When Students Lead: Investigating the Impact of the CREST Inquiry-Based Learning Programme on Changes in Self-Regulated Processes and Related Motivations Among Young Science Students

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Declaration

I declare that the work presented in this document is the original work of the author and that it has not been submitted for any other degree or professional qualification.

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Acknowledgements

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Abstract of Thesis

This thesis explores the impact of an inquiry-based learning programme on students' self-reported levels of self-regulated processes and related motivations in the science classroom. Appreciating the interest seen in developing self-regulated learning and motivation in young students (Gläser-Zikuda & Järvelä, 2008; Zimmerman, 2002) and considering current discussions regarding the way science is taught around the globe (Kalman, 2010, Leou, Abder, Riordan, & Zoller, 2006), it was deemed important to explore the development of these constructs in young science students through participation in a curriculum initiative currently being implemented across the UK - the *CREativity in Science and Technology (CREST)* programme.

The three studies included in this thesis followed a longitudinal quasi-experimental design using a naturalistic setting. After placing the research within a theoretical framework (Chapters 1 & 2) and describing the pilot work and methodology for the three investigations (Chapter 3), Study 1 (presented in Chapter 4) explored the impact of the CREST programme on developing self-regulated processes and related motivations in young students (n=34) compared to a control group of students from the same school (n=39). The findings indicated that students participating in the programme experienced significant increases in their self-reported levels of self-regulated learning and career motivation in comparison to the control group of students and that these developments were retained six months following programme completion. The results also demonstrated the potential for the CREST programme to reduce the decreasing trends relating to self-determination and intrinsic motivation found in the control group and reported in the wider literature in the field.

Study 2 (presented in Chapter 5) built on the methodology of Study 1 and investigated class differences in response to the CREST programme. Study 2 aimed firstly to replicate the findings from Study 1 regarding *group* differences in self-reported levels from pre-test to post-test on the measured variables. While a reference control class (n=18) showed no significant changes from pre-test to post-test, on average, students taking part in the CREST programme showed significant increases in self-regulated learning, self-determination, self-efficacy, intrinsic

motivation, and overall science motivation. However, due to the lack of an appropriate control group of equal size (n=160), conclusions were drawn cautiously. Another aim of this second study was to gain an understanding of whether individual classes of students experienced the programme differently and identify classroom dynamics that might predict the degree of benefit students obtain. The findings showed no class differences in response to the CREST programme relating to the self-regulated processes and related motivational constructs measured, and highlighted the sensitivity of the analyses used in classroom effects research.

Study 3 (presented in Chapter 6) followed a similar quasi-experimental design (n=188) to Studies 1 and 2, with the addition of another intervention condition of students who had participated in CREST the year before the study was conducted. This, more, rigorous methodological design allowed for longer-term retention effects to be investigated. The results from this study highlighted the immediate and three-month delayed impact of the CREST programme on increasing self-reported self-regulation for this sample of students. However, retention at the nine-month delayed post-test was not observed, suggesting that strategies need to be in place in order to maintain any developments through CREST programme participation. Teacher ratings of students' self-regulated learning were also measured and did not align with the students' self-reported results, highlighting the difficulty for teachers to identify and quantify internal processes like self-regulation among their students.

While extensive research has been conducted on self-regulated processes and related motivations in students of all ages, the need for an increased understanding in natural classroom settings through implementing more rigorous research designs in specific learning contexts has been identified. Bringing the findings together, the three studies included in this thesis illustrate the beneficial impact of CREST programme participation on self-regulated processes and related motivations in young science students. The series of intervention studies presented provides a distinct contribution to research, demonstrating that these constructs can be developed in natural classroom settings by promoting an environment that encourages students to be more self-regulated and motivated in their science learning.

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SELF-REGULATED PROCESSES AND RELATED MOTIVATIONS: A CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

Chapter Objectives

This chapter aims to provide an overview of the conceptual framework adopted in this thesis relating to the key constructs that will form the central focus of the research to be presented. Following a review of learning, a conceptual overview of self-regulation and metacognition will be introduced prior to discussing self-regulated learning. The chapter will then continue with a review of models and definitions of self-regulated learning. In order to provide a complete picture of classroom self-regulatory processes, several related motivational constructs will also be introduced in this chapter and incorporated within the conceptual framework presented. Discussing the importance of these constructs generally in educational research and within conceptualisations of self-regulated learning, this chapter will also demonstrate why inclusion of these motivational constructs is essential for research aiming to understand students' learning in science classrooms. This chapter will conclude by highlighting the original contributions to knowledge offered by this thesis.

1.1 INTRODUCTION

One of the primary goals of educational psychology is to understand the learning process and to provide support for those who struggle with it (Greene & Azevedo, 2007). In the late 1980s, driven by the findings of rigorous educational research, several education systems around the world participated in a movement to improve students' levels of 'higher order' thinking skills and encourage learners to become more self-regulated and independent in their learning (Boekaerts & Corno, 2005; Jones & Idol, 1990; National Research Council, 2000; Scottish Executive, 2004; Wongsri, Cantwell & Archer, 2002). While in the past, student success was a function of the quality of the school they attended, now, with technological developments such as the internet and the recent shifts seen in curriculum initiatives and understandings of learning, students have more control over their learning and can be masters of their academic progression (Caprara *et al.,* 2008). Therefore, there is great potential for educators to foster and develop students' abilities to utilise this control effectively in their learning.

The growing body of research regarding the benefits of developing students' self-regulation skills in the classroom has also extended to the implications for the field of science as a whole (Velayutham, Aldridge, & Fraser, 2012). As self-regulated learners in science have the ability to control and reflect on their learning, they are generally more motivated and personally interested in the material being studied, show increased academic performance, and are arguably more likely to provide greater contributions to current scientific knowledge (Velayutham *et al.,* 2012). Together with the downward trends documented in the literature regarding student interest and motivation in science, most threatened between the ages of 10 and 14 years, these findings highlight the relevance of studying these processes in the science subject domain (Archer *et al.,* 2010; Bennett & Hogarth, 2009; George, 2000; Ryan & Patrick, 2001).

Contributing to the understanding of the development of self-regulated processes among learners, which has built up over the past 40 years, this thesis aims to investigate the impact of an inquiry-based programme currently being implemented in secondary schools throughout the UK as a strategy to promote self-regulated processes and related motivations among students in science. Before introducing this programme and situating it within the context of educational psychology intervention research (Chapter 2), the key constructs of interest that will be investigated in the three empirical studies presented in this thesis (Chapters 4, 5, & 6) need to be introduced.

The first part of this chapter discusses the importance and relevance of self-regulated learning in science education today, as well as models and definitions of the construct. In adopting a holistic understanding of both learning and approach to empirical work, discussing related motivations is essential. Therefore, a conceptual framework for understanding self-regulated learning would not be complete without also including some relevant motivational factors involved in this regulatory process. As such, the second part of this chapter presents recent research on motivations relating to self-regulated learning in order to arrive at a complete conceptual framework for understanding self-regulated processes in young science students.

Outlining the specific nature of learning in science classrooms, the following section demonstrates how the constructivist approach to learning has been adopted in school science education. It is important to note that throughout this thesis the term 'student' will refer to adolescent students between the ages of 11 and 14 years, unless otherwise stated. This is an important distinction to make as there is sufficient research suggesting that the processes being discussed may not involve the same level of skill and complexity for younger students and adult learners (Duckworth, Akerman, MacGregor, Salter, & Vorhaus, 2009; Souchay & Isingrini, 2004; Veenman, Van Hout-Wolters, & Afflerbach, 2006; Zimmerman, Bandura, & Martinez-Pons, 1992).

1.2 Current Perceptions of Science Learning

Not all classroom-based learning contexts demand the same level and complexity of learning. The thinking processes necessary for science learning are very different from the thinking involved in understanding other school subjects and everyday life (Reif, 2008). Reif argues that one of the main reasons students struggle with learning science is that they approach their learning in science as they would everyday knowledge, without appreciating the very specific and complex nature of science learning. In addition, researchers argue that students experience difficulty learning science due to the rapid advances in science and technology today, as well as the demands placed on students to independently accumulate vast amounts of knowledge (De Corte, Verschaffel, & Masui, 2004; Duncan & Tseng, 2010). This underlines the importance of science students developing abilities to independently control and monitor their learning.

Learning in general, and learning in science education research are viewed as constructive processes in which students play an active role in their own knowledge acquisition (De Corte *et al.,* 2004; Schraw, Crippen, & Hartley*,* 2006; Velayutham & Aldridge, 2013). This conceptualisation of learning assumes the importance of understanding that students construct their own knowledge bases in science (Leou, Abder, Riordan, & Zoller*,* 2006; Silver & Marshall, 1990). This constructivist process goes beyond simply adding new knowledge to an existing bank, and implies that students connect ideas and new knowledge to pre-existing links, and construct new knowledge structures of interconnected concepts through using higher-order processes like asking questions, critical thinking, problem solving, and the transfer of knowledge within science subjects to real life (Kalman, 2010; Silver & Marshall, 1990). Further, science education has shifted from developing students who just 'know' to students with conceptual knowledge who have a conceptual understanding of what they learn and are aware, in control, and self-regulating their thinking and learning strategies use (Leou *et al.,* 2006). This shift towards developing these higher-order cognitive skills in students has been a specific aim of science education reform worldwide (Leou *et al.,* 2006).

The cognitive and metacognitive processes required in science learning are not only vital during school scholarship but are life-long skills that learners can sustain after graduation and for self-education later in life (Abdullah & Lee, 2007; Boekaerts, 1997; Kaplan, 2008; Kistner, Rakoczy, Otto, Dignath-van Ewijk, & Büttner, 2010). Given the importance of life-long learning, which is at the forefront of both general and science-specific educational reforms (Green, 2003, 2011; Hodson, 2003; Reiss, Millar, & Osborne, 1999), fostering self-regulated processes remains a primary focus of current research (Beishuizen & Steffens, 2011; Dignath & Büttner, 2008; Kistner *et al.*, 2010; Zimmerman, 2002). The specific nature of science learning documented in the literature further reveals the complexity of this learning and highlights the importance of not only understanding the cognitive demands placed on students today in school science, but also helping to support science students' development and progression through the learning process.

1.3 Conceptualisation of Learning in the Context of this Thesis

For the research presented in this thesis, learning will be conceptualised as involving students actively constructing knowledge in a self-regulating process (MacLellan & Soden, 2006; Mayer, 2004). Learning, from this perspective, is therefore not described as a function of ability or socio-economic background, but as a set of personally executed strategies (MacLellan & Soden, 2006; Montalvo & Torres, 2004). In addition to students independently regulating their knowledge and knowledge acquisition, the research conducted in this thesis also appreciates the social nature of the learning experience (Velayutham & Aldridge, 2013). As well as involving active construction and self-execution of appropriate strategies, learning in the context of this thesis is understood to be a function of students' social interactions in the science classroom. Therefore, this thesis will additionally highlight the significance of the collaborative aspects of learning in science classrooms by looking at the impact of participation in a group activity on self-regulated processes and related motivations in young science students.

The work presented in this thesis adopts a cognitive science approach aligning with science and mathematics education research (Rief, 2008; Silver & Marshall, 1990; discussed further in Chapter 2). This definition of learning requires the understanding of three key constructs: self-regulation, metacognition, and self-regulated learning. Similar to the work by Whitebread *et al.* (2009), the research conducted is informed by two traditions in the literature: the socio-cultural (self-regulation) and cognitive information processing (metacognition) traditions which follow on from the understanding of learning itself presented earlier. Therefore, general models of self-regulation and metacognition need to be understood before discussing self-regulated learning, as the latter can be seen as the application of these models in a specific academic learning context (Wolters, Pintrich, & Karabenick, 2003). After introducing self-regulation and metacognition, this chapter will continue with a presentation of how these two constructs are conceptualised before moving on to discuss self-regulated learning. The discussion of these three constructs presented in the following sections will also shed light onto how the understanding of learning adopted in this thesis links to the theoretical framework for conceptualising the constructs themselves.

1.4 Conceptualisations of Self-Regulation and Metacognition

1.4.1 Self-Regulation

Self-regulation has a reputable history in cognitive psychology with roots in Bandura's social-cognitive theory (Bandura 1977, 1978, 1986), which suggests that learning occurs as a dynamic interaction of three factors constantly influencing each other: person, behaviour, and environment (Bandura, 1991; Martin & McLellan, 2008; McAlister, Perry, & Parcel, 2002). For instance, an individual's beliefs, goals, and self-perceptions can influence their behaviours and their behaviours can, in turn, influence their thoughts and emotions. Additionally, an individual's behaviours can determine elements of their environment and their behaviours can also change as a result of their environment. Finally, physical and social factors of an individual's environment can influence their beliefs and cognitive functioning and vice versa (Bandura, 2001). Bandura included self-regulation in his social-cognitive theory of human behaviour, as a process through which individuals control their external environment by conducting self-observations and judgments as well as self-reactions (Bandura, 1982, 1991; Schunk, 2008). More specifically, self-regulation focuses on the result of behaviour that can be seen as the product of the individual-environment interaction (Dinsmore, Alexander, & Loughin*,* 2008). As it allows individuals to adapt to their social and physical environments, many contemporary psychologists view self-regulation as a defining feature of being human, allowing us to live as we do (Bandura, 2001; Martin & McLellan, 2008; Schmeichel & Baumeister, 2004). Several researchers have supported the idea that the development of self-regulation should be the focus of social interaction situations including, but not limited to, learning in the classroom, as it is such an influential feature (Baumeister & Vohs, 2007; Martin & McLellan, 2008).

Researchers have more recently highlighted that self-regulation also involves motivational and affective elements in addition to cognitive and social influences (Beishuizen & Steffens, 2011; Whitebread *et al.,* 2009). It is important to understand that self-regulation is not a unitary construct and that there is no single set of strategies that should be used in general life, but distinct motivational, behavioural, and cognitive strategies that are appropriate in different domains of knowledge, social contexts, and educational tasks (Kaplan, 2008). Therefore, the research presented in this thesis will focus on the development of self-regulatory processes in students through participating in a specific inquiry-based learning task in science classrooms. It is also important to understand at this point that the interpretation of the empirical findings presented in this thesis are limited to this specific subject task.

Self-regulation was a topic for Enlightenment, Romantic, and twentieth-century philosophers aiming to understand the nature of human existence (Martin & McLellan, 2008). However, the majority of research into this construct has been conducted since the early 1980s (Beishuizen & Steffens, 2011; Martin & McLellan, 2007). Despite this long history, it can be argued that there is still a great deal of confusion in psychological research on self-regulation, and even more so in educational research (Dinsmore *et al.,* 2008; Kaplan, 2008; Lajoie, 2008). As the construct of self-regulation is applicable to almost every research area, there is little consistency across and within domains regarding clear definitions of the construct (Beishuizen & Steffens, 2011; Fox & Riconscente, 2008; Kaplan, 2008). This lack of clarity also extends to the operational definitions of both metacognition and self-regulated learning presented in the next two sections of this chapter.

While a wide array of definitions are presented in the literature, many models of self-regulation have a similar cyclical framework involving three phases: (1) *goal setting*, (2) *monitoring* and *adapting* the processes and strategies implemented, and (3) *self-evaluation* (Beishuizen & Steffens, 2011; Schraw *et al.,* 2006; Zimmerman, 2000). These three phases also form the basis for models of self-regulated learning, which will be presented later in this chapter.

1.4.2 Metacognition

When a student learns a new piece of information, this cognitive activity is often preceded by planning and followed by self-monitoring of the understanding obtained. This monitoring and controlling of cognitive processes is often referred to in the literature as *metacognition*. However, going beyond monitoring and controlling cognitive processes, metacognition also concerns the ability to think and reason about mental processes. Metacognition involves the conscious ability to reflect on knowledge about a task, describe actions, thoughts and feelings, be aware of the learning situation, and the ability to use this information to monitor and enhance learning performance (Georghiades, 2006). In this, many researchers conceptualise metacognition as the cognitive aspects of self-regulated learning (Beishuizen & Steffens, 2011; Dinsmore *et al.,* 2008; Whitebread *et al.,* 2009). Therefore, a discussion of metacognition also needs to be presented before moving on to conceptualising self-regulated learning.

Metacognition involves cognitions about cognitions, and like self-regulation, it is also viewed as a fundamental characteristic of being human (Lories, Dardenne, & Yzerbyt, 1998). In other words, it involves an individual thinking about their thoughts and thought processes (Hacker, 1998). This ability to think reflectively is for some, what differentiates human learning from animal learning (Karmiloff-Smith, 1998 cited in Georghiades, 2006). Most cognitive processes are accompanied by metacognitive activities that control and monitor the cognitive activities of individuals (Koriat, 1998; Lories *et al.,* 1998). Flavell (1971, 1979) adopts a view that metacognition involves knowledge of one's cognitive processes and products, and involves regulation, self-monitoring, and evaluation of cognitive activity. Appreciating the presentations of metacognition in the literature, particularly the latter by Flavell, and the discussion of self-regulation above, it is apparent that the two terms overlap in significant ways.

The majority of writing on metacognition in educational research approaches the topic from a cognitive information processing perspective, without appreciating the connection to socio-cultural influences on students' use of metacognitive strategies. However, as much of the learning process in schools involves social interactions among teachers and students, it is essential that researchers also understand the social dimensions of this construct and any impact on the learning experience of students they might have. The research presented in this thesis therefore aims to pay particular attention to metacognitive behaviours occurring in a collaborative inquiry-based learning activity, providing an original contribution to knowledge in the field.

Working with students to foster metacognitive skills is one of the three main developments in teaching techniques emerging over the last three decades of research about how people learn (Zohar & Dori, 2012). Hacker (1998) previously stated that developing effective abilities to monitor and control knowledge and academic processes was not a trivial matter in education. Currently, metacognition is a central issue in educational research (Georghiades, 2006; Zohar & Dori, 2012), with studies documenting performance enhancement in diverse fields including reading (Cross & Paris, 1998; Van Kraayenoord & Schneider, 1999), writing (Lv & Chen, 2010; Negretti, 2012), problem solving (Silver & Marshall, 1990), and mathematics (Pugalee, 2010).

Metacognition is also a focus of science education research with literature investigating the potential positive impact on student learning in science (Adey, Shayer, & Yates, 1991; Baird & Mitchell, 1986; Georghiades, 2006; White & Frederiksen, 1998; Zohar & Dori, 2012). Researchers have found that students can "learn how to learn" (White & Frederiksen, 1998, p. 4) by acquiring and developing metacognitive skills and knowledge in science. Developing these metacognitive skills in science students is essential for successful learning outcomes, as researchers have highlighted that the thinking required in school science is a diverse and complex process (Tweney & Walker, 1990). As the learning taking place in science is very different from learning in other school subjects (see discussion presented earlier in Section *1.2*), metacognition has received a great deal of attention in science educational literature (Driver, 1989; Zohar & Dori, 2012). Further, as metacognition can be viewed or conceptualised as a bridge between learning and cognitive development, as well as motivation and learning (Nelson & Narens, 1994), investigating metacognition in young science students can aid further understanding of the motivational and engagement issues currently seen in school science education (Archer *et al.,* 2010).

1.5 Conceptual Framework for Understanding Self-Regulation, Metacognition, and Self-Regulated Learning in this Thesis

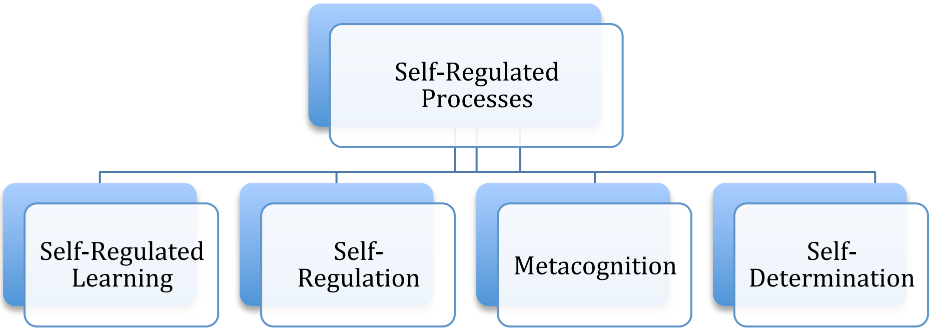
The discussions of both self-regulation and metacognition presented above highlight the overlap between these constructs. By conducting an analysis of over 250 studies investigating self-regulation, metacognition, and self-regulated learning, Dinsmore *et al.* (2008) provided insight into the multiple possible ways of defining these three constructs in the field. In their analysis, Dinsmore and colleagues found that only 49% of research explicitly defined these constructs when used in empirical studies, and suggested this as a key factor contributing to the lack of conceptual clarity in the literature. Taking the suggestions by Dinsmore *et al.* (2008), this section aims to define these terms for the purpose of the research conducted in this thesis.

Theorists have attempted to differentiate between metacognition and self-regulation based on cognition and behaviour, with some researchers viewing self-regulated learning as being a combination of the two (Beishuizen & Steffens, 2011; Dinsmore *et al.,* 2008; Kaplan, 2008; MacLellan & Soden, 2006; Schraw *et al.,* 2006). However, as metacognition takes place in specific environments, it is unlikely that metacognition is unaffected by different environmental contexts (Kaplan, 2008). Similarly, in addition to focusing on behaviour that results from the individual-environment interaction, self-regulation also involves an individual's cognitions (Schraw *et al.,* 2006). Kaplan concluded that metacognition, self-regulation, and self-regulated learning are not conceptually distinct and should therefore not be treated as such in empirical work. However, while educational theorists have stated that the three constructs are nested within each other (Dismore *et al.,* 2008) and interdependent (Fox & Riconscente, 2008), many researchers believe that the three terms should also not be treated as similar constructs as they display meaningful differences (Kaplan, 2008). There is an on-going debate in the literature regarding this issue with researchers striving to reach agreement in order to provide conceptual clarity to inform the empirical work being conducted.

While appreciating that self-regulation, metacognition, and self-regulated learning share self-awareness and regulatory action at the core, this thesis adopts Kaplan's (2008) view that the three constructs refer to related *types* of self-regulated action. Adopting this view allows self-regulation, metacognitive strategies, and self-regulated learning to be investigated as outcome variables within a general framework. This framework was adopted in this thesis with the addition of the closely related construct of self-determination. Self-determination involves control, choice, and self-initiation of behaviour (Glynn, Taasoobshirazi, & Brickman, 2009), and has been shown to be important in helping students retain an intrinsic sense of interest and fostering self-regulated learning (De Bilde, Vansteenkiste, & Lens, 2011; Deci, Vallerand, Pelletier, & Ryan, 1991; Greene & Azevedo, 2007). While not included in many studies of self-regulated learning among students, additional insight may be provided through incorporating this construct into the framework for understanding student self-regulatory processes. Therefore, building on Kaplan's

(2008) framework for understanding the three constructs, Figure 1.1 below presents a modified version of this framework that was adopted in this thesis.

Figure 1.1. A modified version of Kaplan's (2008) framework for understanding self-regulated processes.



Kaplan (2008) additionally highlighted that moving towards dimensions rather than boundaries between the three conceptual terms allows educators and researchers to assess *change* in self-regulatory action. As the research presented in this thesis involves investigating the change in students' self-regulatory processes through taking part in an inquiry-based learning programme, further justification for adopting this framework of understanding for the three constructs is provided. This conceptualisation of the three key constructs is reflected in the choice of analysis presented in Chapter 3.

This chapter will continue with a discussion of self-regulated learning in the context of the research presented in this thesis. The views expressed in this section regarding the model of self-regulated learning adopted will also be reflected in the choice of measurement tools presented in Chapter 3.

1.6 Conceptualisations of Self-Regulated Learning

Self-regulation, described earlier in Section *1.4.1*, gained the attention of several researchers and became a focus in academia when a new term, *self-regulated learning* was developed (Dinsmore *et al.,* 2008; Lajoie, 2008; Wolters, 2010;

Zimmerman, 1989). It was through applying the principles of self-regulation to school learning that the concept of self-regulated learning theory was conceived (Schraw *et al.,* 2006). While self-regulation has a long-standing history in the literature, this new term emerged in the 1980s and became much discussed in the 1990s (Beishuizen & Steffens, 2011; Dinsmore *et al.,* 2008). Self-regulated learning provides important insight into academic learning in current educational psychology research (Schunk & Zimmerman, 1994) and can provide a unified framework for understanding student experiences in the classroom.

Self-regulated learning has become an important topic among educational and psychological researchers principally because it has been found to enhance learning outcomes (Beishuizen & Steffens, 2011). Empirical studies have shown the incidence of poor self-regulation in students today and its impact on academic achievement (Matthews, Ponitz, & Morrison, 2009). Researchers have found that the ability to self-regulate the learning process influences students' goal-setting (Ridley, Schutz, Glanz, Weinstein, 1992; Schunk, 1990), increases their focus while performing academic tasks (Zimmerman, 1990), and helps them assess their learning and the effectiveness of any strategies used (Cleary & Chen, 2009). With the rapid pace of social, information, and technological change, the capacity to self-regulate learning is extremely valuable for students (Caprara *et al.,* 2008). Self-regulated learning is continually gaining attention in the literature as it is also an important factor for distance and online learning success and, it can be argued that education is moving in this direction (Artino & Stephens, 2009; Barnard, Lan, To, Paton, & Lai, 2009; Dewhurst, MacLeod, & Norris, 2000; Eom & Reiser, 2000).

Before discussing conceptualisations of self-regulated learning any further, it is important to outline what does not constitute self-regulated learning as documented in the literature. Researchers in the field have operated with the view that self-regulated learning is not a mental ability, or an academic performance skill, but is a self-directed process through which students transform their mental abilities into academic skills (Cassidy, 2011; Zimmerman, 2002, 2008). Rather than viewing themselves as victims of the learning process, with their learning simply being an event in reaction to teaching, self-regulated learners perform learning activities consciously in a proactive way for their own benefit (MacLellan & Soden, 2006; Zimmerman, 2002). Self-regulation of learning is also not a single personality trait that an individual possesses but involves selective use of specific processes that are personally adapted to each learning task and educational context (Pintrich & De Groot, 1990; Zimmerman, 2002).

1.6.1 Models of Self-Regulated Learning

While the literature regarding boundaries for what does not constitute self-regulated learning is clearly defined, agreeing on a unified understanding of what the process *does* involve, has proved difficult. Within the specific focus adopted for self-regulated learning, models are rooted in several theoretical traditions which, we will see later in this chapter, have led to the variety of operational definitions available for the construct (Wolters, 2010). An overview of the many models of self-regulated learning developed in the literature during the last two decades provides evidence for this (Beishuizen & Steffens, 2011).

While operant models focus on the behavioural dimensions of self-regulated learning, and are based on the idea that learning and behaviour are influenced largely by external stimuli (Mace, Belfiore, & Hutchinson, 2001), cognitive models are rooted in information-processing theories and stress that metacognitive strategies like self-monitoring and evaluation are needed to perform complex academic tasks (Winne & Hadwin, 1998). In contrast to operant and cognitive models, social-cognitive models of self-regulated learning also appreciate interrelationships among self-strategies, beliefs (efficacy), feelings (test anxiety), and physical and social environments (Pintrich & De Groot 1990; Zimmerman, 1989, 2002). In focusing on personal factors relating to self-regulation of academic pursuits, social-cognitive models bring together the influence of cognitive, metacognitive, and motivational factors and incorporate a larger set of self-regulatory mechanisms governing cognitive functions (Abdullah & Lee, 2007; Caprara *et al.,* 2008). This integrated understanding of self-regulated learning highlights that there is a difference between simply possessing the knowledge and skills of self-regulatory behaviour and actually putting them into action (Caprara *et al.,* 2008; Pintrich & De Groot, 1990; Zimmerman, 2002).

1.6.2 General Assumptions of Self-Regulated Learning Models

In line with the constructivist approach to learning adopted in this thesis, the particular model for self-regulated learning that will be used is grounded in social-cognitive theory. However, before presenting the model adopted, an appreciation of some general assumptions of self-regulated learning models will be presented.

Although there are a variety of different models for self-regulated learning, most appreciate that students' use of cognitive and metacognitive strategies to regulate and control their learning are important components of the learning process (Pintrich, 1999). While the models differ in which dimensions they emphasise, and what strategies they encourage to promote academic success (Puustinen & Pulkkinen, 2001; Whipp & Chiarelli, 2004), they also have many similarities and overlap in substantial ways.

Pintrich (2004) presents a summary of the general assumptions of models of self-regulated learning used in the literature in an attempt to provide a unified general framework for understanding self-regulated learning. The first assumption he describes is the *active, constructive assumption* in which most researchers view the learner as an active member in the self-regulated learning process that constructs their own learning. Again, this thesis aligns with the research conducted in the field through adopting this conceptualisation of learning (as discussed earlier in Section *1.3*).

The second assumption Pintrich (2004) outlines is the *potential for control assumption*. This assumption identifies that most models appreciate that the learner has some regulation or control over their motivation, behaviour, cognitions, and environment. While this assumption outlines that some monitoring and control is possible, it does not assume that learners will regulate control over their learning at all times and in all learning situations (Pintrich, 2004). Wolters *et al.* (2003) also acknowledge that most models identify that developmental, biological, contextual, and individual differences can limit the ability of individuals to regulate their learning.

The third assumption outlined by Pintrich (2004) is the *goal, criterion* or *standard assumption,* which is also met by models of self-regulated learning. Most models of self-regulated learning assume that there is some type of criterion or standard, which refers to goals or reference values for educational tasks, against which students make comparisons to assess the progress of their learning (Wolters *et al.,* 2003). The final assumption of most models of self-regulated learning outlined by Pintrich (2004) relates to the fact that self-regulatory activities play a *mediating role between personal and contextual characteristics and actual academic performance*. It is therefore not simply the characteristics of a person or the classroom environment that influence achievement directly, but the self-regulatory processes of an individual that mediates the relationship (Pintrich, 2004). This general framework was also understood to help inform the research conducted in this thesis and the discussion of the findings to be presented.

1.6.3 Defining Self-Regulated Learning in the Literature

The variety of models for conceptualising self-regulated learning has led to a wide array of definitions for the construct. Like many terms in psychology, self-regulated learning is a term that can be used in several contexts, and as a result, it has many different meanings for researchers in an array of subject domains (Kaplan, 2008). While the term suggests that the construct only relates to school and classroom learning, self-regulation of learning can also take place in other contexts including, but not limited to, self-study at home, extracurricular activities, outdoor education, museum learning activities, and distance education (Boekaerts & Minnaert, 1999; Kaplan, 2008; Purdie & Carroll, 2007). However, in the context of the research presented in this thesis, self-regulated learning will be understood in the specific context of school science classrooms (discussed in detail in Chapter 2). While adopting a particular framework for understanding self-regulated learning (discussed in the next section), and limiting the understanding of the construct to school learning situations, an appreciation of other definitions available in the literature is necessary. This section therefore discusses relevant definitions, focusing on similarities and differences, before arriving at the specific operational definition used to understand self-regulated learning in this thesis.

As more researchers contribute to knowledge in the field, more definitions are created. Table 1.1 below presents a timeline summary of just a few definitions, providing further evidence regarding the amount of interest self-regulated learning has received among educators and researchers in the classroom-based learning context.

Table 1.1. A summary of selected definitions for self-regulated learning.

Authors	Definitions
Zimmerman & Schunk (1989)	• the actions, thoughts, and feelings of students working toward attaining a goal
Pintrich & De Groot (1990)	• involves metacognitive strategies including monitoring, management of effort on academic tasks, and cognitive strategies students use to learn material like rehearsing information and identifying important points
Schunk & Zimmerman (1994)	• goal-directed cognitive activities that college students use, modify, and continue to use
Winne (1995, p. 1)	• a deliberate, taxing, and volitionally guided act
(Zimmerman, 2002)	• involves setting goals, adopting strategies to attain goals, monitoring performance, restructuring physical and social context to make compatible with goals, managing time use, self-evaluation, attributing causation to results, adapting future methods
Wolters *et al.* (2003, p. 2)	• an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behaviour, guided and constrained by their goals and the contextual features in the environment
Schraw *et al.* (2006)	• when individuals possess abilities to understand and control their learning environments
Zimmerman (2008)	• a mastery process through which students become the master of their learning
Martin & McLellan (2008); Kaplan, Lichtinger, & Gorodetsky (2009)	• reflective learning that involves monitoring, regulating, and controlling cognition, behaviour, and motivation
Puteh & Ibrahim (2010)	• an integrated learning process involving behaviour growth that affects student learning

Scrutinising the definitions presented in the literature for self-regulated learning, some of which are included in Table 1.1, three main components are present in most: 1) *cognitive strategies*, which provide learners with the skills to memorise and process information; 2) *metacognitive processes*, which enable students to understand and reflect on their cognitive processes; and 3) their *beliefs* about their cognitive and metacognitive skills which in turn affect their abilities to use them (Schraw *et al.,* 2006). In educational research there is divergence in the literature regarding the relative importance of the factors outlined above which contributes to the different conceptions of self-regulated learning (Matthews *et al.,* 2009). There has also been a longstanding discussion regarding the placement of self-regulated learning in the *person* or in the *action* that has additionally contributed to differences in definitions (Martin & McLellan, 2008). However, two kinds of definitions can be interpreted: those with a goal-oriented focus and those with more metacognitively weighted definitions (Puustinen & Pulkkinen, 2001).

According to Zimmerman and Schunk (1989), self-regulated learning is the actions, thoughts, and feelings of students working toward attaining a goal. Therefore, contrasting to traditional teaching methods, this widely-accepted definition suggests that students need to be given opportunities to work toward goals they have set for themselves and to devise their own learning experiences (Boekaerts & Niemivirta 2000). As this definition has very practical implications for curriculum and practice, and is grounded in social-cognitive theory, this understanding of self-regulated learning informed elements of the research presented in this thesis.

Schunk & Zimmerman (1994) later defined self-regulated learning as involving goal-directed cognitive activities that students use, modify, and continue to use. This definition highlights the longevity of self-regulated learning which links to the earlier discussion (Section *1.1*) regarding the recent interest seen in developing life-long learning skills among students. Later, Zimmerman (2002) made further modifications to this definition of self-regulated learning and understood it as involving goal setting, adopting strategies to attain goals, monitoring performance, restructuring the physical and social context to be compatible with goals, managing time on tasks, self-evaluation, attributing causation to achieved results, and adapting future strategies and methods for goal attainment. Puteh & Ibrahim (2010) present a similar definition and state that self-regulated learning is an integrated process involving behavioural change that affects student learning and involves planning and adjusting the learning experience. Considering the multitude of definitions available for this construct, the next section of this chapter outlines the general framework adopted in this thesis for understanding self-regulated learning as well as the operational definition used for the construct.

