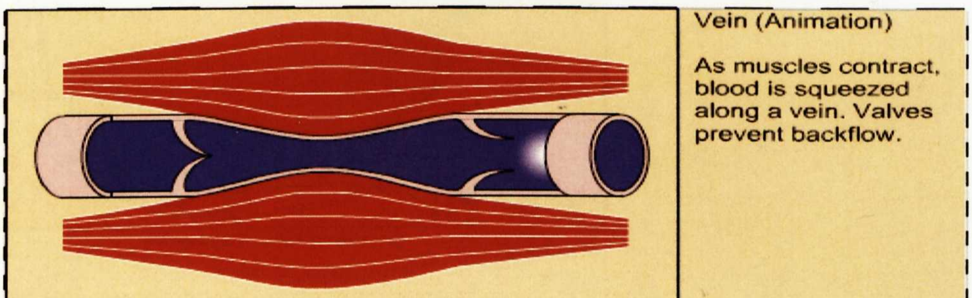
Please watch the movement of the oxygen (O_2) and carbon dioxide (CO_2) in the capillary animation.

What happens to the oxygen (O_2) inside the capillary?

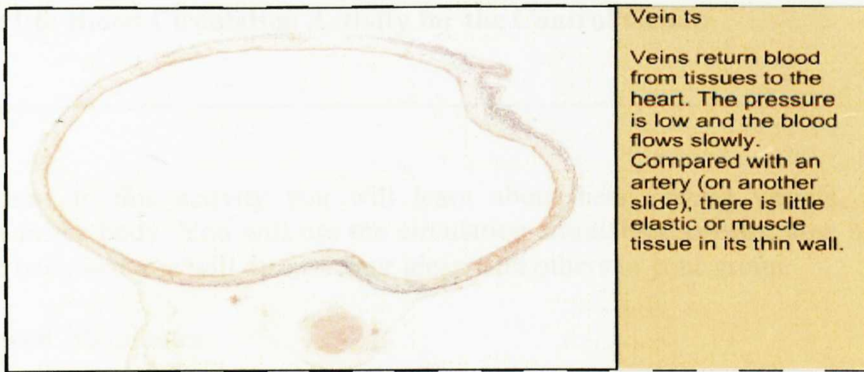
What happens to the carbon dioxide (CO_2) (waste product) in the body tissue?

Please take note of the concepts you do not understand in the task and ask for help from others.

Please clear your screen and click on "Vein (animation)". You will observe that blood from different parts of our body flows back to the heart through veins. Try and observe carefully how blood (represented by a white dot) travels inside the vein. Also, click on the 'Vein ts' to see how the inner part of the vein



Vein (Animation)



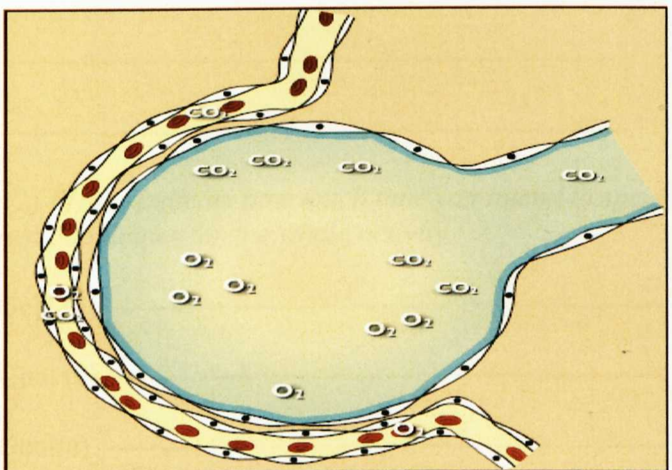
Vein ts

What makes the blood flow through the veins?

Please raise your hand if you need any help at any point during the activity.

What differences do you observe between the artery and the vein?

(You can do this last part if you still have time). Please click on the Alveolus (Animation) and watch what happens in the alveolus of the lungs. Please watch carefully to see if there is any exchange of gas molecule between the alveolus (with the blue membrane) and capillary (with red blood cells in it).



Alveolus (Animation)

You have only few minutes to round up the task.

What do you notice in the movement of oxygen (O_2) and carbon dioxide (CO_2)

What happens to the colour of the red blood cells from the top part of the cell to the bottom part after absorbing oxygen?

If you have more questions, please type them here.

This is the end of the activity, thank you very much.

Appendix D6: Blood Circulation Activity for the Control Group

Name____

Introduction: In this activity you will learn about heart, blood vessels, and blood circulation in the body. You will use the circulation simulation to learn how blood flows around the body and you will discuss your ideas with others in your group.

Time allowed: 50 minutes

Aims of the lesson

To be able to identify and label the four chambers in the heart.

To name the different types of blood vessels in the body. To mention their functions and their differences.
To understand the direction in which blood flows through the heart.

To understand the direction of blood flow around the body.

Learning Activity

Please set three specific learning goals that you want to achieve in this activity.

Can you look through the whole activity before starting to see how it is organised?