1.7 Conceptual Framework for Understanding Self-Regulated Learning in this Thesis

For the purpose of the research presented in this thesis, a social-cognitive model of self-regulated learning will be adopted. In addition, the operational definition of self-regulated learning used in this thesis will also be informed by this theoretical understanding of the construct. In line with the theory underpinning this understanding, self-regulated learning will be investigated in this thesis through adopting a multiple framework including both external and internal variables (as discussed later in this chapter). This section will present the main components of self-regulated learning understood using the framework adopted in this thesis drawing mainly from Pintrich's (2004) model derived from social-cognitive theory. It is therefore important to note at this point that interpretations of the empirical research findings presented in this thesis are limited to this conceptualisation of the key constructs of interest.

According to social-cognitive researchers, self-regulated learning involves three or four interdependent phases through which learners manage their academic progression (Pintrich & De Groot, 1990; Wolters, 2010; Zimmerman, 2002). One phase is *forethought,* which involves planning, setting goals, and selecting strategies for a learning activity. During the *monitoring* phase, a student keeps track of their progress and is aware of their current performance in relation to their goals. The activities involved in the *control* phase refer to implementing and adapting learning strategies to complete the task. Finally, reviewing and responding to the learning experience makes up the *reflection* phase. Table 1.2 below presents an example of a student working through the four phases during a reading task.

Table 1.2. The key phases in social-cognitive models of self-regulated learning.

Forethought	• Plan how much reading to do, decide where and when to read, and decide to use highlighter
Monitoring	• Am I understanding the material and making good progress in my reading toward the goal I set for myself?
Control/management/regulation	• Use different coloured highlighters, make notes summarising each section, read out loud
Reaction and Reflection	• My textbook is difficult to read but using different coloured highlighters helps me organise the material in my head • Studying in a noisy environment does not work

While some researchers represent these phases in cyclical diagrams (Zimmerman, 2002), Pintrich (2004) highlights that they can happen at the same time and do not always have to follow the same order. Therefore, to visually represent his model, Pintrich outlined his framework in a table to avoid the time-ordered interpretation. Table 1.3 below provides a summary of how Pintrich (2004) understood the construct.

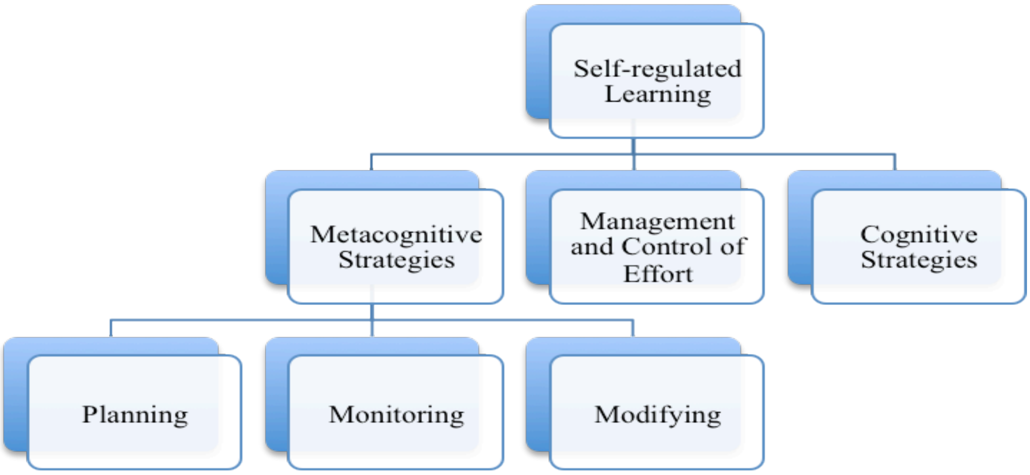
Table 1.3. Pintrich's (2004) understanding of the phases and areas for self-regulated learning.

	Areas for Regulation			
Phases	**Cognition**	**Motivation/Affect**	**Behaviour**	**Context**
1. Forethought, Planning and Activation	Goal setting, metacognitive knowledge activation	Efficacy judgments, perceptions of task difficulty, task value and interest activation	Time and effort planning, planning self-observations of behaviour	Perceptions of task and context
2. Monitoring	Metacognitive awareness and monitoring of cognition	Awareness and monitoring of motivation and affect	Awareness and monitoring of effort, time use, need for help Self-observation of behaviour	Monitoring changing task and context conditions
3. Control	Selection and adaptation of cognitive strategies for learning and thinking	Selection and adaptation of strategies for managing motivation and affect	Increase or decrease effort Persist or give up	Change or leave context
4. Reflection and Reaction	Cognitive judgments Attributions	Affective reactions Attributions	Choice of behaviour	Evaluation of task and context

As shown in Table 1.3 on the previous page, in his framework, Pintrich (2004) lists the self-regulatory activities involved in each phase in four separate areas: cognitive (which includes metacognitive), motivation and affect, behaviour, and context. However, the original self-report measurement tool Pintrich used was developed more than ten years before he finalised this framework, and his measurement tool therefore does not capture the full picture of self-regulated learning. Pintrich (2000, 2004) suggested that the additional factor of context should be included within models of self-regulated learning in addition to the existing factors of motivation, affect, cognition, and behaviour. He suggested that there is interplay between these components, which provide individuals with feedback to see if strategies have been effective in attaining academic pursuits. Therefore, in addition to using elements of Pintrich's (2000, 2004) understanding of self-regulated learning, MacLellen and Soden's (2006) understanding and measurement tool were also included in the research presented in this thesis, as they focus additionally on the environmental context in which the learning is taking place (discussed further in Chapter 3).

Aligning with the original measurement tool, for Pintrich and De Groot (1990), self-regulated learning is defined collectively by three components: metacognitive strategies including planning, monitoring, and modifying; management of effort on academic tasks, which includes elements of motivation; and the cognitive strategies students use to learn material including rehearsing information and identifying important points. This understanding will be used to inform the measurement of aspects of the constructs (presented in detail in Chapter 3). Figure 1.2 on the next page presents a visual summary of this understanding of self-regulated learning.

Figure 1.2. Pintrich & De Groot's (1990) conceptualisation of self-regulated learning.



However, as mentioned earlier, this definition does not include contextual factors of the learning environment. Therefore, in terms of an operational definition of self-regulated learning adopted for the research presented in this thesis, the Wolters *et al.* (2003) definition of self-regulated learning will be used as it combines the definition presented above into a framework for understanding self-regulated learning:

> "Self-regulated learning is an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behaviour, guided and constrained by their goals and the contextual features in the environment."
>
> (Wolters *et al.,* 2003, p. 2)

In addition, remembering the particular definition of learning adopted in this research from a constructivist approach, this definition suggests that while all learners self-regulate, some possess better strategies and a deeper understanding of appropriate strategy use than others (MacLellan & Soden, 2006).

Following on from the operational definition of the construct, the development of self-regulated learning will briefly be outlined within the conceptual framework. From the social-cognitive perspective, self-regulated learning is developed by progressing through four levels with the first two being more external and the second two more internal (Schraw *et al.,* 2006; Zimmerman, 2000). At the first level, learning takes place primarily through making *observations* focusing on modelling behaviour while the second level, *imitative*, involves learning through receiving feedback and social guidance. *Self-control* is the third level where students set standards for their performances and use self-tasks to reinforce, while the fourth level is the *self-regulatory* level where learners believe they have the skills to execute effective strategies they already have knowledge of (Zimmerman, 2000). The *observation* and *imitative* stages of this development model highlight the importance of teachers' behaviours when implementing strategies in the classroom aimed at fostering self-regulated learning. This development model will be discussed further in Chapter 2 relating to inquiry-based learning activities in the science classroom.

1.8 Motivation: Beyond Self-Regulation, Metacognition, and Self-Regulated Learning

The demanding nature of self-regulated processes involves not only the knowledge and implementation of metacognitive and strategic regulation, but also motivational and emotional processes to execute them (Gläser-Zikuda & Järvelä, 2008; Zimmerman, 1994). Researchers have suggested that the latter might explain why some learners cannot regulate their learning in ways that are beneficial for them academically (Gläser-Zikuda & Järvelä, 2008). Other researchers have shown that the self-regulatory process can produce emotional effects that undermine academic performance, motivation, and psychological wellbeing (Bandura, 1991; Malmivuori, 2006). In other words, students may be driving themselves with performance standards that are set too high, ensuring that their achievements do not give them a sense of fulfilment (Bandura, 1991). From the understanding of self-regulated processes within the context of this thesis, it is clear that student motivations play a large role in these processes within school learning contexts. These motivations will now be introduced and discussed in relation to the understanding of self-regulated processes adopted in this thesis.

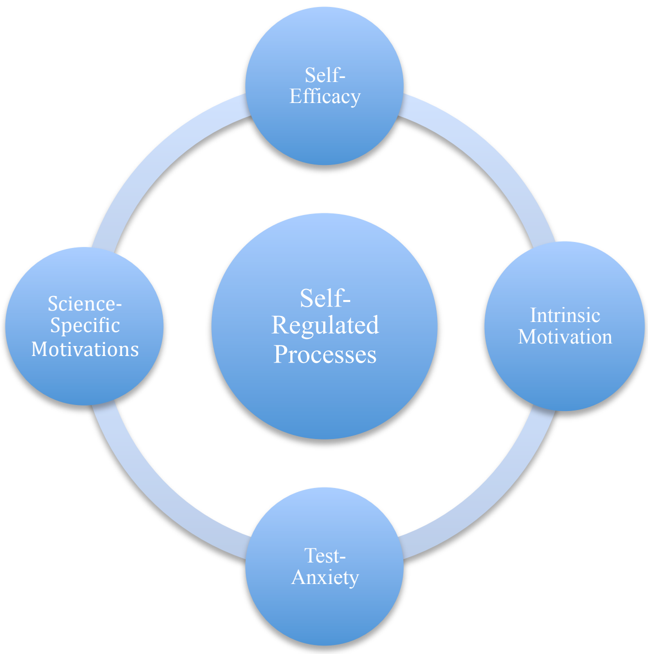
1.8.1 The Importance of Motivation in Models of Self-Regulated Learning

Over the last several years, educational research has seen increased interest in several motivational aspects of learning (Gläser-Zikuda & Järvelä, 2008). Specifically in the self-regulation domain, researchers have identified that students need more than just effective self-regulatory strategy knowledge and implementation (Schraw *et al.,* 2006). Motivational factors have been identified as additional important components of self-regulated learning, as students need to be motivated, believe they can learn effectively, and make positive judgments regarding their ability to employ the strategies they possess (Schraw *et al.*, 2006; Urdan & Schoenfelder, 2006; Zimmerman, 1995). Going further, researchers have highlighted the importance of understanding the motivations and beliefs that underlie students' initiation and persistence of effort within the classroom environment (Zimmerman, 2008). While metacognition and regulatory strategies involve planning, goal setting, monitoring, and evaluating, the related motivational aspects of self-regulated learning involve taking responsibility for performance outcomes, moderating interest and engagement in the task, and having high self-efficacy for performance (Gaskill & Hoy, 2002; Kaplan *et al.,* 2009). For science education, research has highlighted that teachers need to communicate to students and be aware themselves of the pivotal role that motivational beliefs play in fostering and facilitating both boys' and girls' self-regulated learning in science (Velayutham *et al.,* 2012).

Pintrich (2003) highlights that cognitive strategy intervention research in the 1980s failed to appreciate the importance of motivations in terms of academic cognitions. As relatively little research has been done on how motivational factors relate to the operation of self-regulated learning and cognition models of knowledge acquisition, Pintrich devoted his research efforts to developing a model that would capture this complex relationship (Pintrich, 2003, 2004). Pintrich was particularly interested in the role of motivation in the self-regulated learning process and highlighted that activation of self-efficacy and motivational beliefs about the task and the subject generally were involved in the *forethought* phase, discussed earlier in Section *1.7*.

In line with Pintrich's (2004) framework, and the recent concerns voiced in science education relating to the downward trends in student interest and motivation (Archer *et al.,* 2010; Bennett & Hogarth, 2009; George, 2000; Ryan & Patrick, 2001), this thesis will also incorporate the following related motivational constructs into the multidimensional framework for understanding the learning process in science: *self-efficacy, intrinsic motivation (task value), science-specific motivations,* and *test anxiety*. Figure 1.3 below presents a visual summary of this framework incorporating the related motivational constructs.

Figure 1.3. A visual representation of the conceptual framework for understanding self-regulated processes and related motivations.



Before introducing these constructs and discussing them within the context of self-regulated intervention research, different approaches to understanding student motivation will be outlined and the conceptual framework adopted in this thesis for understanding them will be presented.

1.9 Conceptual Framework for Understanding Learning Motivations

Similar to the self-regulated processes discussed above, motivation has been understood from several different perspectives over the years (Urdan & Schoenfelder, 2006). While early work on student achievement and learning separated motivation and cognition, and approached these factors in very different lines of research, there has been a substantial amount of research focusing on the interaction between motivation and cognition and their joint influence on student learning and achievement since the 1980s (Linnenbrink & Pintrich, 2002). This integration was facilitated by a shift in motivational theories from achievement motivation models viewing motivation quantitatively to social-cognitive models understanding motivation as a dynamic multifaceted phenomenon (Linnenbrink & Pintrich, 2002).

While three theoretical perspectives for motivation are available in the literature (achievement goal theory, self-determination theory, and social-cognitive theory), as with the material discussed previously in this chapter, they share several key assumptions (Urdan & Schoenfelder, 2006). The three different perspectives highlight the importance of ensuring that work is challenging enough for students in order to keep them engaged, but also ensuring that tasks are not overly difficult which could result in a potentially negative learning situation (Urdan & Schoenfelder, 2006). The different motivational theories also share a similar focus on the importance of students having a sense of ownership for their learning, which links to the self-regulated learning theories discussed earlier in Section *1.7*.

As with any psychological theory, there are limitations regarding how to interpret the findings of empirical research grounded in theoretical models. Urdan and Schoenfelder (2006) make the bold claim to propose that the view held by many researchers regarding conceptualising motivations as individual-difference variables residing internally in the student is inaccurate. They developed their argument further to propose that this individualistic nature for student motivation takes responsibility away from the teacher and lowers incentives for them to strive to create supportive environments for their students (Urdan & Schoenfelder, 2006). A look into recent theories of motivation demonstrates that psychologists have redeveloped the ideas and that student motivation is a result of a combination of both student and situational characteristics (Burke & Sass, 2008; Opolot-Okurut, 2010; Pintrich, 2003; Urdan & Schoenfelder, 2006). In line with the framework presented above for self-regulated processes, this social-cognitive view of motivation was also adopted in this thesis and the findings to be presented are therefore constrained within this theoretical understanding of the key constructs.

Before moving on to discuss the importance of some key related motivations within the conceptual framework for understanding self-regulated processes in this thesis, a few clarifying points need to be made. Under the social-cognitive perspective of motivation adopted, it is important to understand that motivation should not be measured on a continuum with some students being either motivated or not motivated, but that motivation can take on many forms as students can be motivated in multiple ways (Linnenbrink & Pintrich, 2002). Also, under the social-cognitive framework presented, motivation is not a stable trait, but a dynamic construct that differs by context, situation, and subject domain (Linnenbrink & Pintrich, 2002). These sensitivities were considered when choosing measurement tools to understand these constructs in the empirical research to be presented.

1.9.1 Self-Efficacy Within the Framework of Self-Regulated Processes

While it is important for individual learners to set goals, they need to have a self-regulatory system to work toward those goals (Miller & Brickman, 2004). From the social-cognitive perspective adopted in this thesis, self-regulated learning is a goal directed series of behaviours geared toward attaining goals and outcomes either real or internalised (Miller & Brickman, 2004). This process is influenced by *self-efficacy*, which determines both what goals are set and how they are attained (Miller & Brickman, 2004). It has been highlighted in the literature that self-efficacy is an important factor in students' abilities to regulate their learning and that it has high predictive power over regulatory behaviours (Chularut & DeBacker, 2004; Gaskill & Hoy, 2002; Pintrich, 1999). Self-efficacy within social-cognitive theory is therefore placed within a larger framework of self-regulatory behaviour where students take ownership for their learning (Pintrich & De Groot, 1990; Zimmerman 1995).

Some researchers have suggested that developing self-efficacy might be the most effective way of fostering self-regulated learning in students. If students believe they can do more, they may be further motivated to take control over their learning (Gaskill & Hoy, 2002). Specifically in science, Velaytham and Aldridge (2013) found that self-efficacy influenced the development of self-regulation among science students. The research above implies that in order to promote self-regulated learning in secondary school science, educators must also implement strategies to develop self-efficacy in students toward their science learning. Considering this research and remembering the model of self-regulated learning adopted in this thesis, students' beliefs towards their science learning were also incorporated into the study design (outlined in detail in Chapter 3).

Similar to the discussion presented earlier in Section *1.5* regarding conceptual overlap between metacognition, self-regulation, and self-regulated learning, important conceptual clarifications also need to be made before discussing self-efficacy any further. Similar terms including self-esteem and self-concept are often misidentified as self-efficacy. However, the terms differ in important and significant ways. While self-efficacy refers to very specific judgments relating to a particular task, self-esteem relates to a sense of self-worth, and self-concept is a more global perception of one's self (Gaskill & Hoy, 2002). Self-efficacy describes an individual's beliefs about their ability to complete a task and can affect their learning and achievement through mediating their persistence and effort on learning activities and the amount of stress they experience while taking part (Bandura, 1991; Chulaurt & DeBacker, 2004). The discussions in this thesis will be limited to this understanding of self-efficacy.

The relationships between self-efficacy and the self-regulated processes discussed earlier have been investigated for some time and it is clear that they are complex relationships to study. While some researchers view self-regulated learning and self-efficacy as interdependent, both requiring a set of cognitive strategies to set goals, monitor progress, and make judgments about learning activities (Bandura, 1991; Gaskill & Hoy, 2002), recent research findings suggest otherwise. Berger and Karabenick (2011) conducted a study to investigate the direction of the relationship between self-efficacy and self-regulated strategies use. These researchers found that higher levels of self-efficacy at the beginning of a school term predicted more sophisticated learning strategies use, however, they did not find that learning strategies predicted self-efficacy (Berger & Karabenick, 2011). The results of this research contribute to understanding the complexity of these relationships, which informed the tentative nature of the research predictions relating to self-efficacy in the three empirical studies to be presented in this thesis (Chapters 4, 5, & 6).

Beyond its influence on self-regulated processes, self-efficacy has also been shown to influence academic performance and subject interest. Simpkins, Davis-Kean, and Eccles (2006) showed that students who were more interested and had higher self-efficacy in science were more likely to pursue science during adolescence. Developing self-efficacy in science is also essential as it influences course choice in boys and girls (Simpkins *et al.,* 2006). Beliefs about learning have been highlighted and identified as especially important for adolescent students as this period is sometimes viewed with declining academic motivation (Ryan & Patrick, 2001). In addition to the impact on self-regulated learning, self-efficacy has also been shown to affect some of the other related motivations included in this thesis (Gaskill & Hoy, 2002). These documented findings relating to the influence of self-efficacy on related motivations further support the inclusion of this construct in the research conducted as part of this thesis.

1.9.2 Intrinsic Motivation Within the Framework of Self-Regulated Processes

Motivation has been defined in many ways throughout educational literature, but generally, motivation refers to any drive to do something (Baumeister & Vohs, 2007). A large array of studies has linked motivational processes to educationally relevant outcomes including the quality of student learning and academic performance (Deci, Ryan, & Williams, 1996). A motivated student behaves with the intention to achieve a desired outcome and these outcomes can vary along with the reasons for pursuing them (Deci *et al.,* 1996). Contrasting to the construct of self-efficacy discussed earlier, where higher amounts typically yield better academic outcomes, motivation can also be conceptualised by the quality or type (Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009).

One way in which motivations vary is in the degree to which they are autonomous or controlled (Black & Deci, 2000). *Intrinsic motivation* is an example of an autonomous motivation and has been extensively studied in educational research. When intrinsically motivated, students feel autonomous in their behaviour, experience behaviour as an expression of themselves, and are personally engaged in the learning task being completed (Black & Deci, 2000; Deci *et al.,* 1991, 1996; Wigfield & Eccles, 2002). In contrast, extrinsically motivated students typically need an instrumental reason to perform learning activities, possibly in order to receive rewards or avoid guilt (Deci *et al.,* 1996). While extrinsic motivations are necessary in order to adapt to different social learning contexts (Black & Deci, 2000), Pintrich (1999) showed how self-regulated learning can be constrained by these extrinsic motivations. Conversely, research has documented that intrinsic motivation can play a key role in developing self-regulated learning strategies (Velayutham *et al.,* 2012). As such, fostering intrinsic motivation in students has been a topic of self-regulated process intervention research (Pintrich, 2003). This type of motivation can be fostered in autonomy-supportive learning contexts in which teachers adopt student-centered approaches and move away from focusing on rewards and punishments (Black & Deci, 2000). These research findings provided the basis for the predictions made in the three empirical studies (Chapters 4, 5, & 6) relating to the development of intrinsic motivation in students through participation in an inquiry-based learning activity.

As with self-efficacy, the relationship between intrinsic motivation and self-regulated processes is complex and difficult to study. The research described earlier by Berger and Karabenick (2011) also examined the relationship between the value students place on learning tasks (*task value*) and self-regulated processes. Unlike the results found for self-efficacy, results relating to task value showed that the value students placed on learning tasks at the beginning of the school term did not predict the use of regulatory strategies later in the year. In contrast, the results showed that task value predicted self-efficacy at the end of the term, suggesting that task value may indirectly affect the sophistication of regulatory strategies used by students (Berger & Karabenick, 2011). These findings were also considered when the research predictions relating to intrinsic motivation and task value were made in the three empirical studies reported in this thesis.

In addition to intrinsic motivation, several other motivations have also gained the interest of educational researchers investigating self-regulated processes specifically in science classrooms (Bryan, Glynn, Kittleson, 2011). Among these are students' motivations for achieving high grades as well as their thoughts about how their learning in science can help them in their future careers (Bryan *et al.,* 2011; Glynn *et al.,* 2009, 2011). Therefore in this thesis, in addition to intrinsic motivation and task value, *science-specific motivations* will be incorporated into the social-cognitive framework for understanding self-regulated processes and investigated as outcome measures within the research design (see Figure 1.3, presented earlier on page 33, for a visual representation of this framework).

1.9.3 Test Anxiety Within the Framework of Self-Regulated Processes

Remembering Pintrich's (2004) model of self-regulated learning adopted in this thesis (Section *1.7* above), affect is an important component of the self-regulation process. However, the role of affective factors are not well understood and often not included in current social-cognitive models of motivation. More generally, academic emotions are often neglected in educational research (Pekrun, Goetz, Titz, & Perry, 2002). Smith (1989), and more recently Pintrich (2003), highlight that the time has come for an affective revolution to follow the cognitive revolution in research on students learning in the classroom. Therefore, in line with the research presented by Pintrich and others, an affective component of student learning will also be included in the empirical research conducted in this thesis. This affective component is *test* *anxiety*, which will now be introduced along with current educational research in the field relating to self-regulated processes and related motivations.

Contrasting to the confidence that can come from self-efficacy developments, student anxiety towards taking tests has been a topic of recent concern (Pekrun *et al.,* 2002). Test anxiety specifically refers to the concern and worry associated with outcome expectations during test writing (Rozendaal, Minnaert, & Boekaerts, 2005). High levels of anxiety have been negatively correlated with academic performance in English, Maths, Science, and also in problem-solving activities in students from the age of eight years to graduate school (Cassady & Johnson, 2002; Hembree, 1988).

It is widely accepted in the literature that test anxiety involves two components: emotionality (physiological symptoms) and worry (later termed cognitive test anxiety) (Cassady & Johnson, 2002). This worry, or cognitive aspect of test anxiety has been shown to have the strongest impact on academic performance according to meta-analyses and correlational studies in the literature (Cassady & Johnson, 2002) and specifically in adolescent students (Williams, 1991). While some researchers suggest the reason for the influence of test anxiety on academic performance is that the competing thoughts of worry interfere with the information processing required for the test (Cassady & Johnson, 2002; McKeachie, 1984), other researchers view test anxiety as a trait influenced by situational factors including low confidence, heightened self-awareness, and low preparation (Kurosawa & Harackiewicz, 1995; Zohar, 1998). The latter view has important implications for the development of metacognitive strategies and as such, incorporating test anxiety into research aiming to understand self-regulated processes in students is necessary. The research above will be considered when interpreting the results to come from the three empirical studies conducted in this thesis.

While test anxiety has been researched for decades, there is little agreement in literature investigating test anxiety relating to its impact on academic performance, self-regulated processes, and how to measure the construct itself (Cassady & Johnson, 2002). As performance marks are arguably driving science education, researchers are trying to understand the role that a student's level of anxiety plays while taking tests in class. Therefore, in line with the research discussed in this section and Pintrich's (2004) framework presented earlier, test anxiety will be incorporated as an outcome measure in the three studies presented in this thesis.

1.10 CHAPTER SUMMARY AND CONCLUSIONS

As discussed at the beginning of this chapter, the goal of education today for many policy makers and administrators is to develop autonomous learners (Boekaerts & Corno, 2005; Capara *et al.,* 2008; Jones & Idol, 1990; National Research Council, 2000; Scottish Executive, 2004; Wongsri *et al.,* 2002). Along with the specific nature of science learning discussed, this highlights the importance of developing students who are in control of their learning and who play an active role in their own knowledge acquisition and educational experience in science. In self-regulated learning intervention research, few studies make a point to outline the theoretical models and operational definitions for understanding the constructs being investigated. This chapter was therefore structured in order to provide a clear and concise conceptual overview of the key constructs investigated in the empirical work presented in this thesis.

The first part of this chapter focused on the general framework for understanding three key constructs of interest that form the basis of the research presented: *self-regulation, metacognition,* and *self-regulated learning*. This general framework for understanding these constructs was also used to inform the specific model of self-regulated learning adopted as well as the operational definition of the construct presented. Building on this framework, the second part of this chapter was dedicated to presenting a justification for the inclusion of several related motivational constructs within this framework; *self-efficacy, intrinsic and science-specific motivations,* and *test anxiety*. Through discussing conceptualisations of these related motivational constructs within the framework for understanding self-regulated processes, this initial chapter has presented the complete framework for understanding the learning process adopted in the research presented in this thesis.

These frameworks were used to inform methodological decisions regarding measurement tools (Chapter 3) as well as the interpretation of results presented in the three empirical chapters (Chapters 4, 5, & 6).

As outlined in the introduction to this chapter, this thesis aims to investigate the impact of an inquiry-based programme as a strategy to promote self-regulated processes and related motivations among young science students. The initiative chosen for this research was the *CREativity in Science and Technology* (CREST) award scheme. The CREST programme will now be introduced in Chapter 2 within the context of educational intervention research before presenting an overview and justification of the methods used for the empirical work conducted within this thesis (Chapter 3).

2

THE INQUIRY EXPERIENCE: A THEORETICAL AND PRACTICAL REVIEW OF INQUIRY-BASED LEARNING IN THE SCIENCE CLASSROOM

Chapter Objectives

One of the main objectives of this chapter is to introduce the CREST programme, an inquiry-based learning initiative in the United Kingdom, which is a focus of the research conducted in this thesis. Another aim of this chapter is to place the CREST programme within the context of self-regulated processes and related motivation intervention research. This chapter will begin with an overview of some general trends in science education and classroom practice before discussing problem solving and inquiry-based learning activities within the framework of self-regulated processes and related motivations presented in Chapter 1. Through relating theoretical research findings and suggestions for encouraging self-regulated processes and related motivations among young students to the structure of the CREST programme, this chapter also provides justification for evaluating CREST as a strategy to develop these constructs in young science students. By also presenting a discussion of the state of intervention research in this field, this chapter aims to expose gaps in the literature. The present chapter, together with the first chapter of this thesis, will also serve as a basis for the research predictions made in the three empirical studies to be presented (Chapters 4, 5, & 6).

2.1 INTRODUCTION

> "Good science teaching must ultimately rest on a multiplicity of approaches and on a healthy respect for the variety of characteristics of science. Educators must, in short, expand their conceptions of what science really is." (Tweney & Walker, 1990, p. 306)

While Chapter 1 outlined the very specific and complex nature of science *learning* and the importance of developing self-regulated processes and related motivations in young students, the above quotation demonstrates the complex nature of science *teaching* and the contextual demands placed on science teachers. In order to give students a complete education in science, teachers are expected to offer students a variety of different approaches to learning the material (Reiss, Millar, & Osborne, 1999), as well as themselves appreciating the nature of science today and communicating this to students (Lederman, 1999; McComas, Clough, & Almazroa, 1998), while simultaneously covering curriculum guidelines. As many secondary science teachers have been out of the science laboratory environment for several years, this, understandably, may not be an easy task.

Researchers have highlighted that a possible reason students struggle with science is not because they are too young and lacking in ability, but that they do not know how to develop conceptual models in science and reflect on and monitor the strategies they are using as well as the progress they are making (White & Gunstone, 1989). Implementing problem and inquiry-based learning programmes, which support student creativity and help to develop a more reflective, active approach to learning, may be the answer.

Currently in the United Kingdom, and also around the world, curriculum initiatives are being implemented to provide teachers with structured strategies in order to achieve these aims in their classrooms. The research presented in this thesis investigates the effectiveness of one particular initiative: *The CREativity in Science and Technology* (CREST) award scheme.

This chapter will begin with a discussion of some recent changes in the approach taken to science education and continue by outlining some shifts in classroom practice and how they fit within a self-regulated learning and metacognitive theoretical framework. A detailed description of what the CREST programme involves will then follow alongside a discussion of how the programme aligns with educational research regarding how to promote and encourage self-regulated processes and related motivations in young students. In doing this, this chapter provides a theoretical framework for studying the CREST programme as a pedagogical route to develop self-regulated processes and related motivations among science students. Additionally, placing the programme within this framework also allows for justification of the research predictions formulated for each of the three studies (presented in Chapters 4, 5, & 6). Before describing the programme and placing it within the context of self-regulated learning intervention research, issues relating to recent educational reform in school science will be examined.

2.2 Approaches to Science Education

In science classrooms internationally, the findings of rigorous research are often presented to students as definite facts without addressing how the facts were discovered, the scientific processes involved, or the limitations of the research carried out in order to arrive at the facts (Kalman, 2010; Moss, 2001; Sadler, Chambers, & Zeidler, 2004). For example, a student learning heredity in school may think that the relationship is simple and definite, as their textbook outlines that the results of a punnet square or Mendel Table can be predicted and exact percentages obtained. However, a deeper understanding of the process through which Mendel made the discovery and the limitations he proposed to his theory might help students appreciate that the relationship between genes and expressed characteristics is not absolute.

Developing students' understanding of the nature of science has been at the forefront of educational objectives for over two decades (Driver, 1996; Lederman, 1999; Moss, 2001). Inquiry-oriented, constructivist approaches to science education began in the 1960s (White & Fredriksen, 1998) and the question of whether the focus of science teaching should be on process or outcomes has been the topic of a longstanding debate in science education and has been discussed by a range of classical authors (Bobbitt, 1928; Driver, 1986, 1989; Stenhouse, 1975; Tyler, 1949). Historically, the process approach to science was adopted quite widely and the approach is therefore not new, but is currently being revisited within new metacognitive theoretical frameworks to highlight the potential benefits to learning.

The majority of science educators hold the view that students should take a 'scientific' approach to their learning by constructing their own knowledge, answering personally interesting questions, and using inquiry strategies to build conceptual knowledge in order to appreciate the process behind the findings which contribute to our understanding of the world around us (Dillon, 2008; Kalman, 2010; Keys, 1998; Reif, 2008). Reiss and colleagues (1999), in their review of the English and Welsh science curriculum, suggested that introducing students to how reliable scientific knowledge is formed would be a valuable addition. More recently, Osborne and Dillon (2008) made a similar recommendation specifically for schools in Europe, suggesting that the *way* science works should be a focus of school science across the EU. Together, these researchers highlight the need for students to appreciate that the scientific theories they are learning in school are evolving, and further, that students should approach their learning in science with a 'scientific mindset' (Dillon, 2008; Kalman, 2010; Keys, 1998).

In practice, however, implementing these research suggestions and developing a 'scientific mindset' among secondary school students is difficult if the teachers themselves are not taking this approach to science. From the literature regarding models of self-regulated learning presented previously in Chapter 1, it appears that to generate a 'scientific mindset' among learners, teachers need to model the behaviour for their students. Thus, alongside striving to develop a 'scientific mindset' among students, curriculum initiatives must encourage this mindset among teachers. Further evidence will be presented later in this chapter to highlight the importance of teacher professional support during inquiry-based learning activities.

Providing opportunities for students to perform and engage with real science in the classroom is an essential activity necessary in order to follow the suggestions of researchers mentioned above. The CREST programme, which will be outlined in detail shortly, provides a potential way to achieve this aim while also supporting teachers in implementing these activities.

2.2.1 Changes in Classroom Practice in Science

While the general approach to science education has shifted over time, researchers have also been focused on the importance of the role teachers play in the classroom. Research on science teaching has outlined that teachers' roles in science education need to shift from being the giver of knowledge to facilitating and mediating the learning experience (Barr, 1994; Keys, 1998; Minner, Levy, & Century, 2010; Tobin, Tippins, & Gallard, 1994). Velayutham and Aldridge (2013) view teachers as an integral part of the classroom environment and state that they can influence students by creating an environment where they feel personally efficous and motivated to succeed. This shift is further supported by the research discussed in Chapter 1 regarding conceptualisations of the key constructs investigated in this thesis moving from being understood as individual difference variables to additionally focusing on the social influences on student self-regulated processes and related motivations (Urdan & Schoenfelder, 2006).

However, the shift in pedagogy to a role of mediating learning and facilitating knowledge acquisition can be difficult for teachers to adopt, because they need to develop new content knowledge, pedagogical techniques, assessment protocols, and possibly new classroom management strategies (Edelson, Gordin, & Pea 1999; Lee, Hart, Cuevas, & Enders, 2004). In addition to secondary science teachers, this issue becomes even more essential at the primary education level where teachers may experience low confidence in their science abilities. Therefore, similar to the discussion regarding the development of 'scientific mindsets' in students earlier in Section *2.2*, if teachers are to adequately take these research suggestions on board in their educational practices, they need to be given the appropriate support to implement these changes (Léna, 2011). Again, it will be argued later in this chapter that the CREST programme may provide an effective solution for secondary school teachers.

2.3 Problem Solving Within a Self-Regulated Processes Framework

In addition to giving students more control over their science learning as discussed in Chapter 1 Section *1.2*, there has been a significant amount of research conducted in science and maths education regarding developing problem solving skills in young students (Silver & Marshall, 1990). Providing students with experiences in the classroom that encourage creative problem solving has been shown as an effective means of developing metacognitive strategies and self-regulated learning (Silver & Marshall, 1990; Zohar & Dori, 2012) and improving science comprehension and students' abilities to apply knowledge to different learning situations (Wong & Day, 2009).