(2) *Please indicate how much time you intend to spend on each goal? Note that you have just 50 minutes for the whole activity.*

Goal (a) --

Goal (b) --

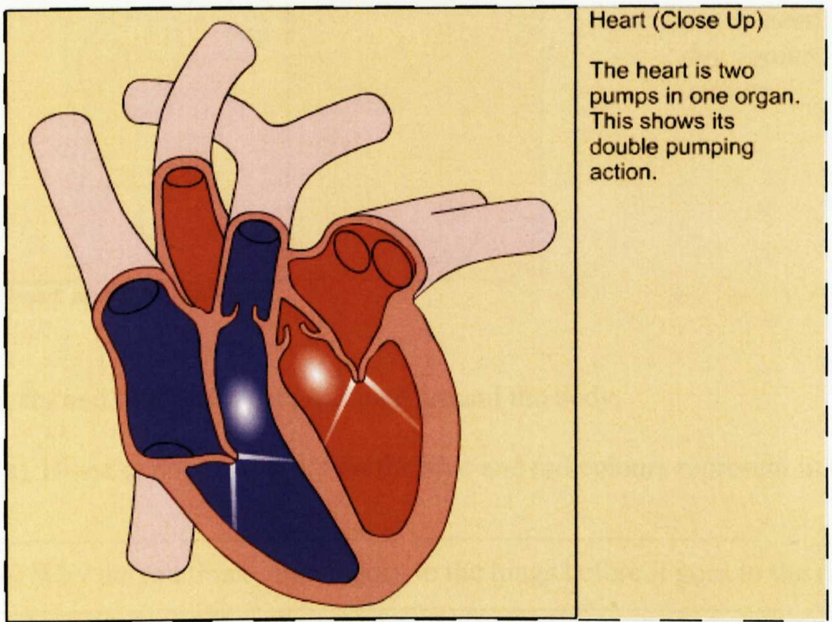
Goal(c) --

Using your everyday experiences, please write what you know about blood circulation.

Please start the simulation by selecting All / Circulation/ Run new. On the top of the left hand side, you will see 'Clear' and 'Settings' buttons. Click on the 'Settings' and place a tick in the box next to 'Notes' then click OK button at the bottom.

At the left hand side of the simulation screen, you will see pictures and animations on blood circulation, please bring up the animation of 'Heart (Close UP)' from the list of animations/pictures. The heart animation shows what happens more closely in the heart. The heart is similar to two pumps working together.

Blood flows from the heart taking dissolved food and oxygen to the tissues (represented by the colour red in the heart simulation). It returns to the heart low in oxygen (represented by the colour blue in the heart simulation) and is then pumped to the lung to collect more oxygen. It returns to the heart again and is then pumped around the body. Note that the movement of blood (in the 'Heart (Close Up)') is represented by the white dot moving from the top chambers to the bottom.



Heart (Close Up)

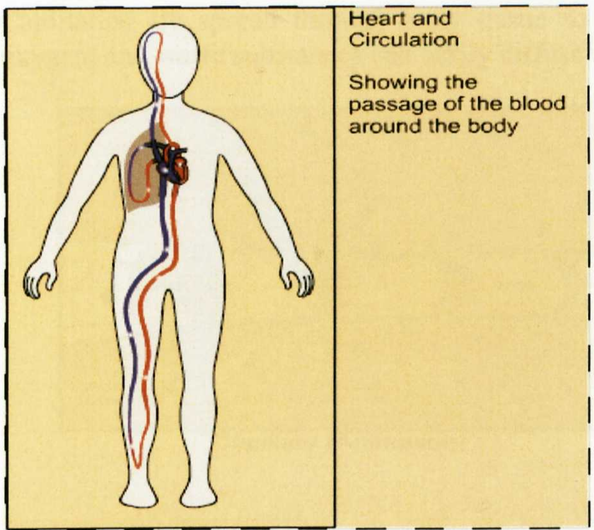
Please take note of the concepts you do not understand in the task.

Looking at the 'Heart (Close Up)' animation, what can you say about oxygenated and deoxygenated blood?

There are four chambers in the heart. The upper part of the heart is made up of two chambers, the right (blue) and left (red) atria. The right and left atria receive the blood entering the heart. The bottom part of the heart is divided into two chambers called the right and left ventricles, which pump blood out of the heart. This pumping action creates pressure in the heart which makes blood flow through the arteries.

Note that the valves (*the pink strips that connect the auricle and the ventricle*) ensure that blood only flows in one direction through the heart. Please try and follow the movement of blood (white dot) in the in the "Heart (Close Up)" animation. Which chamber of the heart sends blood low in oxygen to the lungs where it is given much more oxygen?

Clear your screen by clicking on the "Clear button" and bring up the animation of "Heart and Circulation". The simulation shows the movement of the blood around the body. You will observe that the right side of the heart pumps blood to the lungs where it collects oxygen (this is the left side on the drawing with purple blood going out via double blood vessels) while the left side of the heart pumps blood rich in oxygen around the body.



Heart and Circulation

Please raise your hand if you need any help at any point during the activity.

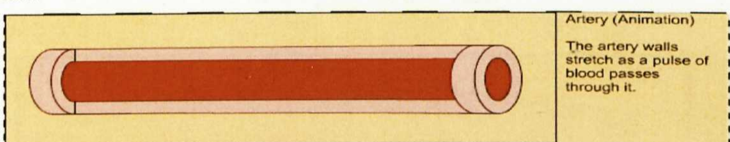
Also, try and follow the path of blood around the body.

(a) Blood is not blue. What do the blue and red colours represent in the animation?

(b) Why do you think blood goes to the lungs before it goes to the rest of the body?

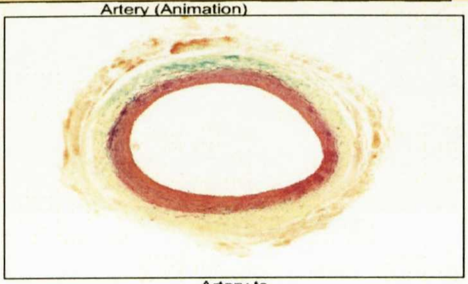
----

(11). There are three types of blood vessels in the body. Now you will learn about them, their functions and their differences. Please clear your screen, and then click on the "Artery (Animation)" from the list. Observe carefully how the blood is pumped through the arteries.



Artery (Animation)

Please write down your observations.

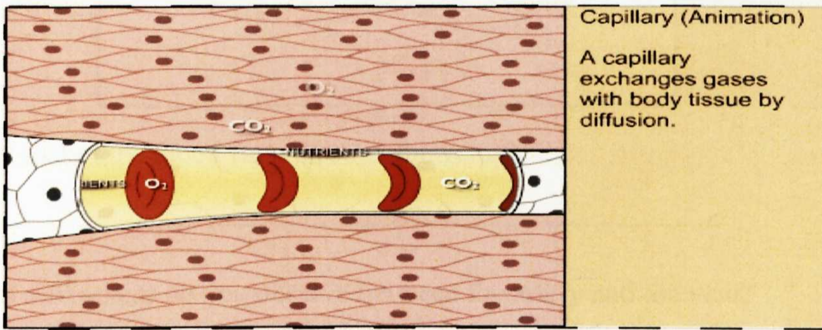

Artery ts

Please check the time remaining to complete the task.

Now select "Artery ts" from the list of the animations to see the inner part of the artery.

What makes blood flow through arteries?

Please clear your screen and bring up the 'Capillary (Animation)'. Capillaries are small blood vessels that join arteries to the veins. Capillary walls are only one cell thick. Capillaries are spread through body tissue so that substances such as dissolved food, oxygen, and waste substances can easily diffuse into and from the blood.



Capillary (Animation)

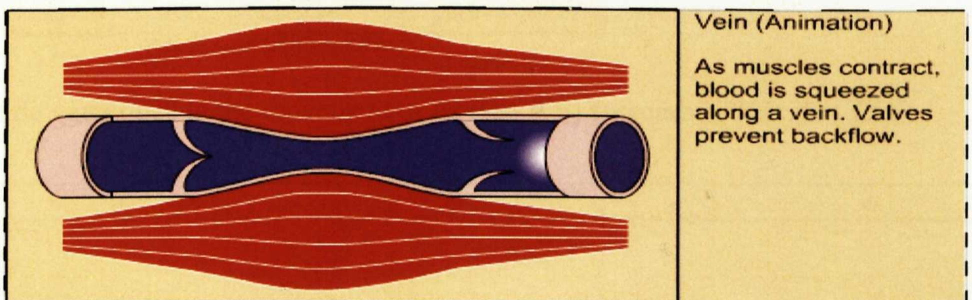
Please watch the movement of the oxygen (O_2) and carbon dioxide (CO_2) in the capillary animation.

What happens to the oxygen (O_2) inside the capillary?

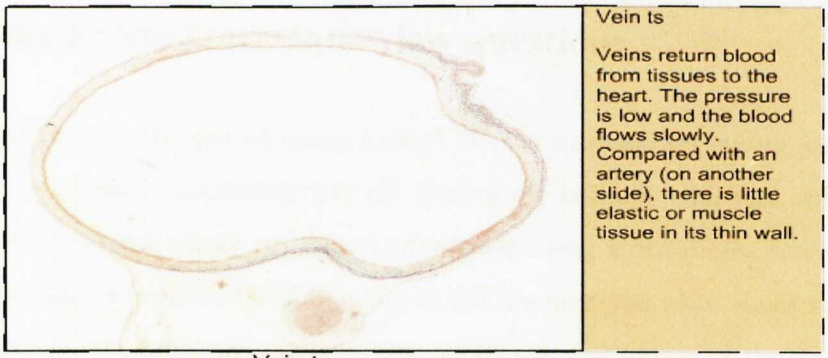
If you need help please ask.

What happens to the carbon dioxide (CO2) (waste product) in the body tissue?