A deeper look into one of the most cited models of problem solving provides insight into why this learning strategy is effective in developing metacognitive and self-regulated strategies in students transitioning into adolescence. George Polya's book entitled *How to Solve It* details his four-phase problem solving model and was first published in 1945. The book has now been translated into 17 different languages and updated frequently with the most recent edition published in 2009. Polya's model for problem solving comprises four phases that a student progresses through: 1) understanding the problem; 2) devising a plan; 3) carrying out the plan; and 4) reviewing the learning experience. When comparing this to the social-cognitive models of self-regulated learning presented in Chapter 1 Section *1.7*, specifically Pintrich's (2004) model adopted in this thesis, several similarities can be seen. The second phase of Polya's model, developing a plan to solve the problem, is similar to the *forethought* phase in Pintrich's (2004) self-regulated learning model in which students select goals and the strategies necessary to attain those goals. Additionally, the final phase of Polya's model, looking back on progress, is similar to the *self-reflection* phase in Pintrich's (2004) model. This fourth phase in Polya's model involves students reflecting on their activities and deciding whether their progress aligns with the plan they set in phase two. While researchers have suggested that

Polya's model be used as a guide for instructional practice in developing metacognitive skills in students (Kilpatrick, 1985 cited in Silver & Marshall, 1990), its links to Pintrich's (2004) model of self-regulated learning also support the appropriateness of its use in informing strategies designed to develop self-regulation among students.

Silver and Marshall (1990) present a summary of several aspects of cognitive theory that are directly related to problem solving activities in science and maths. These researchers focus largely on the importance of effective metacognitive processes in problem solving tasks carried out by students. Silver and Marshall proposed that two types of knowledge are needed for problem solving and that these processes should be used to inform curriculum design for problem solving interventions: meta-level processes (evaluation and monitoring) and meta-level knowledge (beliefs). As with Polya's model for problem solving, these processes identified by Silver and Marshall (1990) have direct links to models of self-regulated learning presented in Chapter 1.

More than two decades ago, Silver and Marshall (1990) highlighted that the research on metacognitive processes showed the importance of these processes in complex problem solving and that there was relatively little empirical research conducted on metacognitive processes and how they relate to scientific problem solving. Building on this research, Zohar and colleagues (2012) have been working to develop a deeper understanding of metacognitive skills in the science classroom. In their recent book *Metacognition in Science Education* (2012), Zohar and colleagues examine the large body of research on metacognition in science. Silver and Marshall (1990) advised that instruction be structured around creating environments in which students become completely immersed in the activities instead of merely giving a checklist approach. The work presented by Zohar and colleagues (2012) further supports this idea. Research has demonstrated that students can improve academic performance by becoming aware of their thinking when solving problems in class (Paris & Winograd, 1990). Through discussing effective problem solving strategies and cognitive and motivational elements of thinking, teachers can help students become aware of their thought processes during learning activities (Paris & Winograd, 1990).

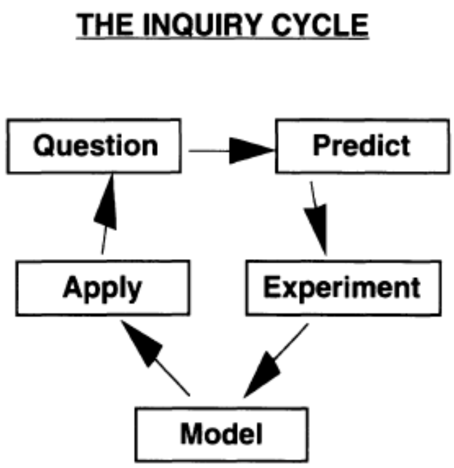
This helps students both by transferring responsibility from teachers to students regarding monitoring the learning process, and fostering the development of positive self-perceptions, motivations, and affect towards their learning (Paris & Winograd, 1990).

2.4 Inquiry-Based Learning Within a Self-Regulated Processes Framework

Similar to problem solving, inquiry-based learning activities were a topic of science education reform in the 1990s (Keys, 1998) and are becoming more frequently incorporated into science classrooms and curricula today (Abrahams & Reiss, 2012). The term *inquiry* has been distinctively associated with 'good science teaching and learning' over the past 50 years (Anderson, 2002). This is possibly driven by the large amount of research support showing that students who participate in inquiry-based learning activities in science achieve higher scores on standardised measures of science learning and on understanding the nature of science (Blanchard *et al.,* 2010; Marx *et al.,* 2004). Research has also shown that participation in inquiry-based learning activities can lead to increased retention at most secondary and middle school levels (Blanchard *et al.,* 2010), as well as increased student interest and conceptual understanding in science (Dillon, 2008).

In light of the discussion at the beginning of this chapter regarding the recent shift in science education towards developing deeper student understanding of the process and nature of science, the appeal of these inquiry activities comes as no surprise. One explanation for the observed benefits of the inquiry experience in classrooms is that inquiry-based learning allows individuals flexibility in the learning process and therefore caters to learners' individual needs (Blanchard *et al.,* 2010). Another explanation for the observed benefits of student participation in inquiry-based learning programmes may be that these activities create environments in the classroom that encourage the development of self-regulated learning in students. As autonomy and control over the learning process can be seen as conditions for self-regulated learning (Bergramin, Werlen, Seigenthaler, & Ziska, 2012), inquiry-based learning opportunities in the classroom may help develop self-regulated learning in young students. This view is further supported by considering the links between White and Frederiksen's (1998) model of inquiry learning in science (shown in Figure 2.1 below) and the social-cognitive models of self-regulated learning discussed in Chapter 1 Section *1.7.* As the framework adopted in this thesis relating to self-regulated learning draws mainly from Pintrich's (2004) model derived from social-cognitive theory, as above, direct comparisons here are made to this model.

Figure 2.1 White and Frederiksen's (1998) model of the scientific inquiry process.



White and Frederiksen (1998) outline how students begin the inquiry cycle by formulating a question and generating several predictions and hypotheses. Through planning and carrying out experiments, students are able to test the contradicting predictions and analyse the results, particularly by creating scientific models. The students then apply their findings to other situations while reflecting on the limitations of what they have learned and what improvements can be made to the inquiry process. This final application phase allows students to develop new questions and the inquiry process begins again through the same cycle of phases. The *apply* stage of White and Frederiksen's (1998) model closely aligns with the *self-reflection* phase of Pintrich's (2004) self-regulated learning model presented in Chapter 1 and discussed earlier in this chapter. In addition, White and Frederiksen (1998) outline that the entire inquiry process is guided by carefully planned research goals, similar to the *forethought* component of Pintrich's (2004) model, and involves students reflecting on the process and what they have learned. Considering the links between the inquiry process and the phases of self-regulated learning, it is therefore possible that while encouraging inquiry-based learning opportunities in the classroom, science education today is also developing students' use of self-regulated learning strategies. White and Frederiksen (1998) suggest that the reason for success and optimism seen in inquiry-based learning in science can be attributed partly to advances seen in self-regulation and metacognition research.

White and Frederiksen (1998) developed curriculum materials in the United States in physics aimed at encouraging metacognitive skills and have proposed an instructional theory in order to make scientific inquiry in the classroom accessible to all students, focusing particularly on widening accessibility for younger and lower-achieving students. The result of their efforts was the *ThinkerTools Inquiry* curriculum, a set of computer materials to help students reflect on their science inquiry experiences in physics, specifically regarding force and motion content. Through participation in the programme, the researchers found that students' performance improved significantly on inquiry and general science assessments, highlighting the potential benefit of developing an awareness of the inquiry process and reflecting on it. White and Frederiksen (1998) suggest that a focus on developing this metacognitive awareness and inquiry expertise was not present in most school curricula at the time. However, while more recently implementation of these inquiry activities in secondary school classrooms in England is increasing (Abrahams & Reiss, 2012), it is important to assess their impact on student perceptions of learning.

Inquiry-based learning activities can take many forms in the science classroom. Activities ranging from pen-and-paper problem solving tasks to more complex student-directed investigations can be structured in order to give students more control over their learning in science. In more technical terms, different types of inquiry outlined in the research include *structured inquiry* which involves the teachers formulating a question with students working through a prescribed procedure, *guided inquiry* where students work with a teacher-formulated question, and *open inquiry* which is the most complex level of inquiry (Sadeh & Zion, 2012).

The particular classroom-learning programme being studied in this thesis is in line with the open inquiry learning structure outlined in the literature.

White and Frederiksen (1998) highlight that inquiry-based learning in science, directed specifically at science investigations, is a complex social and individual activity that is very difficult to create effectively. The following section of this chapter will introduce the science laboratory environment and highlight the importance of furthering our understanding of the problem solving and inquiry-based activities taking place in these specific classroom settings.

2.5 Problem Solving and Inquiry-Based Learning in Science

Science teaching laboratories in secondary schools are places for learning (Lazarowitz & Tamir, 1994). Laboratory investigation in science allows students to work together in order to solve problems and construct new knowledge (Tobin *et al.,* 1994). It has been suggested that no other area in science education has received the attention in literature reviews that the laboratory has regarding learning, teaching and assessment. In addition to providing students with opportunities to develop curiosity and understand the nature of science, the laboratory can be used as a venue for students to identify their preconceptions or alternative perceptions in science (Lazarowitz & Tamir, 1994). By developing science laboratory inquiry skills, students can work to extend and modify any alternative conceptions they have.

However, the above roles are often not communicated to teachers, who more often, view the laboratory experience with a purpose of knowledge verification and developing technical skills (Tobin *et al.,* 1994). Few teacher education programmes help pre-service teachers develop effective pedagogies in laboratory settings, and therefore, some teachers have difficulty seeing the benefit of running laboratory investigations with their students and are not confident in their skills to properly support students through these activities (Abrahams & Reiss, 2012; Harlen & Holroyd, 1997; Lazarowitz & Tamir, 1994). The consequence of this is often laboratory classes including large amounts of closed-ended activities (Fraser, Giddings, & McRobbie, 1995). It is therefore essential that these roles are communicated to teachers and fully understood before students are introduced to laboratory activities in the classroom.

Lazarowitz and Tamir (1994) outline the difficulty of obtaining convincing data on the effectiveness of the learning that takes place in the science laboratory setting. Through conducting a review of laboratory educational research, Lazarowitz and Tamir concluded that elementary school science was underrepresented in the wide body of inquiry-investigation literature in science education and more recent findings suggest that this is still the case (Forbes, Biggers, & Zangori, 2013). Researchers have also highlighted that it is still important to provide empirical support for the role of the laboratory experience and how to ensure that the potential of this pedagogy is realised (Avery & Meyer, 2012; Forbes *et al.,* 2013; Lazarowitz & Tamir, 1994). The present thesis aims to build on the literature and assess student self-regulated processes in science when performing inquiry-based investigations. In addition, as students' attitudes, interests, and cognitive preferences have been seen as important in the laboratory-learning environment (Lazarowitz & Tamir, 1994), this research also includes these relevant motivational constructs in order to gain a full picture of the inquiry experience for young science students.

2.6 Framework for Understanding Science Education in this Thesis

The research presented in this thesis is guided by Polya's model of problem solving and the model of scientific inquiry developed by White and Frederiksen (1998) outlined earlier in this chapter as they show clear links to the social-cognitive models of self-regulated learning, particularly Pintrich's (2004) model, presented in Chapter 1 Section *1.7*. More generally, similar to the constructivist approach taken for understanding self-regulated processes and related motivations (see Chapter 1 Section *1.8*), the research presented in this thesis adopts the view that in science education, students construct their knowledge (Driver & Oldham, 1986).

Following on from the discussions relating to problem solving and inquiry-based investigations in science and their relation to the literature on self-regulated processes, the next part of this chapter aims to provide evidence of support and justification for using the CREST programme as a pedagogical route to further our understanding of students' development of self-regulated processes and related motivations in science. Background information regarding the CREST programme will now be presented followed by an overview of the programme structure alongside theoretical and empirical research regarding the promotion of self-regulated processes and related motivations among students.

2.7 The CREST Programme

The CREST award scheme was developed through recent curriculum evaluations in the UK as an opportunity to increase enthusiasm and motivation in Science, Technology, Engineering, and Mathematics (STEM) and increase the number of students pursuing careers in STEM. Originally developed in the mid-1980s, the programme is now managed by the British Science Association. The CREST programme is currently being implemented in schools throughout Scotland and the wider UK. The research in this thesis explores the impact of CREST on student self-regulated processes and related motivations in science.

The CREST inquiry-based learning programme is offered to schools as a supplement to the UK science curriculum. The programme is designed to allow students to explore the real nature of science and bring their personal interests into their science classrooms. The specific aims of the programme are to promote positive attitudes towards science and scientists, develop and practice science investigation skills, improve communication and problem solving abilities, and also raise awareness of careers in science (Grant, 2007). By participating in the programme, students are provided with an opportunity to creatively solve problems in which they are personally interested. Students work through projects, with support to guide them, and awards are made at three levels depending on the time commitment for the project: Bronze (10 hours), Silver (40 hours), and Gold (100 hours). Events are held throughout the UK, which give students the opportunity to present their projects to other students and researchers. Led by students and facilitated by teachers, this programme focuses on promoting student autonomy, peer collaboration, and providing students with opportunities to perform self-reflection and self-evaluation.

The research presented in this thesis focuses on the first level of the CREST programme, the Bronze level, with students between the ages of 11 and 14 years.

By allowing students to choose their own project hypotheses and methods to answer research questions that interest them personally, CREST also introduces students to the investigative nature of science. This chapter will continue with a detailed discussion of the structure of the CREST programme alongside current intervention research aimed at fostering self-regulated processes and related motivations in students. In doing this, the next section of this chapter also provides support for the research predictions made in each of the three empirical studies conducted as part of this thesis (presented in Chapters 4, 5, & 6).

2.8 The CREST Programme Through the Lens of Educational Intervention Research

Suggestions in the literature for intervention programmes, aimed at developing self-regulated processes and related motivations in young students, outline that students should be given choice, allowed to set personally relevant goals, control their learning and progression through activities, work with peers, and self-assess their performance tasks (Gaskill & Hoy, 2002; Greene & Azevedo, 2007; Schraw *et al.,* 2006). Although the CREST programme does not involve direct strategy instruction by trained researchers, the design of the programme closely aligns with suggestions outlined in the literature regarding necessary components in self-regulated learning interventions. Considering elements of the CREST programme within the context of intervention research in this field and connecting aspects of the programme to the theoretical framework discussed above and in Chapter 1, this section provides support for the CREST award scheme as a viable curriculum activity through which to gain a better understanding of the development of self-regulated processes and related motivations among young science students.

While this section provides justification for understanding the CREST programme within a self-regulation framework, this thesis appreciates that there is no single, correct way to design classroom learning environments aimed at fostering self-regulated processes and related motivations in students (Pintrich, 2003). However, by placing the CREST programme in the context of suggestions outlined in the literature regarding areas in need of further research and also the development of self-regulated learning intervention programmes, this section provides support for using the CREST programme to address the general aims of this thesis.

Educational researchers focusing on curriculum design and delivery have documented a variety of strategies that can be implemented in the classroom to influence the self-regulatory behaviours and motivations of young students (De Corte *et al.,* 2004; Schraw *et al.,* 2006). Among these, researchers have highlighted the implementation of inquiry-based learning programmes that provide students with an opportunity to focus on a process-orientated approach to learning while stimulating active engagement in the classroom (Schraw *et al.* 2006). As autonomy and control over the learning process can be seen as conditions for self-regulated learning (Bergramin *et al.,* 2012), inquiry-based learning opportunities in the classroom may help develop self-regulated learning and self-determination in young students. This view is further supported by considering the links between White and Frederiksen's (1998) model of inquiry learning in science and the social-cognitive model of self-regulated learning adopted in this thesis (discussed earlier in Section *2.4*). As the CREST programme is a student-driven inquiry experience and considering the links between inquiry-learning in science and the model of self-regulated learning adopted in this thesis, it is possible that participation in the programme may foster the development of self-regulated processes and motivations among students. Further, as the literature highlights that interventions need to be easily implemented in natural classroom environments (Martin & McLellan, 2008), this research is therefore particularly pertinent as it investigates the CREST programme within its natural classroom setting.

Before the CREST programme begins, teachers meet with a member of the CREST team, a *mentor*, to become familiar with the programme and obtain support regarding programme administration strategies. Similar to the intervention developed by Boekaerts (1997) aimed at fostering cognitive and motivational self-regulation, the teachers in the CREST programme are encouraged in this session to refrain from giving explicit procedural help to students, allowing them to reflect on their learning. This aspect of the programme may also address the concerns voiced by science educators and researchers through encouraging ‘true’ science investigations and moving away from recipe-type structured investigations (Dillon, 2008; Lazarowitz & Tamir, 1994; Tobin *et al.,* 1994). Research support is rapidly growing for implementing inquiry-based learning opportunities in science classrooms, particularly in the laboratory context as discussed earlier in Section *2.4*. However, while the use of laboratory activities in science classrooms is growing, documented by research reviews of the topic, there appears to be a lack of ‘true’ investigations (Abrahams & Reiss, 2012; Lazarowitz & Tamir, 1994; Tobin *et al.,* 1994).

While laboratory investigations are aimed at developing higher-order cognitive thinking skills, research has documented that the majority of them are very prescriptive and that there is a tendency among educators to rely solely on ‘recipe’ science experiments using lower level skills as opposed to open-ended, student-led investigations (Dillon, 2008; Fisher, Harrison, Henderson, & Hofstein, 1998). Almost two decades ago, researchers urged educators and administrators to move away from relying on lab manuals with prescribed guidelines, and allow students to formulate their own procedures to test their hypotheses (Lazarowitz & Tamir, 1994). The difficulty of conducting these open-ended investigation activities in the classroom setting may provide an explanation for the resistance seen in science classrooms today regarding the uptake of these suggestions. The CREST programme is structured in a way that allows the student-led projects to be initiated and conducted by the students, with teachers merely facilitating the learning. Researchers have also highlighted the importance of teachers being confident and having high efficacy for implementing new development strategies in their classrooms (Gaskill & Hoy, 2002). By providing teachers with appropriate training and support, and structuring the materials to help students take control of their projects and science learning, the CREST programme may help make the classroom transition involved in implementing this new activity easier for the students, and for the teachers involved.

The programme begins with teachers introducing students to CREST and allowing students to select groups of 3-4 peers to work with. At this point, student-led discussions regarding how to work effectively in groups also take place. The CREST programme is structured in a way that allows the students to work together in self-selected groups toward personal goals while also reflecting on their learning in this environment. As the programme is explicitly presented to students as a chance to develop their teamwork skills, understanding the experience of students in the programme has extreme relevance for science education research. In a meta-analysis of self-regulated learning interventions conducted by Dignath & Büttner (2008), larger effect sizes were found for interventions that also contained an element of group work in the programme design. The research conducted by Urdan & Schoenfelder (2006) and Ryan and Patrick (2001) also documented that social aspects of the classroom environment and peer relationships can influence intrinsic motivation, especially for students transitioning from elementary to middle school.

However, while research has shown that working in groups can provide an environment which supports and promotes active reflection, evaluation, and monitoring during inquiry activities (Silver & Marshall, 1990), educators cannot simply place students in science investigation groups and expect positive outcomes (Howe *et al.,* 2007; Tobin *et al.,* 1994). As with self-regulated learning development, students need to be supported in learning how to work collaboratively and develop the skill set necessary for these specific learning environments (Howe *et al.,* 2007; Tobin *et al.,* 1994). As the CREST programme is explicitly presented to students as a chance to develop their teamwork skills and effective collaborative learning strategies are discussed, the design of the CREST programme appears to be in line with research suggestions regarding developing students' abilities to reflect, evaluate, and monitor their learning in science while also supporting teachers in implementing these activities.

During the initial sessions of the CREST programme, classroom teachers work with the students to explore areas of interest and support student groups in formulating a scientific question that they are personally interested in. By allowing students to develop their own project hypotheses and detailed methods, the programme introduces students to the investigative nature of science, addressing the research concerns discussed earlier regarding the development of an appreciation of the nature of science among young students. As self-regulated learning within the framework outlined in Chapter 1 involves goal-directed actions, thoughts, and feelings, providing students with opportunities to work towards goals they have set for themselves and devise their own learning experiences as part of the CREST programme, may also contribute to increases in self-regulated learning, particularly in the *forethought* stage (Boekaerts & Niemivirta 2000). As research has also shown that participating in open inquiry learning activities, giving students opportunities to be autonomous in their learning and have psychological freedom, can increase autonomous motivation and ownership for learning in science students, it is possible that CREST participation will also have this effect (Dillon, 2008; Vansteenkiste *et al.,* 2009). Providing students with opportunities for success and ensuring that students find tasks personally meaningful have also been shown to influence the development of self-efficacy and intrinsic motivation (Pintrich, 2003; Schunk & Miller, 2002). As students are provided with the opportunity to choose projects based on personal interests, CREST may also have a positive impact on the development of these constructs.

By conducting focus groups with young students between the ages of 10 and 14 years, Archer and colleagues (2010) identified that students view the science that happens in the classroom as very different from the 'real science' that scientists perform. Through conducting their work, these researchers found that students view the nature of science as attractive and exciting, but that the science that takes place in school is hard and uninteresting (Archer *et al.,* 2010). As the CREST programme encourages students' appreciation of the investigative nature of science by providing students with the opportunity to perform 'real' science, participation in the programme may help to develop the 'scientific mindsets' among students discussed at the beginning of this chapter.

Considering the CREST programme in the context of interventions designed to develop self-regulated learning provides support for understanding this scheme with a self-regulation focus. Relating to the literature, CREST aligns with the Self-Regulation Empowerment Programme (SREP) developed by Cleary and Zimmerman (2004) to foster self-regulated learning in students. Like the SREP, the CREST programme encourages students to set personal goals, monitor and reflect on their performance processes and outcomes, and make adjustments in order to manage independent projects (Cleary & Zimmerman, 2004). The CREST programme also shares similar design elements with the Cognitive Acceleration Through Science Education (CASE) project in the UK centered on developing metacognitive skills in Maths, English, and Science (Adey *et al.,* 1991) and the Project to Enhance Effective Learning (PEEL) in Australia in secondary school science (Baird, 1986 in Wandersee, Mintzes, & Novak, 1994). Like the above interventions, the CREST programme also directly aligns with De Corte, Verschaffel, and Masui's (2004) Competence, Learning, Intervention, Assessment (CLIA) framework for designing classroom environments that foster self-regulated processes. De Corte and colleagues (2004) identify cooperation among students, active knowledge construction, and self-direction as guiding principles for creating these environments. Therefore, while the programme is not explicitly aimed at developing these self-regulated processes among students, the similarities between CREST and targeted self-regulated interventions, as well as to the CLIA framework, are clear.

After deciding on research questions and formulating predictions, students continue to work together in their groups and conduct the experiments while reflecting on their performance and whether they are on track to reach their goals. The experiments are conducted during classroom teaching sessions and teacher guidance is kept to a minimum, prompting students to think for themselves and manage their projects independently. At the conclusion of the sessions, students are asked to present their projects and results to their peers as well as communicate the real-life implications of what they have found. Assessment of the projects is focused around student self-assessments and reflection with an element of teacher feedback as well.

2.9 Implications for this Thesis

Through placing the CREST programme within the context of educational psychology research in the area of self-regulated processes and related motivations, the previous section has provided evidence and justification for investigating this programme as a strategy to develop these constructs among young students. This chapter will conclude with a discussion of some key original contributions to come from the research conducted as part of this thesis.

2.9.1 Investigating Self-Regulated Processes and Related Motivations in Adolescents

Education policy-makers have documented concerns regarding the recent decline of engagement in school science and the decreasing number of students pursuing university study in this subject (Archer *et al.,* 2010). Studies have shown that student interest in science is most threatened between the ages of 10 and 14 years (Archer *et al.,* 2010; Bennett & Hogarth, 2009; George, 2000). As high positive attitudes towards science may be related to higher performance outcomes (Hattie, 2009; Martin, Mullis, Foy, & Stanco, 2012), these trends are worrying. Further, in a meta-analysis of studies looking into student interest and attitudes towards science, Awan and colleagues (2011) found that students in developed countries showed lower interest and less positive attitudes in science than students in developing countries. Therefore these issues are extremely relevant for the UK, United States, Canada, Japan, and Korea, (Awan, Sarwar, Naz, & Norren, 2011). Going beyond subject interest, motivational, achievement, and self-regulated learning behaviours have also been shown to decline in students transitioning from primary school to secondary school (Van der Veen, De Jong, Van Leeuwen, & Korteweg, 2005). The research presented in this thesis investigates a strategy to foster science interest and motivation in adolescent science students in the UK between the ages of 11 and 14 years. Considering the recent research concerns discussed here, the potential practical implications to come from this empirical work are clear.

In educational research, there is a large body of literature documenting the self-regulated learning experiences of university students (Zimmerman, 1994, 2000, 2002), and more recently of young children (Whitebread *et al.,* 2009). While researchers initially thought self-regulation and metacognitive abilities were late developing capabilities, there is a shift to an understanding of self-regulation as motivational developments in early childhood (Whitebread *et al.,* 2009). Whitebread and colleagues have performed extensive work conducting qualitative observations studies to understand self-regulated processes in infants. Therefore, the research presented in this thesis aims to contribute to the literature through expanding on the research already performed in younger and older students by focusing on students of an intermediate age. The physical, mental, familial, and educational changes experienced during adolescence further highlight the importance of building on the self-regulation and motivation literature relevant to this age group (Cleary & Chen, 2009; Wigfield & Eccles, 2002).

2.9.2 Investigating Self-Regulated Learning in Natural Classroom Settings

Researchers have identified that investigating self-regulated processes and related motivations in real-life learning environments is necessary in order to further our understanding and provide more accurate information regarding student engagement in these contexts (Gläser-Zikuda & Järvelä, 2008). Without looking at real classroom settings, generalisations concerning the practical implications of research findings are of limited value (Martin & McLellan, 2008). The need for more research in the assessment of classroom self-regulated learning schemes has been documented in the literature (Stoeger & Ziegler, 2008).

In spite of its 20-year history, research investigating the impact of participation in the CREST programme on educational and motivational outcomes is only now starting to be produced. Grant (2007) conducted a study to investigate the impact of the CREST programme regarding student content science knowledge, impressions of the programme, and attitudes and aspirations towards science. Through administering self-report questions to teachers (62) and students (512), Grant (2007) found that both teachers and students thought participating in the CREST programme was a worthwhile experience. Results also showed that students improved their content knowledge in the area of science relating to their investigations, felt they had improved in organisational, practical science, and teamwork skills, and gained more clarity regarding the nature of science and how it is relevant to their every day lives. Regarding attitudes towards science, at the Bronze level of the CREST programme, 50% of students reported more interest in science generally following participation, 33% were more interested in pursuing postgraduate study in science, and 30% were more interested in pursuing a science career. The research conducted as part of this thesis aims to build on the results of Grant's (2007) impact study by placing the research within the framework of psychological theoretical principles and research in order to increase the implications for policy makers, educators, and students.

Pintrich (2003) highlighted that future use-inspired research including intervention studies needs to understand effective ways to implement psychological theoretical principles into classrooms and to empirically examine how they work. Through evaluating a classroom scheme, which is currently being implemented in schools throughout the UK, the empirical research presented in this thesis has direct implications for practice and contributes to the identified knowledge gap relating to self-regulation research in natural settings discussed earlier. By viewing the CREST programme through a lens of educational psychology and understanding the programme's influence on student self-regulated learning and related motivations, this thesis provides an original contribution to both educational psychology research and science education practices. Further, as long-term effects of inquiry-based learning programmes on high school science students attitudes, interest, and motivation for pursuing careers is underexplored in the literature (Gibson & Chase, 2002), the studies conducted in this thesis go beyond exploring the immediate impacts of CREST programme participation on self-regulated processes and related motivations. As much of the previous self-regulation research is correlational (Berger & Karabenick, 2011), by evaluating the CREST programme using a quasi-experimental design, this research provides longitudinal insight into fostering self-regulation and motivation in young students.

In addition to its impact on self-regulated learning and motivation, the classroom environment also contributes to the success of problem solving and inquiry-based learning activities (Gabel & Bunce, 1994). While some classrooms may be more traditional, others place more focus on inquiry skills and developing autonomous learners (Pintrich, 2003). Researchers have identified the need to examine motivation and cognitions in innovative, more constructivist, and inquiry-oriented classrooms in order to help understand how classroom processes create, sustain, and change student motivation (Pintrich, 2003). In line with the literature presented in Chapter 1, Pintrich's suggestion above highlights that in addition to investigating the impact of an inquiry-based learning programme on student self-regulated processes and related motivations (Study 1 presented in Chapter 4), important insight can be gained by investigating potential differences in classroom experiences through participation in the CREST programme (Study 2 presented in Chapter 5). Similar to general self-regulated learning research, research examining classroom influences has often not been conducted in realistic, natural classroom settings and has been correlational in nature (Urdan & Schoenfelder, 2006). As the research presented in this thesis adopts a quasi-experimental, longitudinal design, the results and interpretations of the findings to come from Study 2 will contribute to the studies in this area.

Research has shown that there is a predictive relationship between motivation and self-regulation among students and academic outcomes (as discussed in Chapter 1). However, researchers are now focusing additional efforts on the influence of these processes relative to different learning contexts (Cleary & Chen, 2009). Recent publications have stressed the need for self-regulated learning research to be conducted in as specific a context as possible as students' use of self-regulatory strategies is dependent on the educational context in which they are being implemented (Kaplan *et al.,* 2009; Pintrich, 2003). Building on the work of researchers who have been developing our understanding of self-regulation in science classrooms and highlighting the importance of metacognitive focused science instruction (Adey, 1992; Driver, 1989; Driver & Oldham, 1986; White & Frederiksen, 1998; Zohar, 2004, Zohar & Dori, 2012), this thesis looks at the self-regulation processes and related motivations in adolescent students in science classrooms during an inquiry-based learning project. Therefore, the findings to come from the research presented in this thesis will contribute to the knowledge and understanding in this field. Current theoretical discussions regarding the way science is taught in schools around the globe further highlights the relevance of conducting this research in science classrooms and improving science learners' experience in our educational systems internationally (Fensham, 2009). In addition, by studying self-regulatory processes in science education, the research presented in this thesis contributes to the transferability of current self-regulation and motivation research findings to other academic domains.

2.10 CHAPTER SUMMARY AND CONCLUSIONS

Through describing recent shifts in the approach taken to science education, and presenting a discussion of problem solving and inquiry-based learning activities in relation to models of self-regulated learning and metacognition, this chapter has connected the model of self-regulated processes and related motivations adopted in this thesis (presented in Chapter 1 Section *1.7*) to a specific learning task in the science classroom; inquiry-based learning. By also introducing the CREST programme and placing it within the context of relevant intervention research in self-regulation, a framework for understanding its relevance for the studies to be presented in this thesis was provided. Given the theoretical and empirical support for the role of investigative learning opportunities in promoting self-regulated processes and related motivations, the CREST award scheme has been presented in this chapter as a viable means through which to investigate the development of self-regulated processes and related motivations (presented in Chapter 1) in young students.

Considering the points highlighted in these two literature chapters, this thesis addresses gaps in the literature relating to: *1) conceptualising and measuring the key constructs of interest; 2) fostering self-regulated processes and related motivations in adolescent science students;* and *3) conducting longitudinal research in natural classroom settings using quasi-experimental designs*. Together, these initial chapters have outlined the need for this research and have foreshadowed the potential impact and the original, distinct contributions to knowledge offered.

In light of the key points made in these first two literature chapters, three main research questions were developed for the empirical work presented in this thesis. Firstly, this thesis investigates whether participating in the CREST programme has an impact on developing self-regulated processes and related motivations among young science students. Considering the structure of the CREST programme within the context of similar educational interventions discussed in Section *2.8*, it is predicted that participation will have an impact on these key constructs among students. The second question that this thesis addresses is whether all classes of students experience the CREST programme in similar ways. The rationale for this research question is provided by the discussions in Section *2.9.2* relating to conducting research in natural classroom settings. Due to the nature of individual classroom environments, it is predicted that the programme will have different levels of impact for each of the classrooms participating. Finally, going beyond the immediate impact of programme participation, this thesis also investigates whether the programme has a lasting impact on students' development of self-regulated processes and related motivations, as the need for more longitudinal research in this area has been identified (Duckworth, Akerman, MacGregor, Salter, Vorhaus, 2009; Pintrich, 2003; Zimmerman, 2008). Considering the interest seen in life-long learning and that long-term retention of self-regulated learning is needed in order to facilitate transfer of these strategies to learning beyond the school years, provides further rationale for this line of inquiry. It is predicted that any benefits through programme participation will be maintained on the longer-term assessments of the key constructs of interest.

This thesis will now continue with a detailed justification and outline of the methods and analyses employed (Chapter 3) before presenting and discussing the findings of each of the three empirical studies conducted in this thesis (Chapters 4, 5, & 6). In addition to the discussions relating to the findings of each of the three studies in isolation, a synthesis discussion of the results and implications of the work conducted as part of this thesis will be presented in the final chapter (Chapter 7).

3

METHODOLOGY: AN OVERVIEW AND JUSTIFICATION

Chapter Objectives

This third chapter aims to provide an overview of the methodology and design of the empirical work conducted as part of this thesis. After outlining and justifying the general framework, research approach, and design of the three studies (presented in Chapters 4, 5, & 6), a detailed summary and justification of the methods and measurement tools used will be provided. This chapter will conclude with a discussion outlining and justifying the analytical approaches chosen for the three studies. Discussions relating to the strengths and weaknesses of the methodological approaches selected will be incorporated throughout the chapter to demonstrate an awareness of the limitations of the research presented. The resulting implications, in terms of the interpretation of the findings reported in the following three empirical chapters, will also be included in these discussions. By providing this overview and justification for the methodological choices made with regards to the research conducted, this chapter provides support for the validity of the research findings to come from this empirical work.

3.1 INTRODUCTION

The previous two chapters (Chapters 1 & 2) introduced the relevant bodies of literature necessary in order to understand the research context for the studies conducted as part of this thesis. While Chapter 1 outlined some important considerations when conceptualising the key constructs of interest before arriving at the particular framework adopted for understanding these constructs, the discussions presented in Chapter 2 drew connections between this framework and science education research relating to inquiry-based learning and problem solving. Chapter 2 highlighted several areas requiring further attention in educational research in the field of self-regulated processes and student motivation. Through considering the knowledge gaps identified in the literature, empirically, the research presented in this thesis aims to further understand the impact of student participation in a science inquiry-based learning programme conducted in natural classroom settings, on the short and long-term development of adolescent science students' self-regulated processes and related motivations. The CREST programme was chosen as the inquiry-based learning activity to study, and support for viewing this programme through the lens of educational psychology research was also provided in Chapter 2.

Specifically, this thesis aims to address three research questions: *1) does the CREST programme have an impact on changes in self-regulated processes and related motivations among students? 2) do different classes of students experience the same changes through CREST programme participation?* and *3) are any reported changes in self-regulated processes and related motivations retained in the months following programme participation?* In order to address these research questions, a series of three empirical studies were conducted in three different school settings to increase the generalisability of the findings reported. Having slightly different focuses, all three empirical studies are connected as they each address the first research question of this thesis and follow similar quasi-experimental designs. While the overall research questions of the thesis have been outlined in order to address the knowledge gaps identified in Chapters 1 and 2, the specific research questions and predictions relating to each of the three studies will be presented in more detail in the three empirical chapters (Chapters 4, 5, & 6).

Before presenting the findings of the three studies (in Chapters 4, 5, & 6), this chapter sets out to explain the methodological choices made for the empirical research performed. As detailed descriptions of the methods and procedures relating to each of the three empirical studies are included in the three results chapters to come, the aim of this chapter is to present an overview and justification of the approach taken. The present chapter will now begin with an overview of the general research approach for the empirical work presented in this thesis and why this approach was chosen. A discussion of the challenges of using this approach will also be presented. The chapter will then briefly outline the design of the three studies conducted as part of this thesis, and why these three studies have been performed in order to address the general aims of this thesis, before moving on to present the measurement tools used. As particular attention was paid to decisions regarding the choice of measurement instruments and statistical analyses that best addressed the research aims of each of the three studies, this chapter will also focus on justifying the methodological choices and analytical decisions that were made for the studies conducted. Throughout the chapter, methodological issues regarding the strengths and limitations of different approaches will also be presented in order to provide further support for the methodological decisions made.

3.2 An Overview of the Research Approach

Before outlining the specific research design chosen for the studies presented in this thesis, a brief discussion of the general research approach will now be presented. When making decisions regarding which methods to implement, the academic choices we make as researchers are influenced by our epistemological and ontological positions, and these positions are influenced by personal values about the most appropriate way in which to address individual research questions (Greenbank, 2003; Scott, 2002). It is important that researchers communicate that their methods (both qualitative and quantitative) cannot be value-free and that they are likely to be influenced by personal beliefs (Banks, 1998; Greenbank, 2003; Morrison, 2007). From this, it is apparent that educational researchers need to adopt a reflexive approach and be open with respect to how their personal values influence their research and methodologies. The empirical research presented in this thesis will therefore follow a reflexive approach accepting the subjectivity and the influence of values on the research methods as well as the interpretation of empirical findings (Banks, 1998; Greenbank, 2003; Scott, 2002). Discussions relating to motivations for choosing specific approaches will therefore also be included throughout this chapter in order to demonstrate an awareness of any possible research biases.

Greenbank (2003) highlights that adopting this reflective approach is especially important in educational research, which is often conducted with motives and funding support for policy. While the research performed as part of this thesis was not funded by external bodies or supported by the British Science Association (who oversee CREST programme administration in the UK), the research presented here acknowledges the personal desires of the author to promote the CREST programme as a viable scheme to develop self-regulated processes and related motivations in young students (Greenbank, 2003). This chapter will now move on to present an overview of the study design for the research conducted.

3.3 An Overview and Justification of the Study Design

In a summary report for the National Bureau of Economic Research, Angrist (2003) describes the limitations of educational research involving no control groups and discusses the potential benefit of shifting to a more science-based approach using natural experiments to provide powerful evidence of current effects. Angrist (2003) also suggests that researchers in the field of education should be aiming to make scientifically grounded inferences into the current issues in education today. These research suggestions also extend more specifically into the field of self-regulated processes and related motivational research.

Specifically in educational research relating to self-regulated processes and related motivations, while interventions aimed at developing these constructs are growing rapidly, studies reporting the benefit to students through participation in these programmes are mostly exploratory and researchers have outlined that more rigorous, controlled studies are needed (Berger & Karabenick, 2011; Wandersee *et al.,* 1994). As previously stated in Chapter 2 Section *2.9.2,* the majority of studies investigating self-regulated processes and related motivations are correlational or cross-sectional in nature and researchers have determined the need for more longitudinal, developmental studies in this research area in order to gain insight into attainment and retention of these key constructs (Duckworth *et al.,* 2009; Pintrich, 2003; Zimmerman, 2008). The documented decrease in student levels of self-reported motivation and some self-regulated processes over the course of the school year as well as throughout the school years further highlights the importance of extending these methodologies over longer periods of time (Berger & Karabenick, 2011; Zimmerman, 2008). As long-term retention of self-regulated learning is essential in order to promote transfer of these strategies to general life-long learning, discussed previously in Chapter 1 Section *1.2,* understanding these changes in young students is particularly relevant. As the research conducted in this thesis deals specifically with science education, and considering the fast developments of technology in the field of science and engineering, this need is additionally important for this specific research context.

The research presented in this thesis aims to contribute to the knowledge base in the area by implementing a quasi-experimental *pre-test-post-test* design involving both *intervention* (students participating in the CREST programme) and matched *control* groups (students not participating in the CREST programme). Prior to CREST participation, students will receive an initial baseline pack of standardised questionnaires to assess self-regulated processes and related motivations in science. At the conclusion of the programme (or equivalent timeframe for students in the control groups), a post-test will be administered to all students using the same standardised measures as the pre-test. Delayed post-tests will also be administered to students several months following programme completion. As the research presented in this thesis follows the longitudinal development of students' self-reports of self-regulated learning and related motivations, it has potential to provide an original contribution to the advancement of the field. By looking at the CREST inquiry-based learning programme in three different school settings, this research also adopts a slight case study approach for how CREST is implemented and may provide insight into optimal administration strategies for the programme. This process and outcome evaluation and design will also allow for cross-study comparisons to be made in the final discussion chapter (Chapter 7). Before outlining the methodological decisions made for this research, a general overview of the three empirical chapters to come will now be presented.

Study 1 (Chapter 4) investigates the impact of CREST participation on student self-reported levels of self-regulated processes and related motivations, addressing the first research question of this thesis, by means of looking at differences in mean *change* scores from pre-test to post-test between students participating in CREST and a control group of students not taking part in the programme at the time of the study. This study will also investigate whether any observed changes are maintained six months following CREST programme participation, addressing the third research question. Study 2 (Chapter 5) examines the impact of the CREST programme at the class level for an entire year-group of students at an individual school addressing the second research question of this thesis. Through also comparing the pre- to post-test changes of the classes taking part in the CREST programme to a reference control class, this second study design allows for comparisons to be drawn from the findings of Study 1, therefore also addressing the first research question. Study 3 (Chapter 6) builds on the findings of the previous two studies and uses a more complex design involving two different CREST conditions in order to gain a more in-depth understanding of any longer-term retention effects of the CREST programme (Research Question 3). This final study also includes an element of teacher data in order to provide a more complete picture of the changes in self-regulated learning taking place from both the student and teacher perspectives. The data presented in Study 1 has been published in *The Journal of Cognitive Education and Psychology* and both Studies 2 and 3 are currently being drafted for journal submission.

As evident from this outline, the three studies included in this thesis follow a quantitative approach. The use of this approach to research methods and data analysis will now be justified before moving on to discuss the validity of the quasi-experimental pre-test post-test research design adopted for the research presented in this thesis.

3.3.1 Rationale for Using the Quantitative Approach and Self-Reports

The on-going debate in educational research regarding qualitative versus quantitative methodology meant that careful consideration was taken before settling on an approach to answering the specific research questions (outlined in Chapters 4, 5, & 6 along with the empirical findings of the three studies). The strength and justification for using quantitative methods is that the research presented in this thesis is particularly aimed at investigating group *variance* and temporal *changes* in the constructs of interest. While qualitative research on self-regulated processes is advancing rapidly (led by Whitebread and colleagues, 2009), the quantitative approach was taken in order to look at these sensitive *changes* over time. Further, conducting quantitative research investigating the impact of participation in the CREST programme on student self-regulated processes and related motivations will also build on the research conducted by Grant (2007) regarding student experiences in the CREST programme (discussed in Chapter 2 Section *2.9.2*).

There are currently a multitude of choices for research regarding how to measure self-regulated processes and motivations in students of all ages. Among these, qualitative observational measures are gaining support in the literature on student self-regulated processes, especially in young children. These measures record what students are *doing* rather than what they *recall* they are doing, and do not depend on the verbal abilities of learners (Whitebread *et al.,* 2009). Video recording is also becoming increasingly popular among researchers as it allows verbal and non-verbal behaviours, as well as social processes, to be documented in naturalistic settings in relation to self-regulated learning (Ainley & Patrick, 2006; Whitebread *et al.,* 2009).

In the particular context of the research presented in this thesis, conducting qualitative investigations incorporating classroom observations would be difficult as ideally, the observer would be unaware of which experimental group students belonged to (Campbell & Stanley, 1966). Focus groups were also considered for the research presented in this thesis, however, this methodology was not chosen as social pressures within groups were predicted to significantly affect the results for students of this age group (Kitzinger, 1994). In addition, due to the personal nature of self-regulated processes and related motivations and the fact that the research in this thesis is interested in looking at *changes* in specific constructs at the individual student level, further support for not using focus groups as the main method of analyses is provided. Research has also been conducted in the field using the qualitative case study approach involving interviews and performing content analyses (Whipp & Chiarell, 2004). However, as an underlying aim of this thesis was to maximise the practical utility of any research findings documented, these procedures may be too involved for teachers who are not cognitive researchers in the field. Therefore, while semi-structured interviews, focus groups, and qualitative classroom observations were considered, the main method of analysis chosen for the research presented in this thesis was self-report questionnaires. A brief discussion will now follow relating to some issues regarding the use of these measures.

One of the benefits of using self-report questionnaire instruments is that they can be tailored to specific study contexts (Bergamin *et al.,* 2012). Going back to the literature discussed previously in Chapters 1 and 2 relating to the context-specific nature of self-regulated processes and related motivations, this is a desirable quality for a measurement instrument in this field of research. Using self-report instruments also allows researchers to view key variables through the eyes of actual students, which can capture data that an outside observer may miss (Fraser, 1994; Severiens, Ten Dam, & Van Hout Wolters, 2001). The use of self-report questionnaire measures in the research presented in this thesis is further supported by the practical implications of administering them, as they can easily be implemented in classrooms and administered by teachers to assess self-regulated processes and related motivations in young students (Severiens *et al.,* 2001).

While there is substantial support in the literature for using self-report measures in educational research, some assumptions need to be addressed before moving on to discuss validity issues relating to the design of the studies included in this thesis. Using self-report measures, the empirical research presented in this thesis assumes that participants, young students, have the ability to verbally understand and report their thoughts and feelings (Whitebread *et al.,* 2009). However, researchers have identified that this may not always be the case and can lead to measurement error (Field & Hole, 2003; Whitebread *et al.,* 2009). With regard to the work presented in this thesis, as the students involved were between the ages of 11 and 14 years, the self-report instruments were deemed appropriate.

3.3.2 Validity Issues Relating to Quasi-experimental Pre-test Post-test Designs

Having justified the quantitative approach taken and the use of student self-reports, an awareness of some issues relating to this study design will now be presented. While there is growing support for using quasi-experimental designs in educational research and incorporating the use of a control group for comparison, there are several issues relating to internal validity that need to be discussed. Among these are: practice effects of testing, maturation, and history effects (Campbell & Stanley, 1966; Dimitrov & Rumrill, 2003; Field & Hole, 2003).

In addition to testing effects that can come from completing similar questionnaires on multiple occasions, completing a pre-test can, in some cases, have an effect on the observed impact of the intervention as it sensitises students to the strategies and motivations discussed in the questionnaires (Campbell & Stanley, 1966; Dimitrov & Rumrill, 2003). To reduce the chances of pre-testing effects, the questionnaires used in this thesis were formatted to ensure that they were similar to the work students would encounter normally in the classroom following the suggestions of Campbell & Stanley (1966). In addition, all materials were printed on coloured paper to prevent students from viewing the instruments as a test (Abdullah & Lee, 2007).

While maturation (biological and physical changes in participants during a study that can influence post-test scores) and testing effects are often issues for educational research looking at development over time, the design of the research conducted in this thesis helps to control for these factors as both the control and experimental groups in this research experience the same instrumentation, procedures, and attend the same school with no notable differences regarding school and pedagogical experiences (Campbell & Stanley, 1966; Field & Hole, 2003). As the research presented in this thesis also appreciates that experimental attrition can introduce subtle sample biases, only students with completed pre-tests and post-tests were included in the analyses in both the control and experimental groups across the three empirical studies (Campbell & Stanley, 1966).

In addition to history effects relating to events taking place during the intervention timeframe that can influence post-test scores, the research represented in this thesis also appreciates the possibility of intra-session history effects as different teachers implemented CREST and administered the questionnaires. While this issue may have been reduced by selecting the researcher to administer the CREST programme and standardised questionnaires, the decision was made to have teachers as the administrators. Using classroom teachers in intervention research has advantages as it does not disrupt the natural research setting, which can help reduce any reactive effects from students taking part in research studies (Campbell & Stanley, 1966; Dimitrov & Rumrill, 2003). Therefore, teachers were chosen to administer the CREST programme as well as the questionnaires in order to make the empirical research conducted in this thesis valid externally and ecologically, and to extend the generalisability of the study findings to other classes and schools (Campbell & Stanley, 1966; Dimitrov & Rumrill, 2003; Pugh, Linnenbrink-Garcia, Koskey, Stewart, & Manzey, 2010).

In addition to issues relating to internal validity, several issues regarding the external validity of the research presented in this thesis also need to be addressed. One issue relating to external validity that should be discussed at this point is the choice of schools to be included in the empirical work. As mentioned earlier, three schools were included in the empirical studies conducted, however, an additional school was also approached to participate and declined. This school was intended to be a control school in the design of Study 2 (presented in Chapter 5) as no students at the school were participating in the CREST programme. Therefore, the research to be presented in the following three chapters (Chapters 4, 5, & 6) appreciates that the schools taking part in the research presented (all of whom were previously enrolled in the CREST programme) may be atypical in having higher morale, less fear of being inspected, and more desire for improvement and development (Campbell & Stanley, 1966). In this, it is possible that the three schools chosen are not representative of the larger general population and any effects found might be limited to the specific schools studied (Campbell & Stanley, 1966; Fensham, 2009). However, being explicit about the school that declined participation allows the readers of this thesis to gauge the severity of possible selection biases (Campbell & Stanley, 1966). These issues will be considered further in the final discussion chapter (Chapter 7).

3.4 Ethical Considerations

Prior to commencing the studies, ethical approval was obtained from the University of Edinburgh (see Appendix A). After communicating with the Headteachers of each of the three schools, classroom teachers were contacted to participate in the research. It was relayed at this point that no research would be published without verification from the participating schools. Parental and teacher consent, as well as child assent (see Appendix B), were also received and data was coded following the ethical guidelines set by the University of Edinburgh and the British Psychological Society (Caprara *et al.,* 2008). Before completing the first questionnaire, teachers were instructed to read the procedure script out to students (included in Appendix C). The script also communicated to students that they were free to decline or withdraw their participation at any time. Consideration regarding the equal treatment of the control groups was taken by allowing delayed access to the intervention where possible. Further ethical considerations will be outlined in the methods sections relating to the three empirical chapters (Chapters 4, 5, & 6).

3.5 Data Collection and Student Samples

Primary data sources were used in order to address the specific research questions of the three empirical studies included in this thesis. Before selecting the schools to participate in this research, the coordinator of the CREST programme for Scotland was contacted in order to gain information regarding which schools in Edinburgh and the surrounding area participate in the programme. Three schools participated in this research project; two independent schools in Edinburgh and one state school in

Glasgow from high catchment areas. Approximately 450 adolescents between the ages of 11 and 14 years participated. Specific information relating to the student samples for each of the three studies will be presented in detail in each of the three empirical chapters (Chapters 4, 5, & 6).

3.6 An Overview of the Self-Report Measures Used in this Thesis

Having outlined the general research approach and design of the empirical work conducted in this thesis, this chapter will continue with an overview of the self-report measures chosen for the research presented here. After arriving at the decision to use self-report measures for the constructs of interest, considerable care was taken in choosing the particular questionnaire measures, as the use of measurement tools without appreciating their theoretical roots and limitations has been highlighted in educational research on self-regulated processes and student motivation (Kaplan, 2008; MacLellan & Soden, 2006; Pintrich, 2000, 2004).

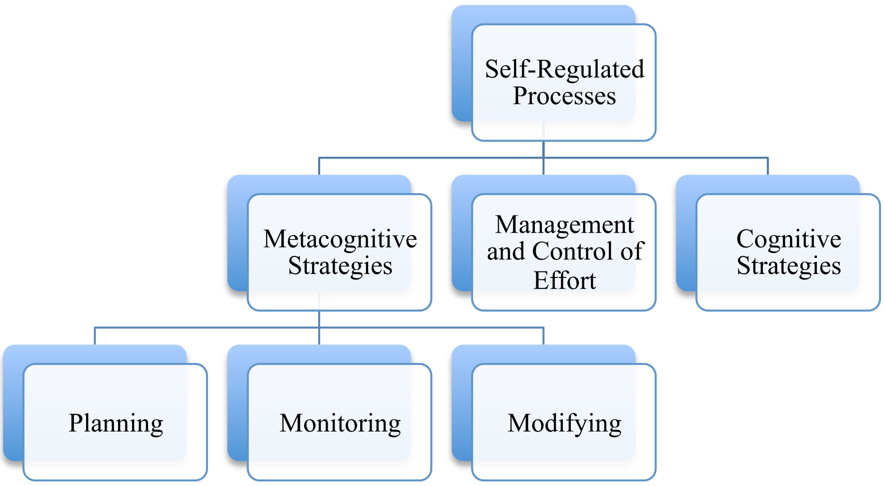
Chapter 1 presented a framework for understanding self-regulated processes and related motivations within the context of this thesis and this understanding of the key constructs informed the empirical work conducted. Recapping from Chapter 1, according to social-cognitive researchers, self-regulated learning involves three or four interdependent phases through which learners manage their academic progression: *forethought*, *monitoring*, *control,* and *reflection* (Pintrich & De Groot, 1990; Wolters, 2010; Zimmerman, 2002). In his framework, Pintrich (2004) lists the self-regulatory activities involved in each of the phases in four separate areas: cognitive, motivation and affect, behaviour, and context. This thesis adopts this multi-dimensional framework for understanding self-regulated learning and, following suggestions presented in recent literature, decisions regarding the measurement tools used in the three studies conducted were guided by this conceptualisation of the constructs (Kaplan, 2008; MacLellan & Soden, 2006). In order to contribute to the disparity seen in the literature regarding the multitude of measures available for the constructs of interest, standardised questionnaires were chosen over developing new measurement instruments for the research presented in this thesis.

As Pintrich's framework for understanding the constructs of interest was adopted, his original measurement tool (the Motivated Strategies for Learning Questionnaire, MSLQ; Pintrich & DeGroot, 1990) was considered for the research presented in this thesis. The MSLQ was selected for this research as it has been extensively used in the literature worldwide, reflecting the reliability and validity of the instrument. Connecting more closely to the framework adopted for the constructs of interest in this thesis, the MSLQ also includes scales for the related motivational factors incorporated in this framework (presented in Chapter 1). Therefore, while some researchers reject the MSLQ because it has self-regulation as a relatively small focus (Weinstein, Zimmerman, & Palmer, 1988), as the research presented in this thesis is interested in related motivational constructs, using this measure allows for all constructs within the adopted framework for understanding self-regulated processes and related motivations to be investigated. The MSLQ has also been used in adolescent science education research, which is of particular relevance for the work presented in this thesis (for a more detailed overview of the MSLQ and its use in past research see Wolters *et al.*, 2003).

However, the original self-report measurement tool Pintrich used (the MSLQ) was developed more than ten years before he finalised the framework described above and in Chapter 1, and therefore does not capture the full picture of self-regulated learning. Pintrich (2004) suggested that the additional factor of context should be included within models of self-regulated learning. As such, connecting with the framework adopted in this thesis for understanding the constructs, in addition to using the MSLQ, MacLellan and Soden's (2006) measurement tool (a modified version of the Martinez-Pons [2000] Five Component Scale for Self-Regulation, FCSSR) was also included in the research presented in this thesis, as it focuses additionally on the environmental context students are learning in. This second measure utilised also complements the MSLQ as it provides an exclusive self-regulated learning focus and has been validated in Scottish schools.

Based on a social-cognitive model, the modified version of the FCSSR includes goal setting, strategy monitoring, and strategy implementation subscales, which together make up the measure of self-regulated learning (MacLellan & Soden, 2006). Both the MSLQ and FCSSR are comprised of three components, which map well onto each other within the framework of self-regulated processes described in Chapter 1. The first component involves metacognitive strategies including planning, monitoring, and modifying, and the second component relates to students managing and controlling their efforts on tasks. The third and final component shared between these measures is cognitive strategy use. Figure 3.1. below presents a visual summary of these self-regulated process components of the chosen methods.

Figure 3.1. Modified self-regulated processes framework relating to measurement tools (MacLellan & Soden, 2006; Martinez-Pons, 2000; Pintrich, 2000, 2004; Pintrich & De Groot, 1990).



The Science Motivation Questionnaire (SMQ; Glynn *et al.,* 2009) was chosen to provide insight into the science specific motivations of students, connecting again to the framework adopted for the constructs in this thesis. Developed to take into account recent literature regarding the motivational components involved in the self-regulatory process and also with the help of science teachers and science students, this questionnaire asks students to answer questions on intrinsic motivation, self-efficacy, test anxiety, and career motivation in science. This measure also includes items for self-determination, a construct that was also incorporated in the self-regulated processes framework described in Chapter 1 Section *1.7*. Before presenting these three measures in detail relating to the specific constructs of interest, alternative measures that were considered will be discussed.

Similar to what is seen in the literature regarding definitions, agreeing on a unified measurement tool for self-regulated learning has proved to be difficult and there are currently several tools used to measure this construct in the academic learning context. As with the limitations discussed in Chapter 1 relating to the implications of research findings being constrained to the particular framework for understanding the constructs of interest, the choice of measurement tools also constrains the results of the empirical work presented in this thesis. While the three self-report measures were carefully chosen for the research presented, several others were considered and are presented below in Table 3.1.

Table 3.1. A summary of the measures considered for the empirical work conducted as part of this thesis.

Self-Report Questionnaire Measure	***Justification For Exclusion***
Self-Regulatory Skills Measurement Questionnaire (Yang, 1991)	Adaptation of the MSLQ (Martinez-Pons & De Groot 1990) with deletion of the motivational beliefs scales. Considering the importance of related motivations in the conceptual framework outlined in Chapter 1, this measure was excluded.
Survey of Learning Behaviours Instrument (Chularut & DeBacker, 2004)	Used with older students (15-22 years) mainly in ESL looking at concept mapping strategies with little focus on self-regulated processes and related motivations.
The Learning and Study Strategies Inventory (Weinstein & Palmer, 1990)	Focuses on general approach to learning not self-regulated processes specifically.
Self-Regulation Strategy Inventory Self-Report (Cleary, 2006)	Used with older students and has an entirely self-regulation focus.
Academic Self-regulated Learning Inventory Scale (Magno, 2010)	Developed to measure self-regulation in college students and does not contain any motivational measures.
The Students Like Learning Science Scale (Martin *et al.,* 2012)	Used in the TIMSS study and considered as a measure for intrinsic motivation and interest. Not chosen as the links to the conceptual framework were more defined for the MSLQ and SMQ. Additionally, this measure was developed after the first study was conducted. Therefore, in order to allow cross-study comparisons to be made, it was not chosen for the final two empirical studies.
The Students' Adaptive Learning Engagement in Science Instrument (Velayutham, Aldridge, & Fraser, 2011)	Focuses on motivation and self-regulation in science but was developed after conducting the first study of this thesis. While this measure might have been appropriate, it was deemed important to ensure consistency of the measurement instruments across the three studies.

From Table 3.1 on the previous page, it can be seen that there are several related measures available in the literature that might also have been appropriate for the research conducted in this thesis. Therefore, while excluding a multitude of measurement tools available in the literature, the empirical work presented in this thesis does not naively assume that only the measures chosen are appropriate. However, in the context of the particular framework adopted for the constructs of interest and the research aims of the work presented, their selection is justified. Appreciating the different conceptualisations and measurement tools available for self-regulated processes, the empirical research in this thesis does not assume that it can contribute to the discontinuity seen in conceptualisations of self-regulated processes in the literature. Instead, it is assumed that by using the model and definition of self-regulation outlined in Chapter 1 of this thesis, the measurement tools chosen will measure the conceptualisations adopted for the key constructs of interest and highlight the connections between the framework for understanding and the methodological tools chosen.

3.7 Questionnaire Subscales Measuring the Key Constructs of Interest

Following on from a description of the self-report questionnaires chosen and a justification for their selection, the piloting process will now be described before presenting the details of each measure in relation to the key constructs of interest. The items will be presented in full in this section, and again more briefly in each of the three empirical chapters (Chapters 4, 5, & 6), along with the scale reliabilities calculated for the measures in each of the student samples.

The three questionnaires chosen were piloted with 40 students matching the target populations for the students included in this thesis (S1, 11-12 years of age and S2, 12-13 years of age). A list of 5 questions was also included at the end of the questionnaire pack relating to the clarity of the instructions and questionnaire items as well as the aesthetics of the questionnaire layout (see Appendix C). Four science teachers reviewed the questionnaire items, minor revisions were made, and piloted for a second time with another 80 students (S1, 11-12 years of age and S2, 12-13 years of age). In an attempt to ensure that the programme was similarly implemented among classes, the piloting process also included observing how the teachers implementing CREST in the studies presented administered the programme with a group of students the previous year. In addition, the British Science Association was contacted and information regarding what quality control measures were in place for the CREST programme across schools throughout the UK was obtained. After discussions, it was felt that the teachers administered the programme in very similar ways and no further related teacher data was collected. This section will now continue with an overview of the subscales used to measure each construct.

3.7.1 Self-Regulated Processes

The self-regulated learning strategies scales from the MSLQ (Self-Regulation[1] and Cognitive Strategies Use), the total score on the FCSSR, and the SMQ Self-Determination Scale were used to measure self-regulated processes in this study. The Self-Regulation Scale on the MSLQ included nine items relating to *metacognitive strategies* ("I ask myself questions to make sure I know the material I have been studying") and *effort management* ("When work is hard, I either give up or study only the easy parts"). For the Cognitive Strategies Use Scale on the MSLQ, students completed 13 items relating to the use of *rehearsal* ("When I read material for science class, I say the words over and over to myself to help me remember"), *elaboration* ('When I study for a science test, I put important ideas into my own words"), and *organisational* strategies ("I outline the chapters in my textbook to help me study"). All items were scored on a 7-point Likert scale (1= not at all true for me, 7= very true for me) and are shown in Appendix C included in this thesis. The FCSSR comprised a total of 45 items including *goal setting* ("When doing my academic work, I always set goals to guide me in my efforts"), *strategy implementation* ("I take notes during class"), and *strategy monitoring* ("I compare the strategy to other strategies to see which is more effective"). All items on this measure were scored on a 4-point Likert scale (1= never, 4= all the time) and are shown in Appendix C.

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[1] Within Pintrich's understanding of self-regulated learning, the metacognitive strategies and effort management scales were collapsed into one scale called 'self-regulation' (Pintrich &

The Self-Determination Scale from the SMQ was also included in the self-regulated processes analysis as described in Chapter 1 within the framework adopted for self-regulated processes. This scale was made up of four items that students rated on a 5-point Likert Scale (1= never, 5= always) and is shown in Appendix C. Table 3.2 below presents a summary of the individual items on these measures relating to the specific constructs of interest. The 45 items on the FCSSR, which make up the self-regulated learning scale are, as mentioned earlier, presented in full in Appendix C. Also included in Table 3.2 are references to any changes that were made to the questionnaire items as a result of the pilot work described earlier.

Table 3.2. A summary of the self-regulated process items on the MSLQ and the SMQ.

	MSLQ Self-Regulation
1	I ask myself questions to make sure I know the material I have been studying
2	When work is hard, I either give up or study only the easy parts (r)
3	I work on practice exercises and answer end of chapter questions, even when I don't have to
4	Even when study materials are dull and uninteresting, I keep working until I finish
5	Before I begin studying, I think about the things I will need to do to learn
6	I often find that I have been reading for class but do not know what it is all about (r)
7	I find that when the teacher is talking I think of other things and don't really listen to what is being said (r)
8	When I'm reading I stop once in a while and go over what I have read
9	I work hard to get a good grade even when I don't like a class
	MSLQ Cognitive Strategies Use
1	When I do homework, I try to remember what the teacher said in class so I can answer thee questions correctly
2	When I study for a test, I try to put together the information from class and from the book*
3	It is hard for me to decide what the main ideas are in what I read (r)
4	When I study I put important ideas into my own words
5	I always try to understand what the teacher is saying even if it does not make sense
6	When I study for a test I try to remember as many facts as I can
7	When studying, I copy my notes over to help me remember material
8	When I am studying a topic, I try to make everything fit together
9	When I study for a test I practice saying the important facts over and over to myself
10	I use what I have learned from old homework assignments and the textbook to do new assignments
11	When I read material for this class, I say the words over and over to myself to help me remember
12	I outline** the chapters in my textbook to help me study
13	When reading, I try to connect the things I am reading about with what I already know
	SMQ Self-Determination
1	I put enough effort into learning the science
2	I prepare well for the science tests and labs
3	I use strategies that ensure I learn the science well
4	If I am having trouble learning the science, I try to figure out why

Note. (r) designates an item that was reverse scored after completion and before data analysis. * 'book' changed to 'textbook'. ** 'outline' changed to 'outline/summarise'.

3.7.2 Related Motivational Constructs

Self-efficacy was measured using scales from the MSLQ and the SMQ. The MSLQ scale included nine items scored on a 7-point Likert scale (1= not at all true for me, 7= very true for me) and the SMQ scale included 4 items which students rated on a 5-point Likert Scale (1= never, 5= always). Table 3.3 below presents a summary of the items on each of these subscales with no changes made as a result of the pilot work conducted.

Table 3.3. A summary of the self-efficacy items on both the MSLQ and the SMQ.

	MSLQ Self-Efficacy
1	Compared with other students in this class, I expect to do well
2	I am certain I can understand the ideas taught in this course
3	I expect to do very well in this class
4	Compared with other students in this class, I think I am a good student
5	I am sure I can do an excellent job on the problems and tasks assigned in this class
6	I think I will receive a good grade in this class
7	My study skills are excellent compared with others in this class
8	Compared with other students in this class, I think I know a great deal about the subject
9	I know that I will be able to learn the material for this class
	SMQ Self-Efficacy
1	I believe I can master the knowledge and skills in the science course
2	I am confident that I will do well on the science labs and projects
3	I am confident I will do well on science tests
4	I believe I can earn a grade of ‘A’ in the science course

For intrinsic motivation, two measures were also used aligning with the task value dimensions defined by Eccles *et* al. (1983), with the exception of *cost*. The 9-item intrinsic value scale from the MSLQ included items relating to *interest* (“I think what we are learning in this science class is interesting”), perceived *importance or attainment value* (“Understanding this subject is important to me”), preference for *challenge* (“I prefer class work that is challenging so I can learn new things”), and *utility* (“I think what I am learning in science is useful for me to know”). The intrinsic motivation and personal relevance scale from the SMQ was also used and included 10 items relating to *interest* (“I enjoy learning the science”), *importance* (“The science I learn is more important to me than the grade I receive”), *challenge* (“I like science that challenges me), and *utility* (“The science I learn is relevant to my life”). The complete set of items relating to these motivations is shown in Table 3.4 on the next page.

Table 3.4. A summary of the intrinsic motivation items on both the MSLQ and the SMQ.

MSLQ Intrinsic Value	
1	I prefer class work that is challenging so I can learn new things
2	It is important for me to learn what is being taught in this class
3	I like what I am learning in this class
4	I think I will be able to use what I learn in this class in other classes
5	I often choose paper* topics I will learn something from even if they require more work
6	Even when I do poorly on a test, I try to learn from my mistakes
7	I think that what I am learning in this class is useful for me to know
8	Understanding this subject is important to me
SMQ Intrinsic Motivation and Personal Relevance	
1	I find learning the science interesting
2	I enjoy learning the science
3	The science I learn has practical value for me
4	The science I learning is relevant to my life
5	The science I learn is more important to me than the grade I receive
6	The science I learn relates to my personal goals
7	I like science that challenges me
8	Understanding the science gives me a sense of accomplishment
9	I think about how I will use the science I learn
10	I think about how the science I learn will be helpful to me

Note. *'paper' changed to 'assignment or project' as students in S1 and S2 are not required to write papers or essays.

Two measures were used for test anxiety; the 4-item scale from the MSLQ ("I am so nervous during a test that I cannot remember facts I have learned") and the 5-item scale from the SMQ ("I become anxious when it is time to take a science test") both with a higher score relating to more anxiety for taking tests. While the items on the test anxiety scale for the SMQ are commonly reverse scored, in order to ease the interpretation of the results presented, the items were left as reported. Table 3.5 below presents a summary of these items relating to test anxiety.

Table 3.5. A summary of the test anxiety items on both the MSLQ and the SMQ.

	MSLQ Test Anxiety
1	I am so nervous during a test that I cannot remember facts I have learned
2	I have an uneasy, upset feeling when I take a test
3	I worry a great deal about tests
4	When I take a test I think about how poorly I am doing
	SMQ Test Anxiety
1	I am nervous about how I will do on the science tests
2	I become anxious when it is time to take a science test
3	I worry about failing the science tests
4	I am concerned that the other students are better in science
5	I hate taking the science tests

The career motivation scale from the SMQ was also used in this research and included two items relating to students' motivations to pursue science careers. The 5-item grade motivation scale from the SMQ was also used in the empirical studies presented in this thesis. However, similar to Glynn *et al.* (2009), very low reliabilities were present and resulted in this scale not being included in all three of the study analyses. Table 3.6. below shows a summary of these two science-specific motivational scales. The overall scale for science motivation from the SMQ (which included all 30 questionnaire items) was also included in the study analyses. All three questionnaires are also included in Appendix C in the format in which they were presented to the students.

Table 3.6. A summary of the science-specific motivation items on the SMQ.