Please clear your screen and click on "Vein (animation)". You will observe that blood from different parts of our body flows back to the heart through veins. Try and observe carefully how blood (represented by a white dot) travels inside the vein. Also, click on the 'Vein ts' to see how the inner part of the vein



Vein (Animation)

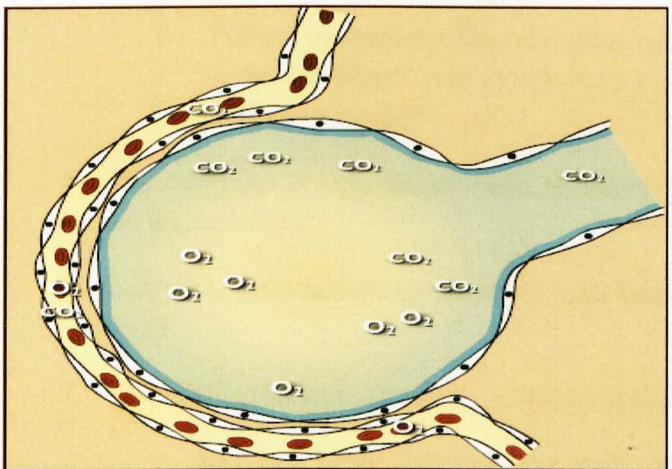


Vein ts

What makes the blood flow through the veins?

What differences do you observe between the artery and the vein?

(You can do this last part if you still have time). Please click on the Alveolus (Animation) and watch what happens in the alveolus of the lungs. Please watch carefully to see if there is any exchange of gas molecule between the alveolus (with the blue membrane) and capillary (with red blood cells in it).



Alveolus (Animation)

You have only few minutes to round up the task.

What do you notice in the movement of oxygen (O_2) and carbon dioxide (CO_2)

What happens to the colour of the red blood cells from the top part of the cell to the bottom part after absorbing oxygen?

If you have more questions, please write them here.

This is the end of the activity, thank you very much.

Appendix E: Students- interview questions

Introduction: How are you all doing today? Thanks so much for taking part in my study since last year, I really appreciate you all. During my sessions with you, we learnt simple circuits, the flowering plants and blood circulation using simulations, activity sheets and Interloc. In today's session, I will like you to tell me how you went about your learning. I will be asking you questions on how you organised and managed the various learning activities in your group. Do you have any question regarding how the section will go before we start?...... My first question is:......

1. Did you enjoy working in your group?
2. Did you all set learning goals and allocate time for your various activities?
    - Can you say a bit more about how easy or difficult you found the activities
3. Did your group members follow the group plan?
4. Did all your group members participate in discussions to reach an agreement?
    - Follow up question like (a) what made everyone in your group participate in the activities? And (b) Do you know why some students in your group didn't participate?
5. Did everyone in your group make an effort in setting the group's learning goals in all the activities?
6. Did you help other group members who had difficulty in understanding the group task?
7. What skills did your group use in working to achieve success on the given task?
    - Did you know anything about the topics (simple circuits, the flowering plants and blood circulation) before?
8. What are the things that made you enjoy working in your group?
9. What are the things that you did not enjoy about working in your group?
10. Can you tell me about two things that you think your group did well?

- Can you tell me about two things that would have helped your group work better?

Appendix F: Teacher- interview questions

Introduction: Thanks so much for your co-operation with me since last two academic year, I really appreciate your effort. During my sessions with your students, they learnt simple circuits, the flowering plants and blood circulation using simulations, activity sheets and *InterLoc*. Today, I will like to ask you few questions on what you actually think about the students' learning in terms of the way they went about organising and managing their learning activities.

1. Do you think the activities undertaken so far in this research were helpful to the pupils' understanding of scientific concepts? If yes can you think of an example?
2. Did the students develop skills of collaborative working during the study?
    a. Did they plan, monitor and manage their time effectively?
3. Do the pupils apply the collaborative skills gained from these research activities to other science lessons?
    a. If any, please, cite some instances you had observed this in other science lessons.
    b. If no,... probe further ....So do they not talk about setting their learning goals or discussing time they will spend on their given task during science lessons?
4. Do you think any student in particular benefited from the study?
5. Is there anything else that you will like to tell me about your observations during my sessions in the school?

Appendix G: Development of cross-tabulation and inter-rater reliability

Table 1: Cross-tabulation of agreement and disagreement between coders 1 and 2 as revealed by CRL indicators in the experimental and control groups over a period of time.

	Study 2						**Study 3**						**Study 4**					
	CRL/SRL			SRL			CRL/SRL			SRL			CRL/SRL			SRL		
	Coder 1			Coder 1			Coder 1			Coder 1			Coder 1			Coder 1		
	A	D	T	A	D	T	A	D	T	A	D	T	A	D	T	A	D	T
Coder 2	**5**	0	5	**5**	0	5	**11**	0	11	**9**	0	9	**11**	0	11	**9**	0	9
	0	10	10	0	10	10	0	4	4	0	6	6	0	4	4	0	6	6
	5	10	15	5	10	15	11	4	15	9	6	15	11	4	15	9	6	15

Legend: A=Agree D=Disagree T=Total

Bold numbers are the hits, the number of units for which coders 1 and 2 agree.

Table 2: Marginal Tables for coders 1 and 2 for the experimental and control groups for study 2

Category	Study2					
	CRL/SRL			SRL		
	n (Coder 1)	n (Coder 2)	pm_i	n (Coder 1)	n (Coder 2)	pm_i
A	5	5	25	5	5	25
D	10	10	100	10	10	100
Total	15	15	$\sum pm_i$ = 125	15	15	$\sum pm_i$ = 125
$PA_E = \frac{\Sigma pm_i}{n^2}$		0.56			0.56	

Table 3: Marginal Tables for coders 1 and 2 for the experimental and control groups for study 3

Category	Marginal					
	CRL/SRL			SRL		
	n (Coder 1)	n (Coder 2)	pm_i	n(Coder 1)	n (Coder 2)	pm_i
A	11	11	121	9	9	81
D	4	4	16	6	6	36
Total	15	15	Σpm_i = 137	15	15	Σpm_i = 117
$PA_E = \frac{\Sigma pm_i}{n^2}$		0.61			0.52	

Table 4: Marginal Tables for coders 1 and 2 for the experimental and control groups for study 4

Category	Marginal					
	CRL/SRL			SRL		
	n (Coder 1)	n (Coder 2)	pm_i	n(Coder 1)	n(Coder 2)	pm_i
A	11	11	121	9	9	81
D	4	4	16	6	6	36
Total	15	15	Σpm_i = 137	15	15	Σpm_i = 117
$PA_E = \frac{\Sigma pm_i}{n^2}$		0.61			0.52	

Legend:
A=Agree D=Disagree T=Total
n = Number of unit coded in common by coders.
pm_i = Each product of marginal.

Table 5: A comparison of CRL indicators detected by coders 1 and 2 for the spoken interactions of experimental group

	Coder 1	Coder 2	Agreement
I	27	32	27
II	13	15	13
III	9	11	9
IV	1	1	1
V	0	0	0
VI	25	31	25
VII	45	45	45
VIII	18	18	18
IX	1	4	1
X	1	5	1
XI	1	3	1
XII	0	0	0
XIII	39	45	39
XIV	32	36	32
XV	37	43	37
Total	249	309	249

Table 6: A comparison of CRL indicators detected by coders 1 and 2 for the spoken interactions of control group

	Coder 1	Coder 2	Agreement
I	4	7	4
II	5	8	5
III	7	7	7
IV	7	9	7
V	0	0	0
VI	0	0	0
VII	21	24	21
VIII	15	18	15
IX	1	1	1
X	1	2	1
XI	2	5	2
XII	0	0	0
XIII	20	23	20
XIV	44	49	44
XV	22	24	22
Total	149	175	149

Table 7: A comparison of CRL indicators detected by coders 1 and 2 from the InterLoc chat scripts, of experimental group over studies 3 and 4.

	Study 3			Study 4		
	Coder 1	**Coder2**	**Agreement**	**Coder 1**	**Coder 2**	**Agreement**
I	26	28	26	33	33	33
II	15	16	15	26	28	26
III	14	14	14	19	19	19
IV	10	12	10	22	24	22
V	4	4	4	10	10	10
VI	19	21	19	26	26	26
VII	40	40	40	50	54	50
VIII	23	23	23	15	15	15
IX	1	1	1	5	6	5
X	3	3	3	2	2	2
XI	2	2	2	3	3	3
XII	0	0	0	4	4	4
XIII	34	34	34	42	42	42
XIV	40	42	40	51	51	51
XV	41	41	41	57	57	57
Total	**272**	**281**	**272**	**365**	**374**	**365**

Table 8: Analysis of CRL indicators detected by coders 1 and 2 from the InterLoc chat scripts for the control group over main studies 3 and 4.

	Study 3			Study 4		
	Coder 1	**Coder 2**	**Agreement**	**Coder 1**	**Coder 2**	**Agreement**
I	11	13	11	15	15	15
II	9	9	9	14	17	14
III	3	3	3	16	18	16
IV	12	15	12	18	18	18
V	5	5	5	12	12	12
VI	12	12	12	16	16	16
VII	19	25	19	30	31	30
VIII	15	19	15	12	13	12
IX	2	3	2	6	6	6
X	4	4	4	3	3	3
XI	2	2	2	5	5	5
XII	2	2	2	3	4	3
XIII	30	30	30	31	31	31
XIV	31	31	31	45	47	45
XV	29	29	29	43	43	43
Total	**186**	**202**	**186**	**269**	**279**	**269**

Appendix H: Ethical approval and consent forms

Appendix H.1: Ethical approval

This memorandum is to confirm that the research ethics protocol for the above-named research project, as revised and submitted on 29/07/2009, is approved by the Open

The Open University

Memorandum

From John Oates
Chair, The Open University Human Participants and Materials Research Ethics Committee
Research School

Email j.m.oates@open.ac.uk

Extension 52395

To Eunice Olakanmi,

Subject **SELF and CO-REGULATED LEARNING IN A COMPUTER SUPPORTED COLLABORATIVE LEARNING ENVIRONMENT**

Ref HPMEC/2009/#615

Date 14 August 2009

University Human Participants and Materials Ethics Committee by Chair's action.

Please note that the HPMEC role in relation to research conducted by taught higher degree students is an advisory one and that the University assumes no liability in relation to such research.