	SMQ Career Motivation
1	I think about how learning the science can help my career
2	I think about how learning the science can help me get a good job
	Grade Motivation
1	I like to do better than the other students on the science tests
2	Earning a good science grade is important to me
3	I expect to do as well as or better than other students in the science course
4	It is my fault if I do not understand the science
5	I think about how my science grade will affect my overall grade point average*

Note. * 'grade point average' changed to 'marks'.

3.8 Teacher Ratings to Increase Study Validity

Before moving on to present an overview and justification for the statistical analyses chosen for this empirical work, an additional measurement instrument will be briefly introduced. Study 3 presented in this thesis also includes teachers' assessments of student self-regulated learning using data triangulation in an attempt to increase the internal validity of the student self-report measures (Gläser-Zikuda & Järvelä, 2008; Reid & Cohen, 1974). In this, students' levels of self-regulated learning will also be assessed using the *Rating Student Self-Regulated Learning Outcomes* (Zimmerman & Martinez-Pons, 1988; included in Appendix C), completed by their teachers both before and after the intervention. This measure will be described fully in Chapter 6 when outlining the methods relating to Study 3 of this thesis. Now that the study design and measurement tools have been outlined, this chapter will conclude with a discussion of the analyses chosen for the empirical work conducted as part of this thesis.

3.9 An Overview and Justification of the Statistical Approach and Analyses

The main statistical methodologies used in this thesis were *analyses of variances* (ANOVAs) and *covariances* (ANCOVAs) investigating differences in pre- to post-test *change scores* between groups, which have been used extensively in relation to student self-regulated processes and related motivations in empirical literature. Data was entered into SPSS 19.0 for each of the three studies presented in this thesis. In order to validate the entered data, 10% of the entries were checked against the source data (the questionnaires) by an independent monitor. Before outlining why the above statistical analyses were chosen, a general rationale for using parametric statistical tests for analysing the data from the three empirical studies will be presented.

As the questionnaire data obtained for this research consisted of the ordinal Likert questions outlined previously in Sections *3.7* and *3.8* of this chapter, non-parametric treatment might be expected (MacLellan & Soden, 2006). However, as the scales were calculated by summing items, the resulting questionnaire data used for the present analyses were interval in nature (Carifio & Perla, 2008; Norman, 2010). Therefore, following the suggestions of researchers who argue that ordinal measures can be subjected to parametric tests when no claims regarding the interval or ratio nature of the data are being made (Knapp, 1990; MacLellan & Soden, 2006; Norman, 2010), the data in the three empirical studies presented in this thesis were subjected to parametric tests.

It is important to note at this point that support is growing for parametric treatment of Likert data even when parametric assumptions, including normality, are violated and when studies use small sample sizes (Norman, 2010). This support is grounded in research looking at the findings of empirical work dating back almost 80 years (Knapp, 1990; Norman, 2010). Support for a parametric approach to the analyses of the questionnaire measures used in the three studies presented in this thesis can also be found by looking at the prevalence of current research studies using the MSLQ, FCSSR, and SMQ parametrically (Bryan *et al.,* 2011; Glynn *et al.,* 2009, 2011; MacLellan & Soden, 2006; Neber & Heller, 2002; Pintrich & De Groot, 1990). In order to increase the generalisability of results, similar to their treatment in the literature, a parametric approach was taken to analysing the questionnaire results presented in this thesis. The particular method employed to investigate mean differences between the groups involved in the study designs presented in this thesis will now be outlined and discussed.

3.9.1 Examining Mean Differences in Pre-test Post-test Study Designs

The analysis of change in pre-test post-test studies has generated heated debates over the last 40 years among researchers in several fields including medicine, psychology, and education (Bonate, 2000; Fitzmaurice, 2001; Fitzmaurice, Laird, & Ware, 2004). Before examining how to investigate the impact of the programme being studied in this thesis, the CREST programme, a discussion on matching pre-test scores is necessary. In any educational quasi-experimental study, it is important to ensure that the sample is representative of entire school or grade before analysing the main results (Cleary & Chen, 2009). Therefore, *t-tests* were conducted on key pre-test variables in order to verify that the groups were matched at the outset of the three studies (Chularut & DeBacker, 2004; Cleary & Chen, 2009). While the presence of any statistically significant pre-test differences between groups does not invalidate the analyses, researchers do need to be careful regarding what conclusions can be drawn from the results of unbalanced samples (Bonate, 2000).

It has been highlighted in the literature that analyses that take into consideration both pre-test and post-test data appropriately acknowledge the possibility of this kind of heterogeneity of baseline scores (Bonate, 2000). Among these analyses, three parametric options were considered for the research presented in this thesis; *covariance analyses, analyses of change scores,* and *repeated measures analyses*. These different approaches will now be described, and justification will be provided in order to arrive at the particular method chosen for the research presented in this thesis.

A commonly used statistical analysis in educational and psychological research is the repeated measures ANOVA. However, some researchers suggest not to use one-way repeated measures, because the underlying model assumes that the pre-test is measured before administration of intervention. As such, repeated measures ANOVAs can be misleading as the F test for treatment main effect is too conservative, since pre-test scores are not affected by interventions (Bonate, 2000; Dimitrov & Rumrill, 2003; Huck & McLean, 1975; Matthews *et al.,* 2009). This repeated measures approach was therefore not adopted in the research presented in this thesis. Having resolved not to take the repeated measures approach to analysis, decisions needed to be made regarding what type of one-way variance analysis to perform. This section will continue by outlining the considerations made when making these decisions.

Some researchers feel that the analysis of covariance (ANCOVA) controlling for any variability in the pre-test scores is a robust statistical analysis to perform. This type of analysis allows researchers to explore differences between groups while controlling for another variable that may be influencing dependent variables (Coolican, 2009; Field, 2009, 2013; Pallant, 2010). In the context of the research presented in this thesis, these ANCOVAs were considered, looking at post-test differences between groups while controlling for pre-test scores. Some researchers argue that the statistical power achieved by ANCOVA analyses in pre-test post-test design studies makes this approach favourable (Bonate, 2000).

However, the view that the ANCOVA approach is the best choice because it offers a more powerful test of group differences is wrong according to Fitzmaurice and colleagues (2004). In contrast, the specific research questions and study designs should guide analysis, not the statistical precision obtained or the power of the statistical tests available (Fitzmaurice *et al.,* 2004). As ANCOVA analyses address research questions relating to how groups differ at post-test if starting at the same pre-test levels, when using this approach, researchers need to ensure that the assumption of equivalent experimental groups at pre-test is appropriate (Fitzmaurice *et al.,* 2004; Smolkowski, 2010).

In the context of the research reported in this thesis, the above assumption would not be appropriate. For this thesis, the studies are not randomised trials but rather, quasi-experiments utilising the classroom structure imposed by the schools. It is therefore possible that with different teachers and peer groups, even without ability grouping, some classes may be higher on some self-regulated processes and related motivational variables than others. Therefore, following the suggestions in the literature, the ANCOVA approach controlling for pre-test scores was not used as it has the potential to explain away meaningful differences between the groups in quasi-experimental studies (Bonate, 2000; Ganju, 2004; Smolkowski, 2010). In addition, ANCOVA analyses do not tell researchers about how the experimental groups change over time (Smolkowski, 2010). As the research presented in this thesis aims to investigate changes in self-regulated processes and related motivations through participation in the CREST programme, the ANCOVA approach offers interpretation problems, which may limit the impact of the research findings for policy makers, teachers, and fellow researchers in this field of educational research (Smolkowski, 2010). Dimitrov and Rumrill (2003) suggest a one-way ANOVA approach using gain scores, which was adopted for the present research.

An alternative approach that takes into account any group differences in pre-test scores is the gain score approach. Instead of controlling for *group* differences at pre-test, gain score analyses control for *individual* differences at pre-test as the computed score is the post-test relative to the pre-test for each subject (Becker, 2000). This gain score approach is criticised mostly due to the likelihood of missing pre-tests or post-tests (Sanders, 2006). As the analyses conducted in this thesis only included students who completed both the pre-test and post-test measurements, this calculated *change* score approach is appropriate. The critical assumption of the gain score approach is that assignment to treatment is not related to pre-test scores (Smolkowski, 2010). In the context of the research presented in this thesis, the experimental groups are not based on pre-test scores, therefore meeting this important assumption. Further support for using the gain score approach also lies in the fact that the results can be easier to interpret (Smolkowski, 2010), and that this analysis addresses the research questions more appropriately than the covariance approach.

3.9.2 Analysing Multiple Measures of Similar Constructs Using a Multivariate Approach

Following the decision regarding the choice of the gain score approach, careful thought was taken when considering how to investigate the several different constructs measured in the empirical work presented in this thesis. It is common in educational research for interventions to focus on more than one measured outcome variable (Pallant, 2010). Multivariate variance analyses are appropriate when more than one dependent variable is present and when the variables are linked in a meaningful way (Coolican, 2009; Field, 2009, 2013; Pallant, 2010). Building on the one-way ANOVA approach, the use of the MANOVA allows researchers to investigate several dependent variables using one test. This MANOVA approach therefore allows us to investigate group differences on a combination of dependent variables (Field, 2009, 2013; Pallant, 2010). The MANOVA essentially forms a composite variable using the dependent variables and performs an ANOVA using this new combined variable (Coolican, 2009; Field, 2009, 2013; Pallant, 2010). This allows researchers to investigate whether groups differ significantly on this combined variable and also performs univariate tests allowing us to see the differences between the original dependent variables (Pallant, 2010).

As the research conducted in this thesis involves using multiple measures of similar constructs, this method of statistical parametric analysis is appropriate to answer the research questions laid out for each of the three studies. While it would also be appropriate to conduct a series of one-way ANOVAs on the change scores from pre-test to post-test for this research, the risk of inflating Type 1 error would increase (Pallant, 2010). Implementing the MANOVA analysis has been documented as the best way to avoid Type 1 error, even though it is a relatively conservative approach (Coolican, 2009). This multivariate approach to analysis also connects with the framework for understanding self-regulated processes adopted in this thesis (see Chapter 1 Section *1.7*), as the variables can be considered under the umbrella of self-regulated processes (the multivariate test) while the resulting univariate ANOVAs allow for the separate constructs to also be viewed (self-regulation, self-regulated learning, cognitive strategies use, and self-determination).

3.9.3 Effect Size Interpretation and Power Calculations

Before concluding this chapter, a brief overview of the interpretation of the statistical tests and the power calculations performed will be provided. A common indicator presented alongside parametric results is the level of significance or the *p* value. However, it is important to note that the significance of statistical tests alone, the *p* value, does not communicate insight regarding the practical significance of the study (Sun, Pan, & Wang, 2010). Sun and colleagues (2010) conducted a review of quantitative studies performed in education and psychology between 2005 and 2007. These researchers found that of the 1243 articles included in the study, only 49% reported effect size and only 57% went further to interpret the effect sizes.

Broadly, there are two types of effect sizes used in the literature: Cohen's d representing mean differences (d) and eta squared outlining the strengths of relations (Sun *et al.,* 2010). For the research presented in this thesis, these effect sizes will be presented alongside the significance values, allowing for cross-study comparisons of the observed effects as well as comparisons in relation to studies presented in the literature (Sun *et al.,* 2010). The presentation of effect sizes will also provide insight into the contributions provided by the results documented in this thesis relating to policy and educational practice.

In addition to presenting effect sizes for the results as described above, careful power analyses were also performed prior to conducting the three empirical studies presented in this thesis in order to ensure that low power was not a threat to the validity of the research findings. Cohen (1988) recommends a power of .80, which translates to an 80% chance of detecting observable differences between groups given the presence of real differences. The power calculations conducted were performed using the GPower 3.1 programme developed by Faul, Erdfelder, Buchner & Lang (2009) and sample sizes were determined before conducting the three empirical studies presented in this thesis. The results of these calculations will be presented in the methods sections included in each of the three empirical chapters of this thesis (Chapters 4, 5, & 6).

3.10 CHAPTER SUMMARY AND CONCLUSIONS

This chapter has presented an overview of the methods employed in this thesis in order to address the research questions of the empirical work conducted. Additionally, this chapter outlined the line of justification followed in order to arrive at the general research approach, study design, measurement tools, and analyses chosen for the studies presented in this thesis.

As discussed in Chapter 1, there are on-going debates in the literature regarding definitions of self-regulated processes and as a result, there are several measurement tools available for researchers to investigate these constructs. Even researchers who adopt similar frameworks for understanding self-regulated processes and related motivations use different measurement tools. In an attempt to shed light on this situation, the present research used multiple self-report measures for the constructs, based on comparable models, with the hope to provide a clearer understanding for researchers who are employing these methods and also highlight issues regarding measuring these constructs in young students. Understanding that the use of self-report measures alone has been criticised in relation to self-regulation, and appreciating the movement of self-regulation research towards more observational methods led by Whitebread and colleagues (2009), there is still value to be gained through implementing these measures when *development* and *change* of the constructs are being investigated.

Throughout this chapter, important limitations of the proposed methods were also discussed and these issues will be considered in both the individual discussion sections of the results in each of the three empirical studies, as well as the main discussion chapter at the end of this thesis (Chapter 7). The three studies, which make up the empirical work conducted as part of this thesis, will now be presented in the following three chapters (Chapters 4, 5, & 6).

4

STUDY 1: INVESTIGATING THE IMPACT OF THE CREST PROGRAMME ON SELF-REGULATED PROCESSES AND RELATED MOTIVATIONS IN YOUNG SCIENCE STUDENTS[2]

Chapter Objectives

The present study aims to investigate the influence of the CREST programme on changes in students' self-reported levels of self-regulated processes and related motivations in science. Following a quasi-experimental design using validated self-report instruments, the study presented in this chapter explores both the short and long-term impact of participation in the CREST programme on the key variables being studied. After introducing literature in order to highlight the relevance of this study, the specific research questions and predictions will be outlined followed by a detailed description of the findings. This chapter will conclude with a discussion of the study results within the context of published research in the field as well as within the framework of the empirical studies conducted in this thesis.

[2] The data from this study is currently in press in the *Journal of Cognitive Education and Psychology, 12(2), Article 4*. The full paper can be found in Appendix D included in this thesis submission. The paper was also presented at the *European Association for Research on Learning and Instruction,* 14th Biennial Conference in Exeter on August 30th, 2011.

4.1 INTRODUCTION

As outlined in the previous three chapters (Chapters 1, 2, & 3), the overarching research aim for this thesis is to investigate the impact of a strategy currently being implemented in schools throughout the UK, aimed at developing motivation and engagement in young science students. Through introducing the self-regulated processes and related motivational constructs studied and placing the CREST programme within a framework of relevant intervention research in education, the initial chapters of this thesis argued that this programme is a viable medium through which to explore the development of these constructs in young students. In addition, through discussing relevant research, Chapters 1 and 2 highlighted several gaps in the literature, which informed the research questions and design of the present study.

Recapping from the previous chapters, without looking at real classroom settings, generalisations concerning the practical implications of research findings are of limited value (Martin & McLellan, 2008). The present study builds on the work of researchers who have been developing our understanding of self-regulation in science classrooms (Adey, 1992; Driver, 1989; Driver & Oldham, 1986; White & Frederiksen, 1998; Zohar, 2004; Zohar & Dori, 2012) through evaluating a science education inquiry-based learning activity administered by classroom teachers. In addition, by studying self-regulatory processes in science education, the research presented in this study, as well as in this thesis as a whole, contributes to the transferability of current self-regulation research findings to other academic domains. This research, therefore, has direct implications for practice and contributes to the identified knowledge gap relating to self-regulation research in natural and specific classroom settings. As research in the last two decades regarding academic performance has stressed the importance of motivational and cognitive aspects of student classroom learning (Wolters & Pintrich, 1998), it is essential to study these self-regulatory processes and related motivations in adolescent students who were experiencing increased pressure to perform. The physical, mental, and educational transitions experienced by adolescent students further highlights the importance of building on the self-regulation and motivation literature relevant to this age group (Cleary & Chen, 2009; Wigfield & Eccles, 2002).

The central aim of this study is to explore the impact of the CREST inquiry-based learning programme in a particular school setting on young students' self-reported levels of self-regulated processes and related motivations in science. Owing to the nature of the CREST programme in relation to educational interventions aimed at developing self-regulated processes among students (discussed in Chapter 2), it is hypothesised that students participating in the programme will increase in self-reported levels of the self-regulatory strategies measured compared to students not taking part in the programme. Also discussed in Chapter 2, as the structure of the CREST programme allows students to conduct investigations on topics they are interested in, it is also predicted that students will experience more enjoyment for their science learning, exert more personal control over their learning, and gain a better understanding of the practical uses of science. These factors, in addition to successfully completing their investigations, may lead to increases in the amount of interest students have for their science learning, the importance they place on it, as well as their self-efficacy in science.

However, as the literature highlights the complex nature of the relationships between the related motivational constructs and the self-regulatory strategies studied (Berger & Karabenick, 2011), the above predictions are made tentatively. In addition, due to the prevalence of reported problems in developing the internal motivations of students in this age group, it is predicted that intrinsic motivation and task value may be more difficult to develop within the timeframe of the present study (Berger & Karabenick, 2011; Bryan *et al.,* 2011; Ryan & Deci, 2000). And finally, as the programme did not involve direct instruction of cognitive strategies, it is hypothesised that smaller increases will be observed on the cognitive strategies use measure included in this study.

Given the importance of performance on academic tests and remembering the *affect* component included in the social-cognitive model of self-regulated learning adopted (presented in Chapter 1 Section *1.7*), the impact of CREST participation on test anxiety is also investigated in this study. As academic emotions are often neglected in educational research (Pekrun *et al.,* 2002; Pintrich, 2003; Smith, 1989), additional support for inclusion of this construct in the present research is provided. Predicting that the CREST programme will develop the above self-regulated processes and related motivations, it is hypothesised that participating in CREST will also lead to reductions in students' levels of test anxiety. While CREST does not focus on developing test-taking skills, it is designed to affect the academic performance of young students and therefore participation may lead to decreased levels of test anxiety.

Appreciating the concerns of educational policy makers regarding the recent declines seen in the number of students pursuing science qualifications (Archer *et al.,* 2010), the present study also investigates the impact of CREST participation on students' motivations to pursue careers in science. Due to the structure of the CREST programme exposing students to the nature of science, and considering the findings of Grant (2007) discussed previously in Chapter 2, it is predicted that programme participation may increase students' interests in pursuing science careers and their motivations to achieve high marks in science.

As adaptations in response to environments specifically relating to self-regulated processes and related motivations are evolutionary, not instantaneous (Winne, 1995), the present study also investigates the impact of the CREST programme beyond immediate post-test. As much of the previous self-regulation intervention research is correlational (Berger & Karabenick, 2011), by evaluating the CREST programme through implementing the quasi-experimental design and following the methods justified in Chapter 3, this study provides longitudinal insight into fostering self-regulated processes and related motivations in young students. It is hypothesised in the present study that any changes on the self-reported outcome measures will be retained in the months following CREST programme participation.

The specific research questions relating to this first empirical study will now be presented along with the predictions made aligning with the research discussed here and in the literature chapters (Chapters 1 & 2).

4.2 Study 1 Research Questions and Predictions

Specifically, the present study aims to address two research questions presented below with the corresponding research predictions. The research predictions were formulated based on the review of relevant literature and the framework for understanding the CREST programme presented in Chapters 1 and 2.

RQ 1: Do students taking part in the CREST programme during the course of the study experience different changes in self-reported levels of self-regulated processes and related motivations immediately following participation in the programme compared to students in the control group?

Prediction 1: The control group will experience no significant increases in self-reported levels of self-regulated processes and related motivations and may show significant decreases in some outcome variables. Meanwhile, the CREST group will show the following trends:

a. Increases in self-reported levels of self-regulated processes;
b. Maintain pre-test self-reported levels of related motivations, if not increase;
c. Decreases in self-reported levels of test anxiety following participation in the programme;
d. Increases in self-reported levels of career motivation, and grade motivation in science.

RQ 2: Are any changes in self-reported self-regulated processes and related motivations retained six months after participation in CREST?

Prediction 2: Any changes in self-reported outcome measures will be retained at the six-month delayed post-test for the students who took part in the CREST programme.

4.3 METHOD

4.3.1 Study Design

As outlined in Chapter 3, the present study followed a quasi-experimental design and involved a 'control' group and a 'CREST' group of students from four classes in an independent school in Edinburgh. While all students in the year-group at the school participated in the CREST programme during the academic year in which the study took place, participation in the programme was staggered. Therefore, students participating later in the year provided a control group for comparison. The questionnaires were administered to both groups (four classes) before and after CREST participation. Delayed post-tests were administered to the original two classes making up the CREST group six months after programme completion. Between post-test and delayed post-test, students in the CREST group continued through the regular school term with, no significant pedagogical interventions or influential events noted. The students making up the control group participated in the CREST programme after the post-test measures were administered and therefore were no longer used as a control group.

4.3.2 Participants and Educational Context

Parental consent and child assent were received and data were coded following the ethical guidelines set by the British Psychological Society (outlined in Chapter 3). Prior power calculations, also described in Chapter 3, were conducted relating to the specific analyses chosen for this study using the GPower 3.1 programme developed by Faul and colleagues (2009). To observe a medium effect size at an alpha value of .05 and achieve a power of .80, a minimum sample of 90 was required to detect differences between the two groups. However, as the research presented here was dependant on the school structure of CREST administration, a slightly smaller sample size was achieved.

Questionnaires were administered to the four classes of 20 students from one school in Edinburgh. Only students who completed both the pre-test and post-test were included in the study analyses, which left a total of 73 students, 37 (51%) females and 36 (49%) males for analysis. Of these, 39 (53%) students were participating in CREST at the time of the study and made up the CREST group, and 34 (47%) were not, which formed a control group. The CREST group was made up of 19 (49%) female students and 20 (51%) male students, while the control group comprised 18 (53%) female students and 16 (47%) male students. The mean age for CREST participants was 11.8 years (SD=0.4). The mean age for control participants was 11.5 years (SD=0.5). The CREST programme implementation occurred over the course of five weeks at the beginning of the school year. Students worked on their CREST projects twice a week; completing a total of 10 CREST sessions, each 55 minutes long (total hours on CREST≅10 hours).

4.3.3 Pre- and Post-test Measures

As outlined in Chapter 3, three self-report measures in the field of self-regulation and motivation were chosen for the present study, aligning with the framework for understanding the key constructs of interest discussed in Chapter 1. The MSLQ (Pintrich & DeGroot, 1990) was selected as it has been extensively used in the literature, specifically in adolescent science education, and includes scales for the motivational factors of interest. In addition to using the MSLQ, MacLellan and Soden's (2006) measurement tool (a modified version of the Martinez-Pons [2000] FCSSR: Five Component Scale for Self-Regulation) was also included in this study as it focuses additionally on the environmental context students are learning in and has been validated in Scottish schools. The Science Motivation Questionnaire (SMQ; Glynn *et al.,* 2009) was also chosen to provide insight into the science-specific motivations of students. Tables 4.1, 4.2, and 4.3 on the following page present a summary of the scale items along with the calculated and published reliabilities of the scales included in these measures, allowing for further comparison.

Table 4.1. Example items and internal consistency (reliability) coefficients for the MSLQ subscales.

Subscale	n	Example Item	α	α (1990)*
Motivation Scales				
Self-Efficacy	9	I expect to do very well in science class	.90	.89
Intrinsic Value	9	Understanding this subject is important to me	.88	.87
Test Anxiety	4	I am so nervous during a test that I cannot remember facts I have learned	.69 [a]	.75
Cognitive Scales				
Cognitive Strategies Use	13	I outline the chapters in my book to help me study	.78	.83
Self-Regulation	9	I ask myself questions to make sure I know the material have been studying	.80	.74

*Published alpha values from Pintrich and De Groot (1990) for the subscales on the MSLQ. [a] Mean inter-item correlation between 0.2 and 0.4 which is acceptable according to Briggs and Cheek (1986).

Table 4.2. Example items and internal consistency (reliability) coefficients for the FCSSR subscales.

Subscale	n	Example Item	α	α (2006)*
Goal Setting	10	When doing my academic work, I always set goals to guide me in my efforts	.77	.88
Strategy Implementation	4	I take notes during class	.84	.90
Strategy Monitoring	15	I compare the strategy to other strategies to see which is more effective	.84	.92
Total	45		.92	

*Published alpha values from MacLellan and Soden (2006). Note: no published alpha value available for the total self-regulated learning composite score.

Table 4.3. Example items and internal consistency (reliability) coefficients for the SMQ subscales.

Subscale	n	Example Item	α	α (2009)*
Intrinsic Motivation Personal Relevance	10	The science I learn is more important to me than the grade I receive	.81	.91
Self-Efficacy	4	I believe I can master the knowledge and skills in the science course	.73	-
Test Anxiety	5	I become anxious when it is time to take a science test	.72	-
Self-Determination	4	I put enough effort into learning the science	.70	.74
Career Motivation	2	I think about how learning the science can help my career	.88	.88
Grade Motivation[3]	5	Earning a good science grade is important to me	.30[a]	.55

*Published alpha values from Glynn *et al.* (2009). *Note:* self-efficacy and test anxiety are included as two composites and therefore no published alpha values available. [a] Mean inter-item correlation =.073, which is not acceptable according to Briggs and Cheek (1986).

[3] Similar to the results of Glynn *et al.* (2009), the reliability for the 5-item Grade Motivation scale was very low and was, therefore, not included in the analysis. While decent Cronbach's alpha values are difficult to achieve for scales with a small number of items, even after looking at the mean inter-item correlation value, this scale was not used as no strong relationship between the items was observed by the statistical analyses run (Pallant, 2010).

Academic performance measured by the first test of the year in science (marked out of 100) was also included in the analyses to investigate whether groups were matched on science achievement at the beginning of the study and to control for any differences present. While this research appreciates that a more complete picture of assessment (including science investigation marks, daily quizzes, presentation and homework marks) would be desirable, due to the timing of this study, the performance marks available were utilised and are arguably sufficient in order to obtain a general sense of student ability in science and contribute to the internal validity of the present study.

4.3.4 Pilot Work

As described in Chapter 3, the three questionnaires were piloted with 20 students matching the target population (S1, 11-12 years of age). Items were initially reviewed by four science teachers, minor revisions were made, and questionnaires were piloted for a second time with another 40 students. In an attempt to ensure that the programme was similarly implemented among classes, the piloting process also involved observing how the teachers implementing the programme in the present study administered the programme with a group of students the previous year. These observations included recording the amount of time spent on the CREST programme, documenting the nature of teacher versus student control, and observing the types of projects conducted. In addition, the British Science Association was contacted and information regarding what quality control measures were in place for the CREST programme across schools throughout the UK was obtained. The author felt confident that the teachers involved administered the programme in very similar ways and no additional teacher data was collected for this study.

4.3.5 Procedure

The pen-and-paper form questionnaires were administered in the classroom to students in both groups immediately prior to the CREST intervention and after its completion. Students were given up to 40 minutes to complete questionnaires and completion times ranged between 25 and 35 minutes. Questionnaires were administered a third time to the CREST group six months following programme completion.

4.3.6 Analysis

The results from the missing data analysis performed in SPSS 19.0 showed that there were no questions with more than 5% missing values. Therefore, no items were removed from the study analyses and all composite measures presented are as published in the literature. Results from Little's MCAR test for each of the measures at pre- and post-test showed that data was missing completely at random. Therefore, listwise deletion of cases for the analyses was used and no imputation was necessary.

Preliminary analyses involved testing for violations of assumptions of normality and exploring the descriptive statistics to provide further support for parametric treatment of the data (Sun *et al.*, 2010). In order to verify that the two groups were matched on pre-test scores and provide justification for interpreting change scores for the sample, independent-samples *t-test*s were performed comparing the CREST and control group on all pre-test measures including science performance. As no significant differences between groups on any pre-test measures were found, change scores (post-test minus pre-test) were calculated and used in the analyses. In addition, as the research questions involved investigating *changes* in student perceptions, change score analysis was chosen over repeated measures analysis of variance (Dimitrov & Rumrill, 2003; Ganju, 2004). Further justification for the use of this approach within the context of the research presented in this thesis was provided earlier in Chapter 3.

As multiple scales for similar constructs were used in this study, the scores could have been standardised and collapsed into single composites for each of the constructs. However, as the results of a redundancy analysis showed that correlations between dependent measures were much smaller than the correlations within each measure, it was decided that results would be presented for the separate scales. As a result, the change scores (post-test minus pre-test) on questionnaires mapping onto similar constructs (multiple measures for self-regulated processes, self-efficacy, intrinsic motivation, and test anxiety) were included in *multivariate analyses of covariance* (MANCOVAs) controlling for academic ability in science. Leaving composite scores as presented in the literature also helps to increase the generalisability of the results and the ease of data interpretation. As no multivariate analyses were needed for career motivation in science, the results were analysed for this variable using *one-way between groups analyses of covariance* (ANCOVAs).

Before MANCOVA analyses were conducted, preliminary analyses exploring gender differences were performed. Gender differences were found for the covariate of science ability; with girls (79.63) performing better on the initial science assessment than boys (71.47), $t(72)=-2.718$, $p=.008$. As preliminary multivariate analyses revealed no main effects of gender on any of the dependent variables, gender was not included in the MANCOVA analyses. For all multivariate tests reported in this study, preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, with no serious violations noted. In order to investigate retention effects of the changes in students' self-reported self-regulated processes and related motivations, student scores on the variables at post-test and delayed post-test were compared by performing paired-samples *t-tests* with Bonferroni corrections for the CREST group only.

As discussed in Chapter 3, effect sizes are also reported in addition to significance values, as reporting and interpreting effect sizes can provide insight into the practical implications of the magnitude of the reported differences (Field, 2009, 2013; Sun *et al.,* 2010). Cohen's d statistic will accompany any *t-test*s presented and partial eta squared ($\eta\rho^2$) values will be included to represent effect sizes for ANOVAs (see Table 4.4 below).

Table 4.4. Guidelines for interpreting effect sizes (Cohen 1988, p. 284-287).

Cohen's d	Size of Effect	$\eta\rho^2$	Size of Effect
≥.10	small	≥.01	small
≥.30	medium	≥.06	medium
≥.80	large	≥.14	large

4.4 RESULTS

4.4.1 RQ 1: Immediate Post-test Group Comparisons

Self-Regulated Processes

Relating to the first research question, it was hypothesised that students participating in CREST would increase in self-reported levels of self-regulatory processes compared to students in the control group not taking part, owing to the nature of the programme, discussed in Chapter 2. A one-way between-groups multivariate analysis of covariance was performed to investigate group differences in self-regulatory processes while controlling for science performance. Four dependent variables were used: MSLQ self-regulation, MSLQ cognitive strategies use, FCSSR total self-regulated learning, and SMQ self-determination change scores (post-test minus pre-test), with the independent variable being group membership (CREST vs. control). While the multivariate test for the covariate of academic science performance was not significant, a statistically significant difference was found between the CREST and control groups on the combined dependent variables ($F(4,51)=2.884$, $p=.031$, Wilks' Lambda=.816, $\eta_p^2 =.184$). This result suggests that academic performance in science does not influence the change scores of students on these variables and that group differences are present when the four variables are considered together.[4]

When considering the results for the dependent variables separately, two variables reached statistical significance, using a Bonferroni adjusted alpha level of .013. The univariate test for the self-regulated learning change score measured by the FCSSR was significant ($F(1,45)=8.491$, $p=.005$, $\eta_p^2 =.136$). An inspection of the mean change scores indicated that the control group decreased ($M_{change}=-.120$, $SD=.425$) while the CREST group increased ($M_{change}=.136$, $SD=.290$) in self-reported levels of self-regulated learning. Further inspection of the 95% confidence intervals around each mean indicated that there was a significant increase in self-reports of self-regulated learning for the CREST group alone. These results are in line with the first research

[4] For the remainder of this chapter, the results from the multivariate tests for pre-test academic performance will not be presented unless significance is found in order to focus the results more clearly.

prediction and suggest that participation in the CREST programme may be influencing students' abilities to regulate their own learning processes.

Similar to the results presented above for self-regulated learning, the SMQ self-determination change score univariate test was also significant ($F(1,54)=6.819$, $p=.012$, $\eta\rho^2 =.112$). An inspection of the 95% confidence intervals around each mean indicated that while the control group experienced significant decreases in self-reported levels of self-determination ($M_{change}=-.307$, SD=.597), the increases were not significant in the CREST group ($M_{change}=.0263$, SD=.598). As it was predicted that participation in the CREST programme would increase students' perceptions of control over their learning, these results are not in line with the research predictions made. As the programme did not involve direct instruction of cognitive strategies, it was hypothesised that smaller increases would be observed in the cognitive strategies use measure included in this study. Table 4.5 below shows a summary of the means and standard deviations for the scores involved in these analyses.

Table 4.5. A summary of the means (standard deviations) of the CREST and control group scores on self-regulatory measures.

Groups	Pre-test	Immediate Post-test	Change Score
MSLQ Self-Regulation			
CREST	4.57 (.716)	4.58 (.742)	.0088 (.640)
No CREST	4.62 (.990)	4.45 (.857)	-.170 (.798)
MSLQ Cognitive Strategies Use			
CREST	4.74 (.616)	4.66 (.797)	-.0813 (.635)
No CREST	4.81 (.790)	4.53 (1.28)	-.231 (1.11)
FCSSR Total SRL			
CREST	2.48 (.346)	2.58 (.436)	.136 (.290)
No CREST	2.56 (.397)	2.44 (.570)	-.120 (.385)
Self-Determination			
CREST	3.74 (.720)	3.77 (.619)	.0203 (.597)
No CREST	3.91 (.624)	3.61 (.723)	-.307 (.597)

Note. SRL= self-regulated learning.

Motivational Constructs

The MANCOVA results investigating group differences in self-efficacy change scores on the MSLQ and SMQ while controlling for academic performance in science showed no statistically significant difference between the CREST and control groups on the combined dependent variables ($F(2,65)=1.745$, $p=.183$, Wilks' Lambda=.949, $\eta\rho^2=.051$). However, the multivariate tests for intrinsic motivation change scores on the MSLQ and SMQ showed a statistically significant difference between the two groups on the combined dependent variables ($F(2,64)=3.229$, $p=.046$, Wilks' Lambda=.908, $\eta\rho^2=.092$). Results from the univariate test for MSLQ intrinsic value were significant ($F(1,65)=5.316$, $p=.024$, $\eta\rho^2=.076$) at the Bonferroni adjusted alpha level of .025. An inspection of the 95% confidence intervals around each mean showed, however, that while both groups decreased, only the control group experienced significant decreases ($M_{change}=-.512$, SD=1.21) in self-reports of intrinsic value. As Levene's Test was significant for SMQ intrinsic motivation and personal relevance (IMPR), a more conservative alpha level of .01 was used following the recommendations of Tabachnick and Fidell (2007). At this level, a non-significant univariate test for this variable was found ($F(1,65)=1.028$, $p=.041$, $\eta\rho^2=.063$). The above results are not in line with the increases that were predicted among these related motivational variables through CREST participation. A summary of the means and standard deviations for all the related motivational constructs is presented in Table 4.6 on page 111.