John Oates
Chair, OU HPMEC

Appendix H.2: Information sheet

The Open University
Walton Hall
Milton Keynes
MK7 6AA
Tel +44 (0) 1908 652402
www.open.ac.uk

SELF AND CO-REGULATION IN A COMPUTER SUPPORTED COLLABORATIVE LEARNING ENVIRONMENT AMONG KEY STAGE THREE STUDENTS

Research Project undertaken by
Mrs. Eunice Olakanmi

What is the project about?

This research investigates various learning behaviours that learners use when learning in an environment where learning is supported with computers. In this study the learning environment is comprised of a science simulation and a collaborative learning environment where groups of learners can work together on a science task.

The students will work in small groups using a science simulation such as Electrical Circuits from Sunflower Company (please note that the selection of simulation to be used for this research will be based on the school curriculum). Alongside the science simulation there will be InterLoc, a collaborative tool with a set of instructions to engage students in talking about the topic e.g. electrical circuits and discussing their learning with other students in their groups. All students shall receive verbal guidelines from the researcher or their teacher on what they are expected to do at the beginning of the research.

What type of information will be collected?

The only personal information that the researcher will keep about you is your name. Other information such as your interaction with other learners while learning in computer supported collaborative learning environment and performance that will be collected during the science lesson will be made anonymous after collection.

How will the information be collected?

The information needed for the research will be collected at school during normal science lessons. First, you will answer a short test related to the science topic you are going to learn and fill in a questionnaire that measures your learning behaviours during science lessons. Then, you will work with a simulation and share your work with your group according to the instructions provided.

The researcher will make video recordings as you are learning during the lesson and she will also take some notes while observing how you learn as an individual and as a group in a computer supported collaborative learning environment. You will take a short test when you finish learning each topic. The tests will be for the purposes of this research only and will not be counted towards any school assessment. After you finish the test you may be asked to talk to the researcher about how you think the activities went for you and this discussion is going to be recorded.

Will the information be confidential?

In order to ensure confidentiality, information about you will be kept confidential and your real name will not be included in the final report or any published work. Your tests results will be anonymised and your identity will not be revealed.

No information will be disclosed to the Head teacher, Form Tutor, Head of Department, other staff members or any other person without your consent. Any notes made by the researcher will be kept in a locked cupboard and taken from the school at the end of the school day. Any computer data will be transferred to the Open University's (OU) secure server as soon as possible.

How will the information collected about me be used and handled?

The researcher will follow OU research guidelines throughout the research project including the handling of the data collected. These guidelines include the Open University Data Protection Code of Conduct, the Open University Research Ethical Guidelines and the British Education Research Association Ethical Guidelines.

How can I become involved in the project?

You should be a member of the group of year 7 students chosen to participate in the project. You will be asked to participate and then should seek permission from your parent or guardian. They will need to complete and return the consent form provided in this pack to show that they agree to your participation.

Will I be informed of the results of the project?

You can receive a report (online or hard copy) of the project results on request.

Can I withdraw from the project at any time?

You will be taking part in this project voluntarily and you are completely free to withdraw from the research at any time without giving any reason and with no consequences. Although the researcher may encourage you to continue, she cannot compel you to do so.

Can I request that the information held about me is destroyed?

You can request access to any information that is collected and held about you or request that it is destroyed.

My contact details are:

Mrs. Eunice Eyitayo Olakanmi
Institute of Educational Technology
The Open University
Walton Hall
Milton Keynes

MK76AA
Tel: 01908652402
Email: e.e.olakanmi@open.a

Other contacts are:

Dr Canan Blake
Institute of Educational Technology
The Open University
Walton Hall
Milton Keynes
MK76AA
Tel: 01908654966
E-Mail: C.Tosunoglu@open.ac.uk

Appendix H.3: Consent forms for students

Participant's Consent Form

Research on "Self- and co-regulation in a computer supported collaborative learning environment among Key Stage three students."
By
Mrs Eunice Olakanmi

I, -------------------------------------(Name of student) agree to take part in the above-named research project.

In giving my consent for participation in this research, I am ticking the boxes below in order to acknowledge that:

☐ The procedures required for the project and the time involved have been explained to me.

☐ I have read the Participant Information Sheet provided.

☐ I understand that my participation in this study is completely voluntary.

☐ I have been informed that I am completely free to withdraw from the research at any time without giving any reason and with no consequences. I may refuse to participate by simply saying so or by filling in the withdrawal form which should then be handed in at the school's main office in a sealed envelope.

☐ I have been informed that I will be video recorded during the lessons.

☐ I have been informed that I will work in small group with other students.

☐ I have been assured that my confidentiality will be protected as explained in the information booklet and in the letter sent to my parents seeking their permission.

☐ I agree that the information that I provide can be used for educational or research purposes only with my name and personal details not being published.

☐ I understand that if I have any concerns or difficulties, I can contact Mrs Eunice Olakanmi on 0190865402 or e.e.olakanmi@open.ac.uk.

☐ If I want to talk to someone else about the project, I can contact the researcher's supervisor, Dr Canan Blake on 01908654966 or C.Tosunoglu@open.ac.uk

Appendix H.4: Consent forms for parents

Research on "Self- and co-regulation in a computer supported collaborative learning environment among Key Stage three students"
By
Mrs Eunice Olakanmi

Parent/Guardian consent

I, ..., give my consent for my child,...

.... to participate in the research project entitled: "Self- and co-regulation in a computer supported collaborative learning environment among Key Stage three students"

In giving my consent I acknowledge that:

1. I have read the Participant Information Sheet provided.

2. I have understood, the procedures required for the project.

3. I understand that my child's participation in this study is completely voluntary.

4. I understand that my child is completely free to withdraw from the research at any time without giving any reason and with no consequences. He / she can refuse to participate by simply saying so or by completing a withdrawal form.

5. I understand that my child will be video recorded during the lessons.

6. I understand that my child will work in small group with other students.

7. I understand that my child's involvement is strictly confidential and no information about him /her will be used in any way that reveals his/her identity.

8. I understand that information that my child provides can only be used anonymously for educational or research purposes including publication.

9. I understand that if I have any concerns or difficulties, I can contact the researcher, Mrs Eunice Olakanmi on 0190865402 or e.e.olakanmi@open.ac.uk.

10. I understand that if I want to talk to someone else about the project, I can contact the researcher's supervisor Dr Canan Blake on 01908654966 or C.Tosunoglu@open.ac.uk

Signature ----------------------------   Date -------------------

Appendix I: Co-Regulated Strategies for Learning Questionnaire (CRSLQ) (Draft)

Co-regulated strategies for learning questionnaire

Instructions: This questionnaire has a number of questions which seeks to find out about the way you learn together with other students during science lesson. Using the scale below, please answer the following questions. There are no right or wrong answers. Just answer as accurately as possible. If you think the statement is very true of you, circle 7; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

Gender: Male / Female

	Not at all true of me	Untrue of me	Somewhat untrue of me	Moderately true of me	Somewhat true of me	Very true of me
Planning						
(1) All members of our science group set learning goals and allocate time for various activities.	1	2	3	4	5	6
(2) When I prepare for my group's science task, I set goals for myself in order to direct my contribution to the group.	1	2	3	4	5	6
(3) Whenever I am preparing for my group's science task, I make up questions to ask other group members.	1	2	3	4	5	6
(4) Before starting my group's science task, I often read quickly through the activities to see how they are organised.	1	2	3	4	5	6
(5) I often think through my group's science task and decide what I am supposed to learn from it.	1	2	3	4	5	6
Monitoring items						
(6) During our group's science task, I often fail to contribute to the task because I'm thinking of other things.	1	2	3	4	5	6

(7) I often remind other members in our science group to contribute their ideas during the group's activities.	1	2	3	4	5	6
(8) When I do not understand ideas contributed by other members in our science group, I often ask for clarification.	1	2	3	4	5	6
(9) When there is disagreement among members of our science group, or if our task is difficult, I either give up or do other things.	1	2	3	4	5	6
(10) All members of our science group participated in the group discussions.	1	2	3	4	5	6
Evaluating						
(11) We often ask ourselves questions in our science group to know whether we've learnt what we want to learn.	1	2	3	4	5	6
Effort Regulation						
(12) I often feel so bored during our science group task that I quit before the group finishes what we planned to do.	1	2	3	4	5	6
(13) I work hard to do well in our science group even if I don't like what we are in the group	1	2	3	4	5	6
(14) When our group's science task is difficult, I often give up or only work on the easy parts.	1	2	3	4	5	6
(15) Even when our group's science task is dull and uninteresting, I often manage to keep on contributing my ideas until we finish the task as a group.	1	2	3	4	5	6
(16) All members of our science group often make efforts to achieve our set goals.	1	2	3	4	5	6
Time Management						
(17) I often feel pleased if other members in our group remind me about the time remaining for completing the group's task.	1	2	3	4	5	6
(4) In our science group, members often remind each other of the time remaining to complete the group task.	1	2	3	4	5	6
Peer Learning						

(19) When working on our group's science task, I often try to explain the task to other group members.	1	2	3	4	5	6
(20) I often try to work with our group members to complete our learning task.	1	2	3	4	5	6
Help Seeking						
(21) I often help our members who have difficulties in understanding our group's science task.	1	2	3	4	5	6
(22) I ask other members of our science group to clarify concepts I don't understand well during our task.	1	2	3	4	5	6
(23) When I can't understand the task, I ask other members of our group for help.	1	2	3	4	5	6
(24) I constantly give feedback to contributions made by other members of our science group during our learning activities.	1	2	3	4	5	6

Appendix J: Co-Regulated Strategies for Learning Questionnaire's Administration Procedure/Evaluation

I would appreciate it if you would follow the procedure outlined below for administering the questionnaire in the class.

- The consent letter and forms should be given to the students at least two days before the questionnaires are administered. Only students who have consent from parents and who are themselves willing should participate.
- Students are expected to complete the questionnaire within 15 minutes.
- Please give a copy of the questionnaire to each student and make sure that they have a pencil with an eraser. (The questionnaire may be completed in ink, but it makes it more difficult for students to change responses). Ask the students to circle their gender.
- Please tell the students that their responses will be kept confidential and will not be made public.
- Kindly read out the instructions on the front page of the questionnaire before the students begin responding to the items. Ask the students to listen attentively while you read aloud the instructions on the front page. Please check with the students that they understand how to respond before allowing them to start.
- If any student has trouble understanding what is meant in a particular item or has another problem which cannot be quickly and easily rectified, simply indicate the problem on the front of the first page of the questionnaire and thank the student.
- Please return the completed questionnaire and the consent forms to the head of science department.
- If there are any comments regarding the questionnaire and the administration procedure, I would really appreciate it if you would write your comments on the following in the space below.