The multivariate results investigating group differences in test anxiety change scores on the MSLQ and SMQ while controlling for academic performance in science showed a statistically significant difference between the CREST and control group on the combined dependent variables ($F(2,64)=5.012$, $p=.010$, Wilks' Lambda=.865, $\eta\rho^2=.135$). As Levene's Test on SMQ test anxiety was significant, a more conservative alpha level of .01 was used as above. When results for dependent variables were considered separately, SMQ test anxiety reached statistical significance using a Bonferroni adjusted alpha level ($F(1,65)=9.305$, $p=.003$, $\eta\rho^2=.126$). An inspection of the confidence intervals indicated that the CREST group increased in levels of SMQ test anxiety ($M_{change}=.267$, SD=.874), while the control decreased ($M_{change}=-.277$, SD=.557). With a Bonferroni adjusted alpha of .05/2, the univariate test for test anxiety as measured by the MSLQ was non-significant ($F(1,65)=4.776$, $p=.032$, $\eta_p^2=.068$). However, an inspection of the change scores shown in Table 4.6 on the next page indicates that as with the SMQ test anxiety results, the control group decreased in levels of test anxiety on the MSLQ while the CREST group increased. Together, the results from the two measurement scales suggest that, contrary to the research prediction outlined earlier, participation in the CREST programme resulted in increased levels of test anxiety among students and that this increase was not influenced by pre-test academic performance marks.

Science-Specific Motivations

A one-way between groups analysis of covariance was performed investigating group differences in science-specific career motivation measured on the SMQ. After adjusting for academic performance at pre-test, there was a statistically significant difference between the CREST and control groups on the dependent variable ($F(1,70)=5.498$, $p=.022$, $\eta_p^2=.073$). Further inspection of the 95% confidence intervals around the means showed that while the CREST group experienced significant increases in self-reported levels of career motivation ($M_{change}=.434$, SD=.960), the control group decreased ($M_{change}=-.0857$, SD=.927). These results support the prediction that participation in the CREST programme has a positive impact on career motivations in science. A summary of the means and standard deviations relating to this construct are included in Table 4.6 on the following page.

While the use of change score analysis was justified for this study, an appreciation of where students were on the scales at both pre-test and post-test is important in order to contextualise the changes. Results from exploratory correlation analyses investigating the relationships between pre-test scores and change scores for all variables in the study showed that higher pre-test scores led to smaller gains. These results will be considered when interpreting the findings.

Table 4.6. A summary of the means (standard deviations) for self-efficacy, intrinsic motivation, test anxiety, and career motivation for the CREST and control groups.

Groups	Pre-test	Immediate Post-test	Change Score
MSLQ Self-Efficacy			
CREST	4.55 (.760)	4.49 (.930)	-.0556 (.717)
No CREST	4.64 (.972)	4.43 (1.31)	-.185 (1.21)
SMQ Self-Efficacy			
CREST	3.61 (.505)	3.54 (.608)	-.0764 (.550)
No CREST	3.71 (.616)	3.80 (.642)	.118 (.469)
MSLQ Intrinsic Value			
CREST	4.95 (.762)	4.86 (.898)	-.0571 (.825)
No CREST	5.08 (1.04)	4.52 (1.31)	-.512 (1.21)
SMQ IMPR			
CREST	3.40(.483)	3.55 (.531)	.138 (.355)
No CREST	3.46 (.661)	3.35 (.852)	-.109 (.568)
MSLQ Test Anxiety			
CREST	3.25 (1.04)	3.76 (1.22)	.506 (1.20)
No CREST	3.06 (1.22)	2.94 (1.09)	-.144 (1.24)
SMQ Test Anxiety			
CREST	2.78(.626)	2.99 (.795)	.267 (.874)
No CREST	2.69 (.806)	2.43 (.778)	-.277 (.557)
Career Motivation			
CREST	3.27 (1.12)	3.71 (.970)	.434 (.960)
No CREST	3.06 (1.08)	2.97 (1.22)	-.0857 (.927)

Note. IMPR= intrinsic motivation and personal relevance.

4.4.2 RQ 2: Delayed Post-test Comparisons for the CREST Group

Table 4.7 on the following page provides a summary of the means on all post-test and delayed post-test measures for the CREST group of students who completed both post- and delayed post-test questionnaires. Differences between the means were tested using paired-samples *t-tests* with a Bonferroni corrected significance value and the results are shown in Table 4.7.

From Table 4.7, it can be seen that no significant differences were found (at the adjusted alpha level) on any of the variables measured at post- and delayed post-test. This result is interpreted as showing that the significant changes in levels of self-reported self-regulated learning, test anxiety, and science career motivation presented earlier in Section *4.2.1,* were retained.

Table 4.7. A summary of the means (standard deviations) of scores on post- and delayed post-tests and paired-samples *t-tests* results with Cohen's d.

Measure	Score	*t*	*p* *	d
MSLQ Self-Regulation				
Post-test	4.57 (.772)	1.042	.305	.182
Delayed Post-test	4.44 (.648)			
MSLQ Cognitive Strategies Use				
Post-test	4.60 (.783)	-1.315	.198	.261
Delayed Post-test	4.78 (.584)			
FCSSR Total SRL				
Post-test	2.57 (.436)	-1.310	.022**	.292
Delayed Post-test	2.44 (.454)			
SMQ Self-Determination				
Post-test	3.72 (.615)	-.485	.631	.0662
Delayed Post-test	3.76 (.594)			
MSLQ Self-Efficacy				
Post-test	4.43 (.932)	-1.710	.096	.234
Delayed Post-test	4.64 (.861)			
SMQ Self-Efficacy				
Post-test	3.53 (.579)	-1.431	.134	.273
Delayed Post-test	3.69 (.595)			
MSLQ Intrinsic Value				
Post-test	4.85 (.919)	-.638	.528	.0982
Delayed Post-test	4.93 (.695)			
SMQ IMPR				
Post-test	3.50 (.523)	-1.310	.199	.198
Delayed Post-test	3.61 (.587)			
MSLQ Test Anxiety				
Post-test	3.70 (1.25)	-1.536	.134	.227
Delayed Post-test	3.97 (1.13)			
SMQ Test Anxiety				
Post-test	3.10 (.759)	-1.587	.122	.493
Delayed Post-test	3.47 (.741)			
SMQ Career Motivation				
Post-test	3.67 (1.00)	-.780	.441	.126
Delayed Post-test	3.79 (.902)			

Note. *two-tailed significance values presented. ** non-significant at Bonferroni adjusted alpha value. SRL= self-regulated learning, IMPR= intrinsic motivation and personal relevance.

4.5 DISCUSSION

4.5.1 Immediate and Delayed Impact of CREST on Student Self-reports

Self-Regulated Processes

The results presented in this first empirical study in relation to self-regulated learning align with the research prediction that participating in the CREST programme fosters the development of this process among students. Giving students the opportunity to control and evaluate their learning and work collaboratively with peers toward their goals appears to influence their ability to self-regulate their learning in science. Berger and Karabenick (2011) conducted a study investigating temporal changes in self-reported levels of self-regulated processes over the course of a school term in mathematic students between the ages of 13 and 14 years participating in regular classroom activities. Over the four-month period in which the study was conducted, Berger and Karabenick (2011) observed significant decreasing trends in self-regulated learning among the sample of students included in the study. Considering the results of the present study in the context of the research conducted by Berger and Karabenick (2011) highlights the significance of these findings further.

With regards to self-determination, while the group of students participating in the CREST programme showed no significant increases in their self-reports, the control group of students experienced significant decreases in self-reported levels of self-determination. Although these results were not directly in line with the research predictions made, they highlight the possibility that self-determination decreases throughout the school year and that participating in the CREST programme may help to reduce the likelihood of these decreases. These results relating to self-regulated processes support the framework for understanding the CREST programme through the lens of educational psychology research aimed at developing these constructs in young students, presented previously in Chapter 2.

It is important to note at this point that significance was not found on the MSLQ self-regulation scale. As the FCSSR has an entirely self-regulated learning focus, it is possible that it is a more sensitive measure compared to the MSLQ. These findings highlight the need for researchers to appreciate the multifaceted nature of self-regulatory processes and possibly suggest that a deeper understanding of the specific aspects of the construct being measured by each tool is needed. The non-significant results relating to cognitive strategies use were in line with the research predictions made, as the CREST programme does not involve direct strategy instruction. However, further research employing similar study designs with different student samples is needed to increase the generalisability of these results relating to these key constructs of interest (addressed in Studies 2 & 3 of this thesis).

Addressing the second research question, the lack of significant changes in levels of self-regulated learning on the six-month delayed post-test is interpreted in this study as evidence that the developments seen at immediate post-test were retained. However, it should be noted that non-significant decreasing trends were found. While decreasing trends over the course of the school year are common (Berger & Karabenick, 2011), this result may suggest that strategies need to be in place in the school context to build on any developments gained through participation in the CREST programme. These findings may also suggest that the self-regulatory skills developed through CREST participation need to be reinforced in other science activities or curriculum subjects to improve retention. While no differences were noted between the school experiences of the control and CREST groups during the six months following the programme, as no delayed post-test data was available for the control group, the above interpretations are made cautiously. Research obtaining data at the delayed post-test from control students with no CREST experience would be an important addition in order to gain a better understanding of these retention effects (addressed in Study 3).

Related Motivational Constructs

The findings of the present study regarding self-efficacy and intrinsic motivation did not align with the corresponding research predictions. Results showed no significant differences between the two groups regarding changes in self-efficacy and while significant differences were found regarding intrinsic motivation, the CREST group of participants did not show any significant increases. One possible interpretation of these results is that the CREST programme did not provide an optimal arena in which to develop these motivational capacities. However, as Boekaerts (1997) stated, students cannot become self-regulated and motivated learners overnight. Therefore, it is possible that the intervention was successful in creating the learning environment required to develop these processes, but that more sessions were needed.

An alternative explanation is possible relating to the results for intrinsic motivation. The significant decreasing trends found in the control group regarding intrinsic value are in line with a large body of research demonstrating that students, on average, experience decreases in intrinsic motivation over the course of the school year (Ryan & Deci, 2000). Therefore, as with the self-determination results discussed above, it is also possible that participation in the CREST programme may have prevented the significant decreasing trends in intrinsic motivation seen in the group of students not taking part in the programme. Further research replicating these results in different student samples will help to provide a more complete understanding of these results (Studies 2 & 3).

In terms of self-efficacy, the results may also be explained by the fact that the CREST programme presents a unique and challenging situation to students who may not be experienced dealing with this amount of control for their learning. As a result, it is possible that students have low self-judgments of their abilities in science immediately after taking part in the programme, and that any benefits related to improved self-efficacy would only be seen on the delayed post-tests. Results from the delayed post-tests showed that while non-significant, students did increase in their self-reports of self-efficacy six months after taking part in the CREST programme. It is therefore possible that participation does influence the development of self-efficacy in students, but that these benefits take a while to come to the surface. Again, research obtaining delayed post-test data for students not taking part in the CREST programme will help shed light onto this issue (addressed in Study 3).

The prediction that the CREST programme would reduce students' levels of test anxiety was also not met in the present study, as the results showed that test anxiety increased for students who participated in CREST. Rozendaal *et al.* (2005) similarly found that self-regulated learning-based innovation programmes may not be able to solve student problems with anxiety. It is possible that the CREST programme does not prepare students for the transition back into test taking. As results for self-regulated learning in this study demonstrated that participation in CREST makes students more aware of their learning, this elevated awareness might also explain the increase seen in students' levels of test anxiety (Kurosawa & Harackiewicz, 1995; Zohar, 1998). These results may also be explained in relation to the self-efficacy findings presented earlier as Pajares (1996) documented that low self-efficacy can lead to higher levels of anxiety towards taking tests. However, further research is needed investigating the influence of CREST programme participation on student levels of test anxiety (Studies 2 & 3).

The results regarding career motivations in science at immediate post-test align with the prediction that taking part in the CREST programme increases students' desires to pursue science careers. In addition, considering the results of the delayed post-tests for career motivation, it was found that these enhanced motivations were retained six months after CREST participation. As the programme introduces students to the investigative nature of science and provides them with an opportunity to act as researchers themselves, participation may give students a different picture of what being a scientist would really be like. Together, these findings provide strong support for the efficacy of this intervention as a strategy to encourage post-secondary science enrolment and the pursuit of science careers.

Finally, as groups were matched on science performance at pre-test, and as results showed that science performance did not predict how much benefit students received from the CREST programme regarding their self-reports of self-regulated processes and related motivations, these results have important implications for designing interventions. A recent trend in educational research highlights the importance of allocating students to different intervention treatment intensities depending on baseline aptitudes (Barnett, Daly, Jones, & Lentz, 2004). The results presented here suggest that this is not necessary, with regards to the CREST programme, and that this programme does not need to be adjusted based on student performance levels in science. This issue will be discussed further in Chapter 7 relating to the results of the other two empirical studies conducted as part of this thesis.

4.5.2 Methodological Considerations and Future Research

The present study does not escape the limitations of similar quasi-experimental projects in educational research. While significant findings have been presented, the limitations regarding the practical significance of these findings need to be discussed. First, it is possible that group differences may have resulted from teacher effects and other confounding background factors that were not explored in this study. While efforts were made to reduce confounding variables, the author does not ignore the possibility of differences in treatment compliance between teachers regarding the guidelines for implementing CREST and the internal validity threats due to the lack of other key background variables.

This study involved students from only one school in Edinburgh and therefore any generalisations need to be made cautiously. In addition, as all students were in the same year-group, it is possible that students in both groups communicated with each other regarding the programme. While this might influence the results by reducing intervention effects and, therefore, providing further support for any significance reported in this study, it is also possible that communication between students heightened the CREST students' awareness of the intervention, thus positively affecting their self-reports of self-regulated processes and related motivations.

While change score analysis was deemed appropriate in order to address the specific research questions for this study, additional exploratory analyses were included to provide insight into the nature of the changes experienced. The results from these analyses demonstrated that students who came into the study with high self-reported levels on the variables measured experienced smaller gains than students with low pre-test scores. These results may be interpreted in several different ways, each providing different sets of implications for practice. Intuitively, the results discussed above are obvious, as students who are already demonstrating high levels of regulatory processes and who possess strong motivations for their learning in science may not have the capacity to develop these further. However, these results may also be explained in relation to the self-report measures used in this study. It is possible that students at the higher end of the self-regulatory and motivational spectrums were not able to report the increases they felt. Further research involving variance analyses using pre-test self-reported levels as the independent variable (low, medium, and high pre-test scorers) is needed in order to gain further insight into this issue (addressed in Study 3).

As the literature presented in Chapter 1 relating to conceptualisations of self-regulated learning highlighted the importance of also appreciating the social nature of student self-regulatory processes in classrooms today, additional research is needed to understand the changes reported in this study at the classroom level (addressed in Study 2). A final limitation worth mentioning here is the presence of power issues in this study. It is possible that the sample involved in this study was not large enough to detect significant trends. However, as this study is part of a series of larger intervention studies, the presence of these power issues will, it is hoped, be resolved.

4.6 CHAPTER SUMMARY AND CONCLUSIONS

Following a quasi-experimental design looking at group differences in change from pre-test to post-test, the results presented in this first empirical chapter revealed that participation in the CREST programme had a significant positive impact on students' self-reported levels of self-regulated learning and career motivation in science. While this study, as part of a series of three intervention studies, supports the curricular potential of the CREST programme both for enhancing self-regulated learning and career motivation as well as limiting decreases in related motivations over the course of the school year, conclusions regarding causal effects are drawn cautiously. The results relating to test anxiety were not in line with the research predictions made for the present study and showed that students experienced increased levels of self-reported test anxiety following participation in the CREST programme. These results were discussed in relation to the structure of the programme and highlighted that additional research conducted with different samples of students is needed.

As the design of the study presented in this first empirical chapter involved administering multiple measures for the key constructs of interest, the results presented allowed for insight to be gained regarding the sensitivity of the standardised measures used. These findings highlight the need for researchers to appreciate the multifaceted nature of self-regulatory processes and suggest that a deeper understanding of the specific aspects of the constructs being measured by each tool is needed.

4.6.1 Thesis Implications

Through conducting this quasi-experimental study in a natural classroom setting and having classroom teachers administer the programme as well as the standardised measures included, the results presented in this first empirical study contribute to the identified gaps in educational literature relating to self-regulated learning presented previously in Chapter 2 Section *2.9*. In addition, by focusing on the development of self-regulated processes and related motivations among adolescent science students, the research presented in this chapter has real implications for practice and addresses very relevant issues at the forefront of education. Overall, appreciating the limitations of this quasi-experimental study, the value of this research, for pedagogical purposes, is clear in terms of helping to persuade teachers and policy makers that the CREST programme warrants further study**.** The results of the second empirical study investigating the impact of the CREST programme on student self-regulated processes and related motivations at the classroom level will now be presented in Chapter 5.

5

STUDY 2: INVESTIGATING THE IMPACT OF THE CREST PROGRAMME AND EXPLORING CLASS DIFFERENCES REGARDING EXPERIENCE[5]

Chapter Objectives

Building on Study 1 presented in Chapter 4, Study 2 aims to investigate the impact of the CREST programme on students' self-reported levels of self-regulated processes and related motivations. Study 2 additionally investigates how different classes of students respond to the CREST programme regarding changes in their self-reported levels of the key self-regulation and motivational constructs measured. This chapter will begin with an introduction outlining the findings of the previous study as well as relevant research in order to place Study 2 in context before moving on to describe the research design and methodology. The focus of this chapter will be on presenting the findings and discussing the results of Study 2 within the context of this thesis and the wider literature published in this area.

[5] The data from this study were presented as part of the PhD seminar series at Moray House School of Education, University of Edinburgh on May 30th, 2012.

5.1 INTRODUCTION

The previous chapter presented results from a quasi-experimental study aiming to understand the impact of participation in the CREST programme on students' self-reported levels of self-regulated processes and related motivations. The findings supported the predictions that participation in the programme fosters the development of self-reported levels of self-regulated learning and career motivation in science among students at immediate post-test and that these developments are retained six months following programme participation. While no significant developments were observed in relation to the other regulatory (self-regulation, cognitive strategies use, and self-determination) and motivational (self-efficacy and intrinsic motivation) constructs studied, contributing to trends in the literature available to date, Study 1 documented significant decreasing trends in the control group, suggesting the impact of the CREST programme on preventing these potential decreases.

Another contradiction to the proposed predictions related to test-anxiety, which significantly increased for CREST participants compared to students not taking part in the programme. Taken together, the results from Study 1 highlighted the need to replicate the findings in a different sample of students and also to closely examine the impact of participation in the CREST programme at both the class and individual student levels. The study presented in this chapter builds on the findings of the first study through investigating these issues.

The literature presented in Chapters 1 and 2, relating to conceptualisations of self-regulated learning, highlighted the importance of also appreciating the social nature of student self-regulatory processes in science classrooms today. Though intuitively understood as internal by definition, these self-regulatory processes are not entirely intra-psychic, as individuals do not operate autonomously without also being influenced by their social environments (Bandura, 1991).

Classrooms are currently understood as social environments (Urdan & Schoenfelder, 2006) and some researchers go as far as to conceptualise different classrooms as different 'cultures' for students (Pintrich, 2003). The classroom climate, defined by Urdan and Schoenfelder (2006) as the general atmosphere in which the learning takes place, can play an important role in developing self-regulated learning and motivation (Vanasupa, Stolk, & Harding, 2010).

Research has shown that teacher and student perceptions of tasks, teacher supportiveness, and social interactions among students are important factors in developing and fostering self-regulation (Patrick, Ryan, & Kaplan, 2007; Ryan, 2000; Vanasupa *et al.,* 2010). As Urdan and Schoenfelder (2006) highlight, the characteristics of the classroom can influence the motivation and cognitions of students in important ways. Therefore, incorporating classroom differences into the research aims of this thesis seems appropriate, and necessary, in order to gain a more complete understanding of these regulatory processes and the student learning taking place through the CREST programme. In addition, as this thesis focuses on understanding these motivations and cognitions through investigating the impact of the CREST programme, focusing additional efforts on the possible influence of different classroom 'cultures' provides an important contribution to knowledge in the field of science education and educational psychology research.

5.2 Study 2 Research Questions and Predictions

Informed by the research discussed thus far in this thesis, and the findings of Study 1, the study presented in this chapter was carried out to gain an understanding of how individual classes of students respond to the CREST programme, focusing on potential class variations. Specifically, the study aims to address four research questions, presented below with their corresponding predictions.

RQ 1: Do classes participating in the CREST programme exhibit different changes in self-reported levels of self-regulated processes and related motivations immediately following participation in the programme compared to the reference control class not taking part in the programme during the course of the study?

<u>Prediction 1:</u> The reference control class will experience no significant increases in self-reported levels of self-regulated processes and related motivations and may show significant decreases in some outcome variables. Meanwhile, the CREST classes will show the following trends:

a. Increases in self-reported levels of self-regulated processes;
b. Maintain pre-test self-reported levels of related motivations, if not increase;
c. Increases in self-reported levels of test anxiety following participation in the programme;
d. Increases in self-reported levels of career motivation, grade motivation in science, and overall science motivation.

RQ 2: Are any developments in the CREST students' self-reports retained four months after participation in the CREST programme for a subset of students?

<u>Prediction 2:</u> Any changes in the self-reported outcome measures will be retained at the four-month delayed post-test for students who participated in CREST.

RQ 3: Are there any differences *between* CREST classes in terms of changes in self-reported levels of the self-regulated processes and related motivations?

Prediction 3: Informed by the results of Study 1, while on average CREST may positively influence changes in the measured outcome variables (Research Question 1 above), it is likely that classes will differ in the extent to which these changes take place through participation in the programme.

RQ 4: If classes are different, does classroom structure at pre-test pertaining to the variables being measured, influence changes in self-reported levels of self-regulated processes and motivation among students participating in the CREST programme?[6]

Prediction 4: The changes experienced through participating in CREST will differ between students based on levels of self-reported self-regulated processes and related motivations at the beginning of the programme. Therefore, in classes with more students with higher pre-test self-reports, more change will be noted.

5.3 METHODS

5.3.1 Study Design

The present study followed a quasi-experimental design, with a different sample of students from Study 1, and involved one 'control' class and nine 'CREST' classes of students from an individual school in Scotland. Students were previously divided into classes based on registration, not ability groups, by the school. Therefore, as students within the year-group were placed into classes and assigned to teachers randomly, the study design is essentially random, which reduces interpretation problems seen in other teacher effect designs (Nye, Konstantopoulos, & Hedges, 2004). All students in the year-group at the school participated in the CREST programme during the academic year except for the one control class. However, due to the small number of the students in the control class (n=18) compared to the total

[6] Research Question 4 will only be addressed if any class differences are found while addressing Research Question 3.

number of students in the nine CREST classes (n=160), this control class will be used more as a reference group than a control group. The questionnaire was administered to all students prior to CREST participation, after CREST completion, and again four months after completion to a subsample of CREST students (just over half, n=90) from the nine classes taking part in the CREST programme. Delayed post-tests were not obtainable for the reference control class as they participated in investigations similar to CREST following the administration of the post-test. While a six-month delayed post-test was desired here to replicate the findings presented in Chapter 4 relating to Study 1, only a four-month delayed post-test was available due to the examination schedules at the school. It should be noted that, contrasting to Study 1, this four-month delayed post-test was administered following the summer break for this sample of students due to the timing of the CREST programme. This will be considered when interpreting the results presented in this chapter.

5.3.2 Participants and Educational Context

Parental consent and child assent were received and data were coded following the ethical guidelines set by the University of Edinburgh and the British Psychological Society. As described in Chapter 3, questionnaires were piloted with 20 students matching the target population (S2, 12-13 years of age). Items were reviewed by two science teachers and approved for appropriateness and relevance with minor revisions made, and piloted a second time with another 40 students. In order to understand the teaching context, classroom observations were also included in the piloting process, similar to Study 1 presented in Chapter 4. These observations included recording the amount of time spent on the CREST projects, documenting the nature of teacher versus student control, and observing the types of projects conducted. As described in Chapters 3 and 4, the British Science Association was contacted and information regarding what quality control measures were in place for the CREST programme across schools throughout the UK was obtained. After discussions, it was felt that the teachers involved in the present study administered the programme in very similar ways, supporting the analysis of pre- to post-test change on the key measures. Therefore, no further related teacher data was collected.

As in Study 1, power calculations were performed prior to conducting the present study using the GPower 3.1 programme developed by Faul *et al.* (2009). To observe a medium effect size at an alpha value of .05 and achieve a power of .80, a minimum sample of 190 was required to detect differences between the classes included in this study. Data were therefore collected from 240 students in 12 classes each made up of 20 students. However, only students who completed both the pre-test and post-test were included in the analyses, resulting in an achieved sample of 190 students. According to Green and D'Oliveira (1999), performing inferential statistics on groups of less then 12 participants is inappropriate in psychological research and therefore, two classes were excluded from the analyses due to low numbers of completed pre- and post-tests, leaving 178 students. Similar to Study 1, this sample size is slightly lower than desired to achieve appropriate power. This will be considered when interpreting the results in the final section of this chapter. In addition, as the delayed post-tests were administered to only a subsample of students (n=90), the achieved power in this section of the analyses might have an impact on the results and will also be considered.

As seen in Table 5.1 on the next page, the gender split between classes in this study was not equal, with males slightly overrepresented. This gender make-up is different to that of Study 1 and generalisations presented in the discussion at the end of this chapter will therefore be made cautiously. In addition, attention should also be drawn to the gender make-up of the reference control class with 13 (72%) male students and only 5 (28%) female students. This will be considered when discussing the results in the final section of the present chapter.

The CREST programme was implemented over the course of eight weeks and students worked on their CREST projects three times a week; completing a total of 24 CREST sessions, each 55 minutes long (total hours on CREST≅22 hours).

Table 5.1. Student numbers, gender split, and mean ages (standard deviations) for all classes included in Study 2.

	Class	Boys	Girls	Total	Mean Age
	Reference/control	13	5	18	13.00 (.00)
	1	12	8	20	13.13 (.39)
	2	9	7	16	13.06 (.25)
	3	10	8	18	13.00 (.00)
	4	8	7	15	13.07 (.26)
	5	8	12	20	13.05 (.22)
	6	10	7	17	13.06 (.24)
	7	11	8	19	13.11 (.32)
	8	10	7	17	12.94 (.24)
	9	11	7	18	13.00 (.00)
Total	**10**	**102 (57%)**	**76 (43%)**	**178**	**13.05 (.25)**

5.3.3 Pre- and Post-test Measures

Similar to Study 1 presented in Chapter 4, three self-report measures in the field of self-regulation and motivation were chosen for the present study. These included: the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich & De Groot, 1990); the modified Five Component Scale of Self-Regulation (FCSSR, MacLellan & Soden, 2006); and the Science Motivation Questionnaire (SMQ, Glynn *et al.,* 2009).

As the reliability and implementation of the above measures proved useful in addressing the research questions for Study 1, it was decided that these measures were also appropriate in order to address the research aims of the present study. Using similar measurement instruments will also allow for a cross-study synthesis interpretation, which will be presented in the final chapter of this thesis (Chapter 7). These measures were presented in detail previously in Chapter 3 relating to the specific constructs of interest. A mean score for each subscale was generated for analysis. The following three tables (Tables 5.2, 5.3, & 5.4) present summaries of the subscales with example items making up each scale. Internal consistency was confirmed by calculating Cronbach's alpha values for each scale based on the sample. The calculated scale reliability results are presented in the following tables alongside the reliabilities reported in the literature for each measure, allowing for comparison.

Table 5.2. Example items and internal consistency (reliability) coefficients for the MSLQ subscales.

Subscale	n	Example Item	α	α (1990)*
Motivation Scales				
Self-Efficacy	9	I expect to do very well in science class	.92	.89
Intrinsic Value	9	Understanding this subject is important to me	.90	.87
Test Anxiety	4	I am so nervous during a test that I cannot remember facts I have learned	.82	.75
Cognitive Scales				
Cognitive Strategies Use	13	I outline the chapters in my book to help me study	.87	.83
Self-Regulation	9	I ask myself questions to make sure I know the material have been studying	.69	.74

*Published alpha values from Pintrich and De Groot (1990) for the subscales on the MSLQ.

Table 5.3. Example items and internal consistency (reliability) coefficients for the FCSSR subscales.

Subscale	n	Example Item	α	α (2006)*
Goal Setting	10	When doing my academic work, I always set goals to guide me in my efforts	.95	.88
Strategy Implementation	4	I take notes during class	.89	.90
Strategy Monitoring	15	I compare the strategy to other strategies to see which is more effective	.90	.92
Total	45		.96	

*Published alpha values from MacLellan and Soden (2006). Note: no published alpha value available for the total self-regulated learning composite.

Table 5.4. Example items and internal consistency (reliability) coefficients for the SMQ subscales.

Subscale	n	Example Item	α	α (2009)*
Intrinsic Motivation Personal Relevance	10	The science I learn is more important to me than the grade I receive	.88	.91
Self-Efficacy	4	I believe I can master the knowledge and skills in the science course	.84	-
Test Anxiety	5	I become anxious when it is time to take a science test	.78	-
Self-Determination	4	I put enough effort into learning the science	.77	.74
Career Motivation	2	I think about how learning the science can help my career	.83	.88
Grade Motivation	5	Earning a good science grade is important to me	.62 **	.55
Science Motivation	30		.90	.91

*Published alpha values from Glynn *et al.* (2009). Note: self-efficacy and test anxiety are included as two composites so no published alpha value available. ** Mean inter-item correlation between .2 and .4, which is acceptable according to Briggs and Cheek (1986).

5.3.4 Procedure

The questionnaires were administered to all students within one week prior to the CREST intervention and within one week after its completion. Delayed post-tests were administered four months following CREST participation to a subset of participating students (n=90, roughly half of the CREST students included in the study). All questionnaires were administered during class time and students were given 40 minutes to complete them. Completion times ranged between 25 and 35 minutes. Some students did not complete the entire questionnaire and several questions were left blank. Missing data was treated as *user-missing* values and coded appropriately in the statistical software package used (SPSS 19.0). As there were no variables with more than 5% missing data, none were removed from analysis. Missing data analysis was performed similar to Study 1, presented in Chapter 4, and the results of Little's MCAR test was not significant, indicating that data was missing completely at random.

5.3.5 Analysis

As discussed in the methodological justification presented in Chapter 3, one of the strengths of the questionnaire measures used in this thesis is that they can be treated parametrically and have been extensively used in this manner in the literature (Glynn *et al.*, 2009; MacLellan & Soden, 2006; Wolters & Pintrich, 1998). Therefore, following suit with researchers who are using these measurement tools, and appreciating the increased power and robustness of using parametric analyses (Zimmerman & Zumbo, 1993), the data presented here for the second empirical study were also subjected to parametric tests.

Descriptive evaluation involved calculating the means and standard deviations for all subscales in order to determine the variability of scores among the students involved in the study. Preliminary analyses included testing for violations of assumptions of normality and exploring the descriptive statistics to provide further support for parametric treatment of the data. Similar to the work conducted by Chularut & DeBacker (2004), one-way analyses of variances (ANOVA) were also performed in preliminary analyses comparing the ten classes included in this study design on all pre-test measures in order to verify that the classes were matched on pre-test scores.

To address the first research question relating to comparisons of the reference control class to the nine CREST classes, paired-samples *t-tests* were conducted to investigate what changes took place in each of the classes from pre-test to post-test. Literature dating back to the 1960's reported the problem of not directly comparing change scores and assuming *group* differences based only on the above *t-tests*. Researchers state that when intact classrooms are assigned to treatments, the paired-samples *t-tests* have too small an error term due to the fact that randomisation is lumpy (Campbell & Stanley, 1966; Zimmerman, 1997). Therefore, following the suggestions of Campbell & Stanley (1966), and more recently Zimmerman (1997), further independent samples *t-tests* were also conducted to directly compare the change scores of each of the nine CREST classes to the reference control class in order to explore the presence of *group* differences. In order to investigate whether any developments in students' levels of self-regulated processes and the related motivational factors studied were retained four months after participation in the programme, student scores on the variables at post-test and delayed post-test were compared through conducting a series of similar paired-samples *t-tests*. As delayed post-test data was only available for a subset of the CREST participants (n=90), only these students were included in this section of analysis.

While both multilevel and regression analyses were considered for this study in order to address the third research question relating to class differences, due to the total sample size as well as the small sample size within each class, the analytical strategy chosen for this study was to look at the differences between classrooms in experience within the CREST programme. Classroom effects in this study are therefore operationalised as between-classroom differences in change scores from pre-test to post-test. As the analysis of change scores addresses group differences, this was the method executed in this study (Smolkowski, 2010; see Chapter 3 for a more detailed justification).

In order to simplify the analyses and make results more manageable, the results will be presented in sections relating to the research questions outlined earlier in Section *5.2*. Table 5.5 below provides an overview of these results sections with an outline of the corresponding parametric analyses that were conducted.

Table 5.5. An overview of results sections included in Study 2.

	Description of Results Section
Part 1: Preliminary Analysis	
	Exploring class pre-test differences on all measured variables • One-way ANOVAs on pre-test scores with post-hoc tests
Part 2: Main Analyses	
RQ 1	Investigating *group* differences in pre- to post-test change • Paired-samples *t-tests* on pre- and post-test scores for all classes • Independent-samples *t-tests* comparing each CREST class to the reference control class
RQ 2	Investigating retention effects for CREST students • Paired-samples *t-tests* on post-test and delayed post-test scores for subset
RQ 3	Investigating *class* differences in pre-to post-test change • MANOVAs and ANOVAs on pre/post-test change scores with post-hoc tests

Note. RQ= Research Question.

Similar to Study 1, and for reasons outlined in Chapter 3, effect sizes are also reported in addition to significance values, as reporting and interpreting effect sizes can provide insight into the practical implications of the magnitude of reported differences (Field, 2009, 2013). As with Study 1, Cohen's d statistic will accompany any *t-tests* presented and partial eta squared ($\eta\rho^2$) values will be included to represent effect sizes for ANOVAs (see Table 5.6 below).

Table 5.6. Guidelines for interpreting effect sizes (Cohen 1988, p. 284-287).

Cohen's d	Size of Effect	$\eta\rho^2$	Size of Effect
≥.10	small	≥.01	small
≥.30	medium	≥.06	medium
≥.80	large	≥.14	large

5.4 RESULTS

5.4.1 Preliminary Analysis: Exploring Class Pre-test Differences on All Measured Variables

One-way ANOVAs were conducted to explore differences between classes on all pre-test variables measured. This step of the analysis was necessary in order to ensure the validity of any further tests of intervention effects. As sample sizes across groups were slightly different, Gabriel's procedure was used following the suggestions of Field and Hole (2003), as this test has greater power than both Turkey HSD and Bonferroni. The Games-Howell procedure was also run following the recommendations of Field (2009, 2013), due to the uncertainty of knowing whether population variances are equivalent. The results from the one-way ANOVAs showed no significant pre-test differences between the 10 classes included in this study on any pre-test variables using a conservative Bonferroni adjusted alpha level (p=.01) (to reduce the risk of Type 1 error). From these preliminary results, it is reasonable to suggest that any systematic differences in the variables being studied at post-test and delayed post-test are likely due to either class or teacher effects through administering the CREST programme. Preliminary analyses also involved exploring gender differences throughout the data. As no significant differences were found between boys and girls on all pre- and post-test measures, the data were combined for the two genders in all subsequent analyses conducted in the present study.

5.4.2 RQ 1: Investigating Group Differences in Pre- to Post-test Change

Before describing the experience of the nine CREST classes, the reference control class results will be presented. To explore changes from pre-test to post-test in students' self-reported levels of self-regulated processes and related motivations in the reference control class that did not take part in the CREST programme, paired-samples *t-tests* were conducted on all variables measured. Results showed that the control class experienced no significant changes from pre-test to post-test on any measured outcome variables. These non-significant results are presented on the next page in Table 5.7 and confirm part of the first research prediction that the students not taking part in the CREST programme would show no significant increases in the self-regulated processes and related motivations measured in this study.

Table 5.7. A summary of pre- and post-test means, standard deviations, and paired-samples *t-tests* results for the reference control class.

Variable	Pre-test Mean (SD)	Post-test Mean (SD)	df	*t*	*p*	d
MSLQ Self -Regulation	4.55 (.857)	4.49 (.939)	17	.417	.682	.067
MSLQ CSU	4.86 (.700)	4.80 (1.04)	13	.358	.726	.068
FCSSR Total SRL	2.26 (.289)	2.25 (.308)	11	.036	.972	.033
SMQ Self-Determination	3.56 (.868)	3.61 (.683)	15	-.356	.727	.064
MSLQ Self-Efficacy	4.82 (.824)	4.78 (.844)	17	.379	.709	.048
SMQ Self-Efficacy	3.43 (.761)	3.64 (.584)	15	-1.979	.066	.31
MSLQ Intrinsic Value	5.00 (.799)	5.10 (.779)	16	-.570	.577	.13
SMQ IMPR	3.50 (.663)	3.53 (.551)	13	-.192	.851	.049
MSLQ Test Anxiety	3.32 (1.58)	3.35 (1.57)	16	-.127	.901	.019
SMQ Test Anxiety	2.64 (.869)	2.79 (.885)	16	-1.166	.261	.17
SMQ Career Motivation	3.29 (.885)	3.27 (.937)	16	.107	.916	.022
SMQ Grade Motivation	3.86 (.644)	3.93 (.444)	15	-.598	.558	.12
SMQ Overall SM	101.69 (14.34)	103.38 (11.47)	12	-.544	.597	.13

Note. *two-tailed significance values presented. Note: CSU= cognitive strategies use, SRL= self-regulated learning, IMPR= intrinsic motivation and personal relevance, SM= science motivation.

The paired-samples *t-tests* presented above were repeated for each of the nine CREST classes included in the present study separately, and taken together in order to investigate the significance of any measured changes from pre-test to post-test. While it may seem counter-intuitive to consider all CREST classes together when looking at pre- to post-test change in a study investigating *class* differences, as the research question here relates to *group* differences, looking at the average change from pre-test to post-test for all CREST classes together may provide helpful insight. In addition, looking at the overall change considering all students participating in the CREST programme together, helps connect to the results presented in Study 1 (Chapter 4) relating to *group* differences, replicating the results with a much larger sample of students. However, it is important to clarify at this point that the control class is only being considered as a reference class and no direct statistical tests are being conducted, as comparing 160 CREST students to the 18 students not taking part in the programme would be inappropriate.

While an alpha level set to .05 may not be expected due to the number of similar tests run in this section of analysis, the results will be carefully interpreted appreciating their practical significance. As the sample size for each class included in the present study design is very small, the likelihood of finding significance is already very low (Feise, 2002; Koretz, 2005). Therefore, if the alpha value is adjusted to reduce the chances of Type 1 error, the chances of Type 2 errors occurring may increase. All results presented below had a medium to large effect size, unless otherwise mentioned and therefore will be considered as significant intervention effects.

Tables 5.8, 5.9, 5.10, & 5.11 (on pages 136, 139, 140, & 143) show the means and standard deviations for each of the nine CREST classes at pre-test and post-test. The computed change scores as well as the significant paired-samples *t-test* results are also presented in the following tables. As no significant changes were found in the reference control class (see Table 5.7 presented previously on page 133), the presence of significant changes from pre-test to post-test in any of the individual nine CREST classes may indicate an intervention effect for the CREST programme. The following four tables (Tables 5.8, 5.9, 5.10, & 5.11) are organised into self-regulated processes, related motivations, test anxiety, and science-specific motivational outcome measures.

Self-Regulated Processes

From Table 5.8 on page 136, it can be seen that Class 7 experienced significant increases in self-regulation measured on the MSLQ from pre-test (M=4.20, SD=.856) to post-test (M=4.56, SD=.936) with the Cohen's d value indicating a medium effect size. Class 2 also showed significant increases from pre-test (M= 2.66, SD= .330) to post-test (M=3.04, SD=.553) in self-regulated learning measured by the FCSSR with the Cohen's d statistic (d=.84) indicating a large effect size. Significant increases were also found in Class 3 on the SMQ measure of self-determination. Results from the paired-samples *t-test* showed that Class 3 experienced significant increases from pre-test (M=3.57, SD=.727) to post-test (M=3.92, SD=.647) with the Cohen's d value indicating a medium effect (d=.50).

These significant findings provide some support for the first research prediction as they demonstrate that, unlike the control class, some of the CREST classes experienced significant changes in self-regulation, self-regulated learning, and self-determination following participation in the programme suggesting the possibility of intervention effects for the CREST programme.

Further support was found for the above results relating to self-regulated processes when considering the nine CREST classes together. The results of the paired-samples *t-tests* conducted for the CREST classes taken together were significant for SMQ self-determination, with the CREST classes on average increasing from pre-test (M=3.62, SD=.797) to post-test (M=3.76, SD=.747). The mean increase in self-reported levels of self-determination was .134 with a 95% confidence interval ranging from .0388 to .229 and the Cohen's d effect size statistic (.18) indicating a small, approaching medium effect. While average changes on the self-regulated learning measure did not show significance at the conservative alpha level of .01 (to control for Type 1 error), a closer look into the effect size of this test highlights the potential practical utility of the result. Table 5.8 presented on the following page shows that the effect size for the increase in self-reported levels of self-regulated learning in the nine CREST classes considered together as a *group*, from pre-test (M=2.44, SD=.615) to post-test (M=2.53, SD=.642), according to Cohen's d statistic (.14), was small.

Together, these results provide support for the overall impact of the CREST programme on the students taking part. They also contribute further evidence for the possibility that, while only three classes appeared to demonstrate significant changes on some self-regulated process measures following CREST participation, the overall trend in the nine classes taking part in the programme on these outcome measures was an increasing one. Overall, the results presented in this section provide support for the first research prediction relating to the impact of CREST programme participation on self-regulated processes and also externally validate the results presented previously in Study 1 by replicating them in a difference student sample.

Table 5.8. A summary of the means (standard deviations) of the nine classes for the self-regulated process measures and the corresponding paired-samples *t-test* results.

Class	Pre-test	Post-test	Change Score	Paired-samples *t-test* results*
MSLQ Self-Regulation				
1	4.35 (.739)	4.27 (.494)	-.0802 (.624)	N.S
2	4.24 (.431)	4.57 (.607)	.333 (.769)	N.S
3	4.65 (.828)	4.84 (.806)	.191 (.306)	N.S
4	4.64 (1.02)	4.66 (.569)	.0185 (.775)	N.S
5	4.48 (.991)	4.38 (1.02)	-.0994 (.945)	N.S
6	4.68 (.870)	4.45 (1.11)	-.222 (.578)	N.S
7	4.20 (.856)	4.56 (.936)	.360 (.611)	$t(16)=-2.423$, $p=.028$, d=.40
8	4.13 (.914)	4.30 (.726)	.170 (.752)	N.S
9	4.32 (.801)	4.02 (.649)	-.296 (.780)	N.S
Total	4.37 (.861)	4.41 (.841)	.0288 (.776)	N.S
MSLQ Cognitive Strategies Use				
1	4.33 (1.00)	4.43 (.582)	.0995 (.866)	N.S
2	4.87 (.631)	5.35 (.999)	.482 (1.06)	N.S
3	5.23 (.812)	5.07 (1.17)	-.165 (1.02)	N.S
4	4.93 (.960)	4.82 (.673)	-.118 (.790)	N.S
5	4.46 (1.16)	4.51 (1.01)	.0486 (.647)	N.S
6	5.16 (1.12)	5.12 (1.20)	-.0462 (.894)	N.S
7	4.54 (.875)	4.70 (.963)	.158 (.543)	N.S
8	4.13 (1.02)	4.53 (.791)	.412 (.892)	N.S
9	4.56 (.967)	4.30 (.571)	-.260 (.989)	N.S
Total	4.62 (.997)	4.71 (.909)	.0860 (.850)	N.S
FCSSR Total Self-Regulated Learning				
1	2.32 (.605)	2.33 (.465)	.0083 (.302)	N.S
2	2.66 (.330)	3.04 (.553)	.381 (.467)	$t(12)=-2.946$, $p=.012$, d=.84
3	2.69 (.346)	2.65(.611)	-.0384 (.339)	N.S
4	2.50 (.631)	2.65 (.710)	.142 (.515)	N.S
5	2.29 (.742)	2.38 (.748)	.0915 (.490)	N.S
6	2.67 (.403)	2.82 (.317)	.153 (.342)	N.S
7	2.55 (.572)	2.67 (.610)	.114 (.363)	N.S
8	2.28 (.742)	2.36 (.497)	.0778 (.612)	N.S
9	2.17 (.537)	2.09 (.613)	-.0785 (.357)	N.S
Total	2.44 (.615)	2.53 (.642)	.0899 (.429)	$t(114)=-2.24$, $p=.026$, d=.14
Self-Determination				
1	3.47 (.546)	3.47 (.676)	.000 (.493)	N.S
2	3.89 (.532)	4.19 (.528)	.297 (.726)	N.S
3	3.57 (.727)	3.92 (.647)	.347 (.550)	$t(17)=-2.678$, $p=.016$, d=.50
4	3.82 (.616)	3.88 (.705)	.0536 (.539)	N.S
5	3.36 (.944)	3.48 (.853)	.125 (.582)	N.S
6	3.84 (.701)	3.82 (.930)	-.0147 (.555)	N.S
7	3.96 (.683)	3.96 (.683)	.000 (.507)	N.S
8	3.20 (1.21)	3.59 (.718)	.391 (.832)	N.S
9	3.54 (.806)	3.58 (.723)	.0417 (.564)	N.S
Total	3.62 (.797)	3.76 (.747)	.134 (.602)	$t(156)=-2.783$,$p=.006$, d=.18

Note. *two-tailed significance values presented. N.S= non-significant.

Related Motivations

Table 5.9 on page 139 presents a summary of the pre- and post-test means and change scores for the nine CREST classes, as well as any significant paired-samples *t-test* results for the related motivational variables. From Table 5.9, it can be seen that significant increases were observed in Class 2 relating to both measures of self-efficacy. On the MSLQ measure of self-efficacy, Class 2 showed significant increases from pre-test (M=4.88, SD=.927) to post-test (M=5.44, SD=1.10) with the Cohen's d value for this test (d=.55) indicating a medium effect size. Similar significant increases from pre-test (M=3.64, SD=.683) to post-test (M=3.97, SD=.816) were also noted on the SMQ measure of self-efficacy with the Cohen's d value also indicating a medium effect size (d=.43). While no other CREST classes demonstrated significant increases in self-efficacy, increasing trends were observed with no significant decreases noted. These results are in line with the first research prediction as they suggest that the CREST classes experienced significant changes in self-efficacy while the reference control class did not (as shown previously in Table 5.7 on page 133).

Providing support for the observed trends described above, Table 5.9 also shows that, overall, the CREST classes experienced significant increases in self-reported levels of self-efficacy from pre-test (M=3.50, SD=.854) to post-test (M=3.70, SD=.788) on the SMQ at the adjusted alpha level of .01. The mean change score was .202 with a 95% confidence interval ranging from .105 to .299 and the Cohen's d statistic (.23) indicated a small, approaching medium effect. A similar increasing trend (not significant at the adjusted alpha level) was found for self-efficacy measured on the MSLQ when all classes were considered together and the Cohen's d statistic for this test (d=.17) indicated a small, approaching medium effect.

Relating to intrinsic motivation, Table 5.9 shows that Class 2 experienced significant increases on the SMQ measure of intrinsic motivation and personal relevance with the post-test score (M=4.08, SD=.620) being significantly higher then the starting pre-test score (M=3.34, SD=.445) measured before participation in the CREST programme. The Cohen's d value for this test documented a large effect size (d=.81).

While no other classes demonstrated significant increases in intrinsic motivation, similar to self-efficacy, increasing trends were noted. The observation of these increasing trends for intrinsic motivation and personal relevance measured by the SMQ were supported by the analysis of the CREST classes considered together.

Results from the paired-samples *t-tests* considering all nine CREST classes together showed that the classes, on average, increased significantly from pre-test (M=3.48, SD=.745) to post-test (M=3.63, SD=.718) on levels of self-reported intrinsic motivation and personal relevance measured on the SMQ. The mean change score for this variable was .153 with the 95% confidence interval ranging from .0711 to .235 and the Cohen's d statistic (.21) indicating a small, approaching medium effect. Similar to the self-efficacy results presented above for the MSLQ, paired-samples *t-tests* for intrinsic motivation measured on the MSLQ did not reach significance at the conservative alpha level of .01.

Relating back to the first set of research predictions outlined at the beginning of this chapter, the results here regarding changes in self-efficacy and intrinsic motivation align with the predictions made pertaining to these motivational variables. The results presented above relating to self-efficacy and intrinsic motivation provide support for the presence of *group* differences in this study relating to these constructs. As significant changes in self-efficacy and intrinsic motivation were reported in some of the CREST classes, with no significant changes reported in the reference control class (see Table 5.7 reported earlier), the presence of intervention effects for the CREST programme is possible regarding these related motivations.

The above results provide further support for the first research question in regards to the specific trends expected on these outcome measures following CREST participation. While it was predicted that levels of self-efficacy and intrinsic motivation would not decrease following participation in the CREST programme, the above results suggest that for this sample of students, unlike in Study 1, self-reported levels of self-efficacy and intrinsic motivation, on average, increased following participation in the programme. However, these results are interpreted with caution as the absence of a control group matching the size of the CREST group for this study (n=160) limits the conclusions that can be drawn from these findings alone.

Table 5.9. A summary of the means (standard deviations) of the nine classes for the related motivational measures and the corresponding paired-samples *t-test* results.

Class	Pre-test	Post-test	Change Score	Paired-samples *t*-test results*
MSLQ Self-Efficacy				
1	4.37 (1.12)	4.68 (.924)	.304 (.937)	N.S
2	4.88 (.927)	5.44 (1.10)	.556 (.916)	$t(13)=-2.269$, $p=.038$, d=.55
3	5.81 (.783)	5.69 (.885)	-.111 (.563)	N.S
4	5.07 (.1.08)	5.31 (.791)	.238 (.897)	N.S
5	4.19 (1.18)	4.36 (1.07)	.170 (.524)	N.S
6	5.16 (1.04)	5.11 (1.16)	-.0513 (1.28)	N.S
7	4.59 (.777)	4.64 (1.11)	.0468 (1.05)	N.S
8	4.27 (1.23)	4.68 (1.32)	.419 (.159)	N.S
9	4.46 (.992)	4.48 (.834)	.0131 (1.12)	N.S
Total	4.66 (1.09)	4.85 (1.09)	.185 (1.02)	$t(135)=-2.12$, $p=.036$, d=.17
SMQ Self-Efficacy				
1	3.32 (.799)	3.55 (.852)	.237 (.568)	N.S
2	3.64 (.683)	3.97 (.816)	.328 (.604)	$t(15)=-2.174$, $p=.046$, d=.43
3	3.68 (.742)	3.86 (.875)	.181 (.574)	N.S
4	3.92 (.638)	3.90 (.712)	-.0167 (.359)	N.S
5	3.32 (1.04)	3.55 (.915)	.237 (.757)	N.S
6	3.48 (1.06)	3.72 (.943)	.234 (.716)	N.S
7	3.78 (.656)	3.89 (.585)	.118 (.529)	N.S
8	3.19 (.986)	3.44 (.634)	.250 (.771)	N.S
9	3.21 (.811)	3.44 (.622)	.235 (.627)	N.S
Total	3.50 (.854)	3.70 (.788)	.202 (.615)	$t(155)=-4.09$, $p=.000$, d=.23
MSLQ Intrinsic Value				
1	4.52 (.901)	4.58 (.942)	.0585 (.835)	N.S
2	5.15 (.688)	5.56 (1.05)	.403 (.823)	N.S
3	5.70 (.885)	5.72 (.772)	.0247 (.684)	N.S
4	5.11 (1.09)	5.25 (.595)	.143 (.780)	N.S
5	4.58 (1.16)	4.74 (1.18)	.161 (.554)	N.S
6	5.47 (.950)	5.38 (1.17)	-.0940 (1.19)	N.S
7	4.54 (.812)	4.69 (1.14)	.146 (.790)	N.S
8	4.44 (1.12)	4.49 (.830)	.0519 (.752)	N.S
9	4.43 (1.17)	4.28 (.702)	-.148 (1.13)	N.S
Total	4.80 (1.05)	4.89 (1.05)	.0886 (.844)	N.S
SMQ IMPR				
1	3.31 (.767)	3.47 (.644)	.163 (.359)	N.S
2	3.34 (.445)	4.08 (.620)	.438 (.638)	$t(15)=-2.740$, $p=.015$, d=.81
3	3.64 (.743)	3.51 (.796)	-.131 (.433)	N.S
4	3.69 (.597)	3.86 (.676)	.171 (.427)	N.S
5	3.43 (.810)	3.57 (.747)	.144 (.354)	N.S
6	3.68 (.761)	3.69 (.779)	.0125 (.515)	N.S
7	3.55 (.681)	3.71 (.715)	.153 (.347)	N.S
8	3.11 (1.05)	3.41 (.783)	.293 (.768)	N.S
9	3.29 (.716)	3.45 (.603)	.153 (.567)	N.S
Total	3.48 (.745)	3.63 (.718)	.153 (.506)	$t(156)=-3.692$,$p=.000$, d=.21

Note. *two-tailed significance values presented. IMPR= intrinsic motivation and personal relevance.

As Study 1 reported significant increases in test anxiety for students participating in the CREST programme, similar significant increasing trends were predicted here. However, Table 5.10 below presents the results from the paired-samples *t-tests* conducted for test anxiety, which showed no significant changes in any of the nine classes taking part in the CREST programme with the overall trend also indicating no significant changes in this outcome measure. These results are not in line with the research prediction relating to increases in test anxiety and suggest that, in contrast to the findings documented in Study 1, participation in the CREST programme did not have a significant impact on students' self-reported anxiety levels towards taking tests. This result is further supported by the non-significant results reported earlier in Table 5.7 for the reference control class. However, an inspection of the means and change scores shown in Table 5.10 below relating to test anxiety indicates an increasing trend which will be considered when interpreting these results in the discussion at the end of this chapter.

Table 5.10. A summary of the means (standard deviations) of the nine classes for the test anxiety measures and the corresponding paired-samples *t-test* results.

Class	Pre-test	Post-test	Change Score	Paired-samples *t-test**
MSLQ Test Anxiety				
1	3.46 (1.25)	3.64 (1.18)	.184 (1.12)	N.S
2	3.70 (1.36)	4.23 (1.65)	.531 (1.40)	N.S
3	3.44 (1.47)	3.28 (1.46)	-.167 (.984)	N.S
4	3.29 (1.89)	3.48 (1.53)	.192 (1.11)	N.S
5	3.78 (1.38)	3.64 (1.31)	-.132 (1.22)	N.S
6	4.37 (1.46)	3.89 (1.31)	-.481 (1.27)	N.S
7	3.47 (1.45)	3.89 (1.36)	.417 (1.07)	N.S
8	4.04 (1.04)	4.00 (1.03)	-.0357 (1.41)	N.S
9	3.86 (1.37)	3.94 (1.07)	.0781 (.995)	N.S
Total	3.71 (1.40)	3.80 (1.31)	.0912 (1.18)	N.S
SMQ Test Anxiety				
1	2.69 (.725)	2.88 (.790)	.189 (.735)	N.S
2	3.26 (1.04)	3.18 (.979)	-.0875 (.495)	N.S
3	2.83 (.914)	3.24 (.884)	.400 (.718)	N.S
4	2.87 (.956)	2.80 (.932)	-.0714 (.717)	N.S
5	2.66 (.813)	2.65 (.885)	-.0100 (.733)	N.S
6	2.55 (1.10)	2.88 (.949)	.325 (.786)	N.S
7	2.36 (1.22)	2.65 (1.05)	.295 (.729)	N.S
8	2.50 (1.06)	2.48 (.723)	-.0250 (1.02)	N.S
9	2.68 (.614)	2.66 (.769)	-.0222 (.548)	N.S
Total	2.70 (.955)	2.82 (.898)	.115 (.735)	N.S

Note. *two-tailed significance values presented.

Science-Specific Motivations

Table 5.11 presented on page 143 shows the means and standard deviations for the science-specific motivational measures. No significant changes from pre- to post-test were reported in any of the nine CREST classes in terms of self-reports of career motivation (results shown in Table 5.11). While an increasing trend was observed, the paired-samples *t-test* conducted for career motivation with all CREST classes considered together was not significant and is also shown in Table 5.11. These results are not in line with the research prediction that participating in the CREST programme would significantly increase students' self-reports of motivation for pursuing science careers from pre-test to post-test (as documented in Study 1). From the results presented in Table 5.11, and the non-significant reference control class results presented earlier in Table 5.7, it can be concluded that no differences between the groups were found relating to this outcome measure.

As outlined earlier in Section *5.2*, it was predicted that grade motivation in science and overall science motivation would increase alongside any increases in related motivations. For grade motivation in science, significant *decreases* were found from pre-test (M=4.03, SD=.447) to post-test (M=3.77, SD=.601) in Class 7 with the Cohen's d statistic indicating a medium effect size (d=.57). While significance was only found in this class, decreasing trends were observed in most CREST classes. Considering the non-significant results presented earlier in Table 5.7 for the reference control class, these results suggest the possibility of *group* differences relating to grade motivation.

Supporting the observed decreasing trends, the results from the paired-samples *t-tests* conducted on all nine CREST classes taken together showed that for grade motivation, self-reports at pre-test (M=3.84, SD=.642) were significantly higher than self-reports at post-test (M=3.73, SD=.622). The mean decrease in self-reported levels is shown below in Table 5.11 and the 95% confidence interval ranged from -.0247 to -.217 with the Cohen's d statistic (.19) indicating a small, approaching medium effect size. As grade motivation was not included in Study 1, no results were available to be replicated. However, it was expected that in addition to increasing levels of career motivation in science, the CREST programme would also have a positive influence on students' self-reports of their motivations to attain high grades in science class. The results presented above relating to grade motivation therefore go against the research predictions and suggest that participation in the CREST programme led to decreases in students' motivations for achieving high grades in science. These results will be discussed further at the end of this chapter.

Relating to overall science motivation measured by the SMQ, Class 1 showed significant increases from pre-test (M=98.2, SD=15.7) to post-test (M=103.1, SD=15.6) with the Cohen's d statistic indicating a medium effect size (d=.32). Similar results were found in Class 2, with significant increases from pre-test (M=111.2, SD=9.58) to post-test (M=119.4, SD=6.80) and with Cohen's d indicating a large effect size (d=.99). Together with the non-significant changes in the reference control class presented in Table 5.7 earlier, these results provide support for the presence of *group* differences relating to overall science motivation following CREST participation. When investigating changes for all CREST classes considered together, for total science motivations as measured by the SMQ, pre-test self-reports (M=103.16, SD=17.3) were found to be significantly lower than post-test values (M=106.72, SD=16.65). The mean change score was 3.56 with the 95% confidence interval ranging from 1.85 to 5.26 and the Cohen's d statistic (.21) indicating a small, approaching medium effect. These results provide further support for the research prediction that participating in the CREST programme would have a positive impact on students' overall motivations for their science learning.

Table 5.11. A summary of the means (standard deviations) of the nine classes for the science-specific motivation measures and the corresponding paired-samples *t-test* results.

Class	Pre-test	Post-test	Change Score	Paired-samples *t-test**
Career Motivation				
1	3.61 (1.09)	3.58 (1.00)	-.0278 (.915)	N.S
2	4.00 (.775)	4.41 (.554)	.406 (.800)	N.S
3	4.17 (.874)	3.86 (1.03)	-.306 (.622)	N.S
4	4.17 (.900)	4.00 (.756)	-.167 (.976)	N.S
5	3.70 (1.07)	3.93 (1.05)	.225 (1.16)	N.S
6	3.94 (1.18)	4.13 (.866)	.188 (.834)	N.S
7	3.87 (.814)	3.87 (1.01)	.000 (.726)	N.S
8	3.53 (1.68)	3.62 (.857)	.0882 (1.73)	N.S
9	3.53 (.899)	3.72 (.647)	.194 (.667)	N.S
Total	3.82 (1.06)	3.89 (.899)	.0669 (.984)	N.S
Grade Motivation				
1	3.71 (.664)	3.77 (.632)	.0706 (.587)	N.S
2	4.12 (.428)	4.11 (.429)	-.0154 (.360)	N.S
3	3.87 (.644)	3.83 (.789)	-.0333 (.505)	N.S
4	4.03 (.523)	3.96 (.461)	-.0667 (.635)	N.S
5	3.81 (.538)	3.71 (.587)	-.100 (.461)	N.S
6	3.98 (.619)	3.78 (.546)	-.200 (.490)	N.S
7	4.03 (.477)	3.72 (.601)	-.316 (.658)	$t(18)=2.093$, $p=.050$, d=.57
8	3.47 (1.02)	3.29 (.705)	-.173 (1.00)	N.S
9	3.68 (.599)	3.47 (.504)	-.211 (.487)	N.S
Total	3.85 (.642)	3.73 (.622)	-.121 (.594)	$t(148)=2.484$, $p=.014$, d=.19
Overall Science Motivation				
1	98.20 (15.7)	103.1 (15.6)	4.93 (6.49)	$t(14)=-2.946$, $p=.010$, d=.32
2	111.2 (9.58)	119.4 (6.80)	8.23 (8.77)	$t(15)=-3.381$, $p=.005$, d=.99
3	106.6 (15.2)	110.5 (18.5)	3.87 (9.87)	N.S
4	108.4 (13.4)	108.9 (12.9)	.545 (9.48)	N.S
5	100.4 (22.1)	103.7 (19.9)	3.27 (9.06)	N.S
6	107.8 (18.6)	109.2 (21.0)	1.46 (8.55)	N.S
7	106.2 (12.2)	108.1 (13.7)	1.90 (8.97)	N.S
8	91.83 (25.1)	97.67 (18.2)	5.83 (15.7)	N.S
9	97.57 (16.6)	99.93 (12.2)	2.36 (9.90)	N.S
Total	103.1 (16.9)	106.9 (16.6)	3.56 (9.70)	$t(126)=-4.135$,$p=.000$, d=.21

Note. *two-tailed significance values presented.

5.4.3 Validation of Intervention Effects Relating to RQ 1

The results presented, thus far, provide some support for the first set of research predictions that the CREST classes experienced different changes on several measured outcomes compared to the reference control class included in this study. However, in order to verify the presence of any intervention effects and *group* differences, independent-samples *t-tests* directly comparing the change scores of each CREST class to the reference control class were performed when significant increases were found from pre-test to post-test in a CREST class. Table 5.12

presented on page 145 shows the significant differences that were found for these CREST class versus reference control class change score comparisons.

Significant differences were found between the MSLQ self-regulation change scores of Class 7 (M=.360, SD=.612) and the reference control class (M=-.556, SD=.566) with the Cohen's d value indicating a large effect size (d=.726). Together with the significant increases seen from pre-test to post-test in Class 7 on MSLQ self-regulation in the previous results section (reported in Table 5.8 earlier), these results provide further support for the impact of the CREST programme on self-regulation in this class. Significant differences were also found on FCSSR self-regulated learning between CREST Class 2 (M=.381, SD=.467) and the reference control class (M=-.0037, SD=.359) with the Cohen's d value again indicating a large effect size (d=.924). While significant pre- to post-test change was noted in Class 2 on this variable in the previous analysis, the findings presented in Table 5.12 on the following page provide further support for the effectiveness of the CREST programme in increasing self-regulated learning in this class.

The results of the independent-samples *t-test* comparing the MSLQ self-efficacy change scores of Class 2 (M=.556, SD=.916) to the reference control class (M=-.0432, SD=.484) were statistically significant with the Cohen's d value indicating a large effect size (d=.818). Significant differences were also found for the grade motivation self-reports of Class 7 (M=-.316, SD=.658) and the reference control class (M=.0625,SD=.418) with the Cohen's d value indicating a large effect again (d=.691). These results, therefore, provide further support for the *group* differences noted earlier regarding these outcome variables

No significant differences were found in the other CREST versus reference control class comparisons performed for the significant paired-samples *t-tests* reported earlier in Tables 5.8 through to 5.11. In other words, while some classes experienced significant changes in self-determination, overall science motivation, and intrinsic motivation from pre- to post-test, when directly compared to the changes experienced in the reference control class, no significant *group* differences were found on these variables. This section of results validating the changes reported above relating to the presence of group differences highlights the importance of directly comparing the change scores among the classes included in this study.

Table 5.12. A summary of the significant independent samples *t-test* results for CREST vs. Control comparisons.

Class	Variable	[a]CREST (SD)	[b]Control (SD)	df	t	*p**	d
2	MSLQ SE	.556 (.916)	-.0432 (.484)	30	-2.385	*.024*	.818
2	FCSSR SRL	.381 (.467)	-.0037 (.359)	23	-2.296	.030	.924
7	MSLQ SR	.360 (.612)	-.556 (.556)	33	-2.085	.044	.726
7	Grade Motivation	-.316 (.658)	.0625 (.418)	33	1.986	.048	.691

[a] Mean pre-test to post-test change score for CREST class. [b] Mean pre-test to post-test change score for reference control class. *Note.* *p values presented are two-tailed. SE= self-efficacy, SRL= self-regulated learning, and SR= self-regulation.

5.4.4 RQ 2: Retention Effects for the CREST Students

In order to investigate the presence of any retention effects for developments in self-reported levels of the self-regulated processes and related motivations measured, paired-samples *t-tests* were conducted on the subset of students that completed the four-month delayed post-tests. This subset included 90 students from the 160 students participating in CREST (56% of the CREST students included in the study).

Table 5.13 on the following page shows the means and standard deviations of the post-tests and delayed post-tests as well as a summary of the paired-samples *t-test* results. The only test presented in Table 5.13 to reach significance was intrinsic motivation and personal relevance measured by the SMQ. Students that completed the delayed post-tests showed significant decreases in their self-reports of intrinsic motivation and personal relevance from post-test (M=3.50, SD=.70) to delayed post-test (M=3.33, SD=.67) with the Cohen's d value indicating a small approaching medium effect size (d=.249). This result will be discussed in relation to published literature documenting decreasing trends in these intrinsic motivations.

The absence of any other significant changes in the measured variables suggests that the changes observed in the outcome measures reported in the results sections above were retained four months following CREST participation. These results also suggest that no consolidation of effects occurred in the months following programme participation. In other words, on the outcome measures that showed no immediate group differences or intervention effects (cognitive strategies use, test anxiety, and career motivation), no delayed impact of the intervention was later reported.

Table 5.13. A summary of the post- and delayed post-test means and standard deviations, and the delayed paired-samples *t-test* results.

Variable	Post-test Mean (SD)	Delayed Post-test Mean (SD)	df	*t*	*p* *	d
MSLQ Self-Regulation	4.35 (.828)	4.42 (.891)	81	-.959	*.341*	.0812
MSLQ CSU	4.59 (1.00)	4.67 (.945)	79	-1.02	*.309*	.0822
FCSSR SRL	2.47 (.623)	2.47 (.602)	69	-.103	*.918*	.00930
SMQ Self-Determination	3.62 (.774)	3.62 (.812)	89	.035	.972	.00340
MSLQ Intrinsic Motivation	4.62 (1.11)	4.69 (1.05)	85	-.713	*.478*	.0479
SMQ IMPR	3.50 (.695)	3.33 (.672)	87	2.951	***.004***	.249
MSLQ Self-Efficacy	4.61 (1.12)	4.64 (.961)	83	-.308	.759	.0287
SMQ Self-Efficacy	3.54 (.802)	3.47 (.814)	90	1.066	.289	.0866
MSLQ Test Anxiety	3.85 (1.22)	3.96 (1.45)	83	-.817	.416	.0821
SMQ Test Anxiety	2.74 (.830)	2.71 (.850)	88	-.376	.708	.0363
SMQ Career Motivation	3.79 (.857)	3.60 (1.10)	90	1.883	.063	.193
SMQ Grade Motivation	3.63 (.608)	3.74 (.604)	83	-1.823	.072	.182
SMQ Overall SM	103.7 (15.5)	101.9 (17.1)	74	1.363	.177	.110

Note. *two-tailed significance values presented. CSU= cognitive strategies use, IMPR= intrinsic motivation and personal relevance, and SM= science motivation.

5.4.5 RQ 3: Investigating Class Differences in Response to the Intervention

The results presented earlier relating to the first research question demonstrated the presence of *group* differences between the classes taking part in CREST and the reference control class. As some of the CREST classes did not experience significant changes from pre-test to post-test while others did, the above findings suggested the possibility of *class* differences regarding the effect of the programme on the students participating. However, as with the direct comparisons made in Section *5.4.3* in order to validate the research results relating to the first research question of the present study, similar direct comparisons need to be made in order to address the third research question relating to *class* differences in terms of changes in self-reported levels of the outcome measures following participation in the CREST programme. While it may seem that the results presented in this section under-cut some of the previous findings presented, what this additional analyses provides is clear insight into the influence of the statistical approach adopted on the research findings in studies investigating class differences in response to interventions.