- The clarity of the wording ....
- Do you think Key Stage 3 students were able to answer all the questions? ....

  ....

The layout and style of the questionnaire...

Thank you very much for your help.

Appendix K: Inter-item correlation

Table 1: Monitoring Scale

Inter-Item Correlation Matrix								
	Q19	Q22	Q16	Q20	Q04	Q17	Q12	Q01
Q19	1	1.0	0.83	0.84	0.73	0.55	0.54	0.41
Q22	0.95	1	0.85	0.80	0.71	0.53	0.55	0.39
Q16	0.83	0.85	1	0.87	0.71	0.51	0.49	0.46
Q20	0.84	0.80	0.87	1	0.80	0.50	0.51	0.47
Q04	0.73	0.71	0.71	0.80	1	0.38	0.38	0.42
Q17	0.55	0.53	0.51	0.50	0.38	1	0.41	0.50
Q12	0.54	0.55	0.49	0.51	0.38	0.41	1	0.44
Q01	0.41	0.39	0.46	0.47	0.42	0.50	0.44	1

Table 2: Help-seeking and help-giving

Inter-Item Correlation Matrix					
	Q07	Q18	Q21	Q05	Q10
Q07	1	0.84	0.73	0.50	0.48
Q18	0.84	1	0.66	0.49	0.53
Q21	0.73	0.66	1	0.43	0.42
Q05	0.50	0.49	0.43	1	0.42
Q10	0.48	0.53	0.42	0.42	1

Table 3: Effort-regulation

Inter-Item Correlation Matrix					
	Q08	Q13	Q06	Q14	Q02
Q08	1	0.55	0.54	0.48	0.40
Q13	0.55	1	0.52	0.29	0.39
Q 06	0.54	0.52	1	0.30	0.40
Q 14	0.48	0.29	0.30	1	0.34
Q 02	0.40	0.39	0.40	0.34	1

Table 4: Planning

Inter-Item Correlation Matrix			
	Q09	Q10	Q15
Q09	1	0.50	0.45
Q10	0.50	1	0.53
Q15	0.45	0.53	1

Appendix L: Tests for the homogeneity of the variance-covariance matrices in chapter 5 and 6

Table 1: Box's Test of Equality of Covariance Matrices

Box's M	15.05
F	.59
df1	21
df2	5311.03
Sig.	.93

Table 2: Box's Test of Equality of Covariance Matrices

Box's M	52.37
F	1.12
df1	36
df2	4858.85
Sig.	.28

Box's test investigates the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups. Tables 1 and 2 show that the tests are not significant at an alpha level of 0.05 for the data presented in Chapters 5 and 6.

Appendix M: Group statistics for students' activity sheets

Table 1: Group Statistics

	Learning condition	N	Mean	Std. Deviation	Std. Error Mean
Activity sheets' scores	Experimental	20	12.05	2.69	.600
	Control	20	9.00	3.46	.78

Table 2: Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Activity sheets' scores	Equal variances assumed	2.416	.128	3.11	38	.00	3.05	.98
	Equal variances not assumed			3.11	35.77	.00	3.05	.98

Appendix N: Statistical analyses for KTFP and KTBC

Table 1: Group Statistics for Pre-KTFP and Post-KTFP

	Learning condition	N	Mean	Std. Deviation	Std. Error Mean
Pre-KTFP	Experimental	20	8.05	3.284	.734
	Control	20	7.5	2.502	.559
Post-KTFP	Experimental	20	10.35	2.560	.573
	Control	20	9.85	3.048	.682

Table 2: Independent Samples Test for Pre-KTFP and Post-KTFP

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Pre-KTFP	Equal variances assumed	1.29	.26	.65	38	.52	.60	.92
	Equal variances not assumed			.65	35.50	.52	.60	.92
Post-KTFP	Equal variances assumed	.43	.52	.56	38	.58	.50	.89
	Equal variances not assumed			.56	36.90	.58	.50	.89

Table 3: Group Statistics for Pre-KTBC and Post-KTBC

	Learning condition	N	Mean	Std. Deviation	Std. Error Mean
Pre-KTBC	Experimental	20	8.20	3.14	.70
	Control	20	7.60	2.66	.60
Post-KTBC	Experimental	20	10.60	3.22	.72
	Control	20	10.00	2.62	.59

Table 4: Independent Samples Test for Pre-KTBC and Post-KTBC

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	F	Sig.
Pre-KTBC	Equal variances assumed	.05	.83	.65	38	.518	.60	.92	1.26	2.46
	Equal variances not assumed			.65	37.02	.519	.60	.92	1.27	2.47
Post-KTBC	Equal variances assumed	.78	.38	.65	38	.522	.6	.93	1.28	2.48
	Equal variances not assumed			.65	36.48	.522	.60	.93	1.28	2.48