In order to address the third and final research question of the present study, a series of one-way between-groups MANOVAs and ANOVAs were performed to investigate differences among the nine CREST classes regarding changes in self-reported levels of the self-regulated processes, related motivations, and science-specific motivations measured in this study. Table 5.14 on page 149 presents a summary of these results.[7] From Table 5.14, it can be seen that all of the analyses of variance results reported in this section indicate small, approaching medium effect sizes.

For self-regulated processes, similar to the MANOVA analysis presented for Study 1, four dependent variables were used: MSLQ self-regulation, MSLQ cognitive strategies use, FCSSR self-regulated learning, and SMQ self-determination change scores (post-test minus pre-test). As the third research question of this study investigates whether the classes participating in the CREST programme change in levels of the outcome measures to the same extent, the independent variable here is *class*. As shown in Table 5.14, no statistically significant differences were found between the nine CREST classes on the combined dependent variables for the self-regulated processes. Relating back to the third research question regarding the presence of *class* differences and building on the analyses presented thus far in the chapter, these results suggest that the nine classes participating in CREST experienced similar changes in their self-reports of the self-regulated processes measured in this study. Remembering the findings discussed earlier relating to the first research question, these results suggest that while no differences between classes regarding the changes from pre-test to post-test were observed, on average, students taking part in CREST showed significant increases in self-reported levels of self-regulated learning and self-determination. These results were not expected in the present study.

[7] All pre-test, post-test, and change score means and standard deviations were presented previously in Tables 5.8, 5.9, 5.10, and 5.11.

The multivariate results investigating class differences in self-efficacy scores on the MSLQ and SMQ (presented in Table 5.14) showed no statistically significant differences between the classes on the combined dependent variables. Similar non-significant results were also found on the multivariate tests for intrinsic motivation change scores on both the MSLQ and SMQ and are also presented in Table 5.14. As with self-efficacy and intrinsic motivation, the multivariate results investigating class differences in test anxiety change scores on the MSLQ and SMQ showed no statistically significant differences between the classes on the combined variables (see Table 5.14). These results are not in line with the research predictions relating to the presence of class differences outlined at the beginning of this chapter. From the results presented above relating to these constructs, it can be interpreted that the nine classes taking part in the CREST programme experienced similar changes in their self-reports of these related motivations answering the third research question. Recalling the results presented earlier in Section *5.4.3* relating to the first research question of the present study, these results also suggest that while the nine CREST classes experienced similar changes in these variables, on average, they showed significant increases in self-efficacy and intrinsic motivation, with no statistically significant changes from pre-test to post-test reported on either of the test anxiety measures.

A series of one-way ANOVAs comparing the change scores of the nine CREST classes was also performed investigating class differences in the science-specific motivations measured on the SMQ; career motivation, grade motivation, and overall science motivation. As shown in Table 5.14, there were no statistically significant differences between the nine CREST classes regarding these three science-specific motivations measured. Similar to the above results relating to self-regulated processes and related motivations, these non-significant findings are not in line with the third research prediction in this study. This suggests that the nine classes did not differ in terms of the impact of the CREST programme. Again recalling the results presented earlier in Section *5.4.2* relating to the first research question, together these results suggest that the nine CREST classes were no different in the pre-test to post-test changes they experienced and, on average, they experienced no changes in career motivation, decreases in grade motivation, and increases in overall science motivation.

Table 5.14. A summary of the multivariate and univariate analyses of variance results.

Analyses conducted	*Wilks' Lambda*	df	F	*p*	ηρ²
Multivariate One-way ANOVAs					
Self-Regulated Processes	.724	4,84	.891	*.641*	.078
Self-Efficacy	.535	2,123	.934	*.927*	.034
Intrinsic Motivation	.888	2,124	.953	*.509*	.058
Test Anxiety	.866	2,125	1.163	*.299*	.069
One-way ANOVAs*					
Career Motivation	-	8,148	.824	*.583*	.042
Grade Motivation	-	8,140	.686	*.703*	.038
Overall Science Motivation	-	8,118	.796	*.608*	.051

Note. df= degrees of freedom, F= MANOVA or ANOVA score, *p*= significance level, ηρ²= partial eta squared (effect size). *Wilks' Lambda results are not reported for the univariate ANOVAs as this statistic is not relevant for these tests.

5.5 DISCUSSION

The present study aimed to understand the impact of participating in the CREST programme on changes in self-reported levels of self-regulated processes and related motivations, extending the results presented in Study 1 (Chapter 4). This study was also interested in looking at the experience at the classroom level in order to investigate the presence of differences between the nine CREST classes in regards to the changes observed on the outcome measures included. Before the main analyses were performed, preliminary data analyses checking for assumptions and ensuring appropriate support for the internal consistency of the self-report measures administered were conducted. The results presented in the previous sections will now be discussed in relation to the three research questions presented at the beginning of this chapter.

5.5.1 RQ 1 & 2: Exploring the Experience of CREST Classes Compared to the Reference Control Class and Retention Effects

Self-Regulated Processes

The present study aimed, firstly, to explore the differences between changes in self-reported levels of self-regulated processes and related motivations in classes taking part in the CREST programme to a reference control class of students not participating in the programme. The results presented in this study provide some support for *group* differences regarding changes in self-reported levels of the key self-regulated process outcome measures. Results showed that while the reference control group did not experience any significant changes in self-reported levels of any variables measured, significant changes from pre-test to post-test were found in some of the CREST classes on self-regulation, self-determination, as well as self-regulated learning. However, when verifying these results by comparing the change scores of the classes that experienced significant changes along the outcome measures to the reference control class, significant differences were only found on the self-report measures of self-regulated learning and self-regulation in two classes. These results support the claims of researchers who state that the paired-samples *t-tests* have too small an error term due to the fact that randomisation is more lumpy in studies utilising natural classroom structure (Campbell & Stanley, 1966; Zimmerman, 1997). The conclusion that can be drawn from these results is that *group* differences were found for self-regulation and self-regulated learning, but only in two of the nine classes taking part in the CREST programme. However, as the classes involved in this comparison include very small sample sizes, conclusions are drawn cautiously.

As the above analyses only found significant group differences on self-regulation and self-regulated learning for two classes, it could be concluded that no other group differences were present. However, as the analyses described earlier included looking at *all* students participating in CREST, the results also indicated that on average, students taking part in CREST showed significant increases in self-reported levels of self-determination and self-regulated learning. These results suggest that while only a few classes showed significant pre-to-post-test change on the self-regulated process variables measured, with only two of these classes being significantly different from the reference control class, general increasing trends were noted among the CREST participants. While no comparisons can be made between these trends and the reference control class (due to large differences in sample sizes), comparing these results to other research findings may provide further support for group differences in self-determination and self-regulated learning.

Considering the downward trends over the school term documented by Berger and Karabenick (2011) and discussed in Chapter 4 Section *4.5.1*, the practical significance of the overall increases in self-regulated learning and self-determination reported among students taking part in the CREST programme in this study are highlighted. Therefore, together with the documented literature findings and the results presented in Study 1, the results of Study 2 provide strong support for the practical utility of investigating the CREST programme within a self-regulated learning framework and exploring the impact of participation in the programme on these regulatory processes in students.

While significant changes were found for self-regulated learning and self-determination, no significant changes were observed in self-reported levels of cognitive strategies use for the students participating in the CREST programme. However, relating these findings to published research, as well as to the results presented in Study 1 (Chapter 4), provides additional insight into how to interpret these results. Van der Veen and Peetsma (2009) conducted a study with similarly aged students and found that levels of cognitive strategies use, as measured by the MSLQ, decreased over the course of the school year. Through looking at the means presented earlier in Table 5.8 on page 136, it can be seen that while some classes taking part in CREST did experience small decreases in levels of self-reported cognitive strategies use throughout the course of the study, the majority of CREST classes experienced increases in self-reported levels of cognitive strategies use. In addition, while some of the classes showed decreasing trends, it is important to note that overall, no significant decreases were reported among the students taking part in the CREST programme. These results suggest that while CREST does not involve explicit cognitive strategies instruction, participation may help students maintain pre-test levels of self-reports of this construct. Through relating these findings to the work of Van der Veen and Peetsma (2009) and appreciating that they replicate the results presented in Study 1 (Chapter 4), it seems possible that the CREST programme prevented the decreases in levels of perceived cognitive strategy use that may have occurred without intervention.

Graham and Harris (1993) highlight that self-regulated process strategies need to be maintained over longer periods of time and be transferable to other classroom-learning subjects. Similar to Study 1, delayed post-tests were also incorporated in the present study design in order to investigate the presence of any long-term impacts of CREST programme participation. Relating to all self-regulated process variables, the results of this study are in line with the findings of Study 1 in that no significant changes in self-reported levels were observed from post-test to delayed post-test. From these results, it can be interpreted that any developments documented in these outcome measures (increases in self-regulated learning and self-determination) were maintained at the four-month post-test for the students that took part in the CREST programme. However, similar to Study 1, as no delayed post-tests were obtained from the reference control group, and considering the possibility of limited power as data was collected from only a subset of CREST students (n= 90), the conclusions here are drawn cautiously.

Related Motivations

Other significant changes in self-reports measured in Study 2 were found for self-efficacy and intrinsic motivation and personal relevance. These findings are in line with the predictions outlined at the beginning of this chapter regarding significant increasing trends in self-efficacy and intrinsic motivation for students taking part in the programme but are, however, different from the findings of Study 1 presented in this thesis. In Study 1 (reported in Chapter 4), no significant changes in levels of self-reported self-efficacy and intrinsic motivation were found, which was not in line with the predictions made. As a more detailed synthesis discussion of the findings of all three studies conducted in this thesis will be provided in the final discussion chapter (Chapter 7), the present discussion will move on to examine the significant increases in self-efficacy and intrinsic motivation documented in the present study within the context of similar studies reported in the literature.

In their work, described earlier in relation to the self-regulated process results for the present study, Berger and Karabenick (2011) also investigated changes in self-efficacy and intrinsic motivation over the course of the four-month study which was conducted in the United States. Their results showed that while self-efficacy remained stable over the course of the school term for students in mathematics, self-reported levels of intrinsic motivation decreased. There seems to be a general consensus in the literature that self-efficacy and intrinsic motivation decrease, or remain stable over a school term or a course at college, with little evidence of increasing trends without pedagogical intervention (Chase, 2001; Fredricks & Eccles, 2002; Gao, Lee, Solomon, & Zhang, 2009; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Moritz, Feltz, Mack, & Fahrbach, 2000; Pajares, 1996; Pintrich & Schunk, 2002; Ryan & Deci, 2000; Wigfield *et al.,* 1997; Zusho, Pintrich, & Coppola, 2003). In line with the research trends discussed here, self-reported levels of self-efficacy and intrinsic motivation remained stable in the reference control class over the course of Study 2.

In contrast, recent research findings have documented increases in self-efficacy and intrinsic motivation in students following participation in interventions aimed at developing self-regulated learning (Fuchs *et al.,* 2003; Stoeger & Ziegler, 2005, 2008, 2010). Giving students more responsibility and choice, and providing them with opportunities to plan and evaluate their learning, builds self-confidence and can help maintain high levels of self-efficacy and intrinsic motivation (Patall, Cooper, & Wynn, 2010; Schunk & Ertmer, 2000; Zimmerman, 2000). The results documented here for Study 2 are in line with these literature findings as CREST students, on average, showed significant increases in their self-reported levels of these constructs.

Results presented in this chapter also indicated that the developments seen in self-efficacy described above were retained four months following CREST programme participation. However, regarding intrinsic motivation measured on the SMQ, significant decreases were found for all CREST students on average from post-test to delayed post-test. These results suggest that while intrinsic motivation was higher following participation in the programme, these developments were not retained four months later after the summer break. Considering the decreasing trends presented in the literature discussed earlier, it is possible that these significant decreases would also be seen in a control group of students not taking part in the programme with potentially more dramatic decreases observed. However, these results do suggest that measures may need to be in place in order to build on the motivational developments for students taking part in the programme.

In the present study, no significant changes were found in self-reported levels of test anxiety for the reference control class and the nine CREST classes. One possible explanation for the lack of significant changes in test anxiety could be due to the fact that the temporal interval implemented in the present study design (eight weeks) was too brief to detect intervention effects (Berger & Karabenick, 2011). However, as Study 1 investigated changes over the course of only five weeks and documented significant increasing trends in self-reported levels of test anxiety for students participating in the CREST programme, this explanation seems unlikely.

While no significant *group* differences were found relating to test anxiety at the adjusted alpha level of .01, increasing trends were noted among the CREST classes. As discussed in Study 1 (Chapter 4), Rozendaal and colleagues (2005) similarly found that self-regulated learning-based innovation programmes may not be able to solve student problems with anxiety. As Rozendaal and colleagues highlighted that various forms of anxiety are detrimental to the development of self-regulatory skills, further research is needed in order to understand the impact of CREST programme participation on student levels of self-reported test anxiety.

It is also important to discuss the results for the related motivational constructs above in terms of the different measurement instruments used in the present study. As with Study 1, the present study included two measures for each of the related motivational constructs (self-efficacy, intrinsic motivation, and test anxiety) and different results were obtained in terms of statistical significance. While the SMQ measures showed mostly significant changes, the MSLQ did not. One possible explanation for these results could be that while the MSLQ can be formatted to be subject specific (as it is in this thesis for science learning), the SMQ was specifically designed for implementation in science classrooms. These results have important implications in terms of measurement issues and also researchers' choice of which measures to include in their work. These differing results were also seen in Study 1, presented previously in Chapter 4, and will be discussed further in the final chapter of this thesis (Chapter 7).

Science-Specific Motivations

The findings presented above relating to the science-specific motivations showed significant increases in overall science motivation and while not significant, an increasing trend for career motivation in science was also found. These findings are in line with the research predictions outlined at the beginning of this chapter. Taking part in the CREST programme allows students to experience hands-on science and motivates them generally, but also specifically to increase their interest in pursuing science careers, and these developments are retained four months following programme participation.

Contrary to the research predictions made regarding grade motivation in science, the results presented in this chapter showed significant decreases for the CREST classes, on average, for grade motivation in science. Group differences were also found between the reference control class and CREST Class 7. This may be explained by the timing of the study as students and teachers were focusing on completing the CREST programme with no unit tests coming up. During the CREST programme, as classroom teaching time is devoted to completing the projects, it is possible that this lack of anticipation for an upcoming test could explain the decrease in grade motivations seen. It is also possible that participation in the CREST programme helps students understand that science education is about more than achieving good grades however, further research is needed to explore these possibilities. Considering recent shifts regarding the importance placed on grades by educators and policy makers, as well as the detrimental effects of students being motivated solely by external rewards, highlights the practical implications of these findings relating to grade motivation (Kohn, 2011).

5.5.2 RQ 3: Investigating Class Differences in Response to the CREST Programme

Another aim of the study presented in this chapter was to investigate *class* differences regarding changes in self-reported levels on the key variables measured. From the paired-samples *t-test* results presented above for the nine CREST classes, one conclusion that could be drawn is that, as some of the classes experienced significant changes while others did not; the classes were different regarding their responses to the CREST programme. However, in order to directly compare these differences, ANOVA analyses were conducted on the pre-test to post-test change scores on all outcome measures.

The overall non-significant ANOVA results comparing the change scores of the nine CREST classes suggest that these differences were not large enough to reach statistical significance. From the CREST class ANOVA comparison results presented in this study, the conclusion that no class effects were found on any of the variables could be inferred. Another possibility is that while the other classes were not significant, they were reaching significance and overall, classes on average, increased. These results may explain the overall non-significant multivariate results presented in the previous section relating to class differences in change scores. From this perspective it could be concluded that no class differences were present and, on average, students developed self-regulated learning, self-determination, self-efficacy, intrinsic motivation, and overall science motivation through participating in the CREST programme.

Nye *et al.* (2004) found that teacher effects for promoting academic achievement were lower in higher socio-economic status (SES) schools compared to lower SES schools. As this research was conducted in a rural school in Glasgow, arguably a high SES school, the lack of classroom differences in response to the CREST programme could be explained by considering the findings reported by Nye *et al.* (2004). However, as no data was collected relating to the SES status of the school and the students taking part in the study, further research is needed to assess this explanation. Nye and colleagues (2004) also highlighted that finding no teacher effects does not mean that all teachers demonstrate similar effectiveness in the classroom practice being studied. This highlights the importance of gaining an understanding of teachers' perceptions of the programme studied in this research. This will be incorporated into the design of Study 3, presented in the next chapter (Chapter 6).

The lack of classroom differences found in the present study may also be explained through considering the research conducted by Skibbe, Phillis, Day, Brophy-Herb, and Connor (2012). Skibbe and colleagues (2012) conducted research in the United States investigating classroom effects in students between the ages of 6 and 10 years. They found that classrooms with stronger self-regulated learners experienced more gain through a reading comprehension and vocabulary skills intervention than those with lower self-regulating peers. These researchers explained that students with lower levels of self-reported regulation may distract their peers, interrupt teaching, and may also require more teacher attention and intervention. Within the context of the research findings presented in this second empirical chapter, it is possible that the nine CREST classes had similar distributions of self-regulated learners, and therefore no class differences in response to the intervention were noted. The results from the preliminary analyses documenting that classes were matched on pre-test self-reports provide further support for this explanation.

There is also some research to suggest that classroom and teacher effects occur over time and do not surface immediately (Nye *et al.,* 2004). It is therefore possible that any differences between classes regarding changes in self-reported levels of the measured variables in the present study might develop further after the intervention, and surface at the four-month delayed post-test. This would explain the lack of class differences seen on immediate post-tests. However, as only a subset of students completed the four-month delayed post-test, the present study design was limited to looking at class differences using the pre- and post-test data.

5.5.3 Methodological Limitations and Future Research

A key internal validity issue in the present study is that, due to the lack of ability, SES, and family structure data, there is no way to know how equivalent the classes are on key background variables. While it was stated that groups were matched at pre-test on the variables measured in the study, it is not possible to discern whether the classes were matched on unmeasured pre-test variables (Nye *et al.,* 2004). In addition, no covariates controlling for these pre-existing differences in background variables among students in each classroom could be included in this study. As Rowan, Correnti, and Miller (2002) identified the confounding effects of SES and prior academic performance on classroom differences in achievement, it is possible that these effects extend to the self-regulated processes and related motivations studied here as well. However, while it is unfortunate that previous achievement data could not be obtained, randomisation of students into classes by registration should make pre-test achievement score adjustment unnecessary (Nye *et al.,* 2004).

Considering the ANOVA analyses presented in Section *5.4.5* with the paired-samples results presented earlier in Section *5.4.2* allows several insights to be gained. The results highlight the sensitivity of small group sizes in variance analyses and the limitations of paired-samples *t-tests* regarding direct group comparisons. It is possible, in the present study, that the absence of robust differences in the ANOVA analyses presented earlier on the change scores of the nine CREST classes was due to the small number of students in each class (Sun *et al.,* 2010). This issue has been documented as one of the main limitations of classroom effect studies due to the high sample sizes needed and the inherent small sample sizes within natural class structure designs, with classes usually ranging from between 20 and 30 students.

It is important to note that the ANOVA analyses presented in this study could also be masking smaller class differences as only 2 out of the 9 classes showed significant changes through CREST programme participation and therefore, the overall weight of the change may have been pulled down by the other CREST classes. However, as highlighted in the methods outlined for the present study, the sample size was slightly less than anticipated which contributed to lower power than required for the paired-samples *t-tests*. This may explain the lack of significant paired-samples *t-tests* for the CREST classes individually. While the findings presented in the final results section of this study addressing class differences by conducting ANOVAs on the change scores for the nine CREST classes may seem to undercut the findings presented previously from the *t-tests*, the inclusion of these results is very important in order to highlight the limitations regarding investigating classroom effects.

The limitation of the present study regarding retention effects, as well as Study 1 presented in the previous chapter, is that not all students were followed longitudinally. In the first study, only students taking part in the CREST programme were given delayed post-tests and in the present study, this data was available for only a subset of the CREST students. This limits not only the interpretation of results, but also the analyses that could have been performed had all students in the study completed the four-month delayed post-test. These issues were considered when designing Study 3, presented in the following chapter.

Another aspect of the methods of Study 2 that informed the design of Study 3, related to which variations to investigate. Van Horn *et al.* (2008) state that intervention main effects are important in intervention research but highlight that additional insight can also be gained through evaluating potential variations for subgroups of participants. This was considered and incorporated into the design of the final study, Study 3, presented in the following chapter of this thesis.

As with Study 1, it is not possible to unpack which aspects of the CREST programme contributed to the changes seen in Study 2 on the measured outcome variables. Similar difficulties have been documented in intervention studies (De Corte *et al.,* 2004; Glaser & Brunstein, 2007; Williams & Binnie, 2003) and will be considered when discussing the findings to come from Study 3. In addition to the limited information regarding which aspects of the programme are influencing self-regulated processes and related motivations in students, it was not possible in the present study to discern classroom effects from teacher effects. More qualitative data may provide a solution for this issue through obtaining the perspectives of teachers and students as to why they experienced what they did through CREST programme participation. Looking at teacher beliefs and their influence on the effectiveness of the CREST programme may also provide additional insight (Moos & Ringdal, 2012; Sugrue, 1997).

Finally, as this study included ten classrooms from one rural school in Glasgow, it is necessary for further research to investigate these group and class differences across several school settings in order to obtain reasonable measurement precision and allow for the findings to be generalisable to other educational settings (Nye *et al.,* 2004). In addition, similar to Study 1, the gender split of the sample was not equal which could also present limitations in terms of the generalisability of the results presented in this chapter. More specifically, the gender make-up of the reference control class with 73% boys was different from the nine CREST classes and this may have contributed to the lack of significant pre- to post-test changes seen in this class.

5.6 CHAPTER SUMMARY AND CONCLUSIONS

This chapter has presented results from a longitudinal quasi-experimental study carried out to examine changes in students' self-reported levels of self-regulatory processes and related motivations in science through taking part in the CREST programme. The study included a total of 178 students and was conducted in an individual school setting with students from one year-group. Similar to Study 1, previously published and validated measures of self-regulatory processes and related motivations were included as dependent variables. However, in the present study, student classroom allocation was also used as the independent variable in order to investigate the presence of any differences between the nine CREST classes in terms of changes in self-reported levels on the measured variables.

The results showed that overall, students experienced significant increases in levels of self-reported self-regulated learning, self-determination, self-efficacy, intrinsic motivation and personal relevance, and overall science motivation through participation in the CREST programme. By contrast, a reference control class of students not taking part in the programme showed no significant changes in any measured outcomes. These results provided some support for the first two research predictions that CREST students would show different changes from pre-test to post-test compared to the reference control class and replicated some of the findings of Study 1 relating to retention effects. However, as comparisons between the 160 CREST students and 18 reference control students were limited, these results were interpreted with caution.

The findings documented in this chapter also revealed no significant differences between changes in self-reported levels on the outcome variables measured among the nine classes included in this study that participated in the CREST programme. These results highlighted the sensitivity of classroom effect studies regarding the choice of analyses and sample size limitations. Further insight was also provided regarding the sensitivity of the self-report measures used in this research.

5.6.1 Thesis Implications

The overall findings of Study 2 presented in this chapter demonstrate the impact of the CREST programme on changing students' self-reported levels of self-regulatory processes and related motivations regarding their learning in science. Through replicating some of the findings of Study 1 in a different school context with students in their second year of senior school (Study 1 included first year students between the ages of 11 and 12 years), the present results provide further support for the conclusions made in the previous chapter (Chapter 4). In addition, the discontinuity seen between other results highlights the importance of investigating the impact of this inquiry programme in another sample of students and also highlights some methodological elements that need to be addressed including increasing the design strength of the control group. Building on these suggestions, the subsequent chapter (Chapter 6) reports the findings of Study 3, informed by both the results presented in the first empirical chapter (Study 1) and the findings reported in the present chapter relating to Study 2.

6

STUDY 3: INVESTIGATING THE IMMEDIATE AND DELAYED IMPACT OF CREST PARTICIPATION ON STUDENT SELF-REGULATED PROCESSES, RELATED MOTIVATIONS, AND TEACHER PERCEPTIONS OF SELF-REGULATED LEARNING[8]

Chapter Objectives

This final empirical chapter presents the results of Study 3. Building on the findings presented in the previous two empirical chapters (Chapters 4 & 5), Study 3 investigates the impact of participation in the CREST programme on the key outcome measures within a different school setting and following a more rigorous intervention evaluation approach. Using a quasi-experimental design involving two intervention conditions and one control group, students' changes in self-reports of self-regulated processes and related motivations immediately following participation in the CREST programme are examined. By administering delayed post-tests to all students involved, this study provides an in-depth investigation of possible retention effects of any observed changes. Expanding the design of the previous two studies, Study 3 also investigates changes in teachers' perceptions of students' self-regulated learning through CREST programme participation. The findings will be discussed in relation to relevant literature as well as within the context of the empirical research presented in this thesis.

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[8] The data from this study were presented at the *International Association of Cognitive Education and Psychology* (IACEP) European Regional Conference in Geneva as part of a symposium for self-regulated learning on May 25th, 2012.

6.1 INTRODUCTION

The previous two chapters (Chapters 4 & 5) presented evidence of changes in students' self-reported levels of self-regulated processes and related motivations after participating in the CREST inquiry programme. Together, the findings suggest that the CREST programme contributes to changes in students' self-reported levels of self-regulatory processes and some related motivations regarding student learning in the science classroom. Specifically, Study 1 (presented in Chapter 4) documented the beneficial impact of CREST participation on student levels of self-regulated learning and self-determination. Unexpected increased levels of test anxiety were also observed in students participating in the programme, which highlighted the need for further research to be conducted with a different sample of students. The findings from Study 2 (presented in Chapter 5) replicated aspects of these results with significant increases seen in some classes of students participating in CREST while no significant increases were seen in a reference control class. Study 2 also documented significant changes in self-regulated learning, self-determination, self-efficacy, intrinsic motivation, and overall science motivation from pre-test to post-test on average for students taking part in the CREST programme.

However, conclusions relating to these findings were limited as no control group of equal size (160) was available for comparison in Study 2. The results reported in Study 2 also showed no class differences on the outcome variables measured, suggesting that students experienced similar changes in these constructs despite having different teachers implementing the programme. The complex nature of the findings reported in Study 2 highlights the need for replication with a different sample of students. The empirical results from both Studies 1 and 2 also provided some evidence of retention effects for the immediate post-test results seen.

Study 3 builds on these empirical findings and also recommendations regarding the need to extend methodologies in the self-regulation domain beyond cross-sectional and immediate post-test designs (Berger & Karabenick, 2011; Severiens *et al.,* 2001; Wandersee *et al.,* 1994; Zimmerman, 2008). Literature over the last two decades has highlighted the relevance of investigating changes in student processes and responses to tasks over longer periods of time (Duckworth *et al.,* 2009; Pintrich, 2003; Zimmerman, 2008). Changes in students' levels of motivation and self-regulatory processes throughout the course of the school year, as well as the difficulties in retaining any developments in self-regulatory processes, provide additional support for the importance of understanding these constructs on a longer-term basis (Throndsen, 2011; Zimmerman, 2008).

Appreciating that long-term retention of self-regulated learning is essential in order to encourage and promote the transfer of regulatory processes to general life-long learning, further highlights the need for research in this area. In addition, it can be argued that this transfer is especially important in science education with rapid advances in technology requiring new knowledge bases to be formed in individuals on an ongoing basis (De Corte *et al.,* 2004; Duncan & Tseng, 2010). While Studies 1 and 2 incorporated delayed post-tests into their study designs, the studies were limited in that longitudinal data at pre-, post-, and delayed post-test were only available for a subset of students from the intervention conditions in the samples.

In view of the issues outlined above, a key focus of Study 3 will be on unpacking the longer-term impacts of the CREST programme on student self-reports of self-regulated processes and related motivations. To enhance the research design and provide more evidence regarding the impact of CREST, a number of methodological changes were implemented in Study 3. Firstly, the self-regulated processes and related motivations were measured at three time points for *all* participants in the present study, contributing to the validity of the research findings obtained. This methodological change will facilitate more detailed examination of the longer-term impact of CREST on self-regulated processes and related motivational constructs by allowing comparisons to be made between students taking part and not taking part in the programme. Secondly, the present study includes two intervention conditions (*S1 CREST* who participated in CREST the previous year, and *S2 CREST* who participated in CREST during the course of the study) in addition to a control group (*No CREST*), in order to provide further insight into the longer-term impact of the CREST programme.

Similar to other research domains, researchers studying self-regulatory processes in classroom learning environments have identified that multiple approaches greatly facilitate increasing the validity of research findings and their contributions to professional teaching practice (Matthews *et al.,* 2009; Zimmerman, 2008). Researchers have come to realise that the richest data comes from natural school settings, and that interpretations from both teachers as well as students are important, valid components that should be included in analyses wherever possible (Kahle & Meece, 1994; Matthews *et al.,* 2009; Zimmerman, 2008; Zimmerman & Martinez-Pons, 1988). Zimmerman and Martinez-Pons (1988) conducted research using teachers' observations of students' self-regulated learning performances in an attempt to validate a particular student self-report measure of the construct. These researchers proposed that the teacher observations provided a performance-based measure of the construct that can help to examine the validity of student self-report measures.

Taking these suggestions into consideration, in addition to replicating the findings of Studies 1 and 2 and building on their longitudinal designs, the present study also involved investigating teachers' perceptions of the changes in levels of self-regulated learning for each student included in the study. While it is important to investigate any changes that students perceive they are having regarding their use of self-regulatory strategies and their levels of motivation toward their science learning, understanding these changes from the teachers' point of view is also important. By including the teacher data, in addition to investigating the student perspective of any developments in self-regulated processes and related motivations, Study 3 also attempts to triangulate data from different sources.

In summary, Study 3 builds on Studies 1 and 2 in order to provide a more complete picture of the impact of student participation in the CREST programme on self-regulated processes and related motivations. Through following a more rigorous experimental design involving two intervention conditions, collecting student and teacher data, and administering delayed post-tests to all participants, this study aims to provide insight into the longer-term impacts of participation in CREST.

6.2 Study 3 Research Questions and Predictions

Before outlining the methods and procedures followed for this study, the research questions and predictions used to focus the investigation, which were informed by the study results presented in Chapters 4 and 5, will be presented.

RQ 1A: Do students in the S1 CREST condition who participated in the CREST programme prior to the study have higher self-reported levels of self-regulated processes and related motivations, compared to students coming into the study with no previous CREST experience (S2 CREST and No CREST conditions)?

<u>Prediction 1A:</u> Students in the S1 CREST condition who participated in the CREST programme the year before the study began will have higher pre-test levels of self-reported self-regulated processes and related motivations than students in the other two conditions with no previous CREST experience.

RQ 1B: Do teachers report higher levels of self-regulated learning for students in the S1 CREST condition who participated in the CREST programme before the study began, compared to students coming into the study with no previous CREST experience?

<u>Prediction 1B:</u> Teachers' pre-test self-regulated learning reports will be higher for students in the S1 CREST condition who previously participated in the CREST programme, compared to students with no CREST experience prior to joining the study.

RQ 2A: Do students in the S2 CREST condition taking part in the CREST programme during the course of the study experience different *changes* in self-reported levels of self-regulated processes and related motivations immediately following programme participation, compared to students not taking part in the programme (S1 CREST and No CREST conditions)?

Prediction 2A: Students in the S2 CREST condition taking part in the CREST programme will experience positive changes in their self-reported levels of self-regulated processes and related motivations immediately following participation in the programme. Smaller changes may be noted for cognitive strategies use and intrinsic motivation, but no decreasing trends are expected in this group. In addition, students not taking part in the CREST programme during the course of the study (S1 CREST condition), and with no prior experience in the programme (No CREST condition), will show no significant positive changes in the measured variables and may experience decreases in their self-reported levels of self-regulated processes and related motivations.

RQ 2B: Do teacher ratings of student self-regulated learning document different *changes* from pre-test to post-test for students in the S2 CREST condition taking part in the programme during the course of the study, compared to students not taking part in the programme? In other words, do teacher ratings map onto the student self-reported results relating to self-regulated processes and related motivations?

Prediction 2B: Teacher reports will increase from pre-test to post-test for students participating in the CREST programme during the study (S2 CREST condition) and smaller changes may be noted in the two other groups not participating in the CREST programme (S1 CREST and No CREST conditions).

RQ 3A: Are any changes observed in students' self-reported levels of self-regulated processes and related motivations retained three months following CREST programme participation for the S2 CREST condition?

Prediction 3A: Any positive changes in self-reports of the measured variables for the students taking part in the CREST programme during the course of the study (S2 CREST condition) will be retained three months following programme completion.

RQ 3B: Are any developments observed in teacher perceptions of student self-regulated learning from pre-test to post-test retained three months following CREST programme completion for the S2 CREST condition? In other words, do teacher ratings map onto the student self-reported results relating to self-regulated processes?

Prediction 3B: Any developments in teacher ratings of student self-regulated learning will be retained three months following CREST programme completion. In addition, increases will be seen in teacher ratings of self-regulated learning from pre-test to delayed post-test for the group taking part in the CREST programme during the course of the study (S2 CREST condition). Decreases may be noted in the other two groups included in the present study design.[9]

6.3 METHOD

6.3.1 Study Design

Similar to the previous two studies presented in this thesis (Chapters 4 & 5), the structure of the classes included in this study were based on school registration lists, with students being randomly assigned to classes. At the time of data collection, all students involved in the study were in their second year of senior school. While all students at the school participate in the CREST programme at some point during senior school, participation in the programme was staggered. Of the 12 classes of

[9] If teacher ratings of self-regulated learning do not mirror the changes in student self-reports of the self-regulated processes measured, further analyses will be required to explore whether the teacher ratings are correlated to the other related motivational variables measured in the present study.

students taking part in this study (the entire year-group from the school), four classes had taken part in the CREST programme the previous academic year (in their first year of senior school, 9 months before the pre-test was administered). These classes made up the first intervention condition (S1 CREST) included in the study design in order to investigate longer-term retention effects relating to the benefits of participation in the CREST programme. Another four classes were participating in the CREST programme during the course of the study and made up the second intervention condition for the analyses (S2 CREST). The final four classes included had no previous experience with the CREST programme in either their first or second year of senior school and made up the control group included in the analyses (No CREST). This quasi-experimental study therefore followed a three group (S1 CREST, S2 CREST, & No CREST) and three phase (pre-test, post-test, delayed post-test) design producing a 3 x 3 mixed method design with the group variable being the independent measure and the change scores between the phase outcome measures being the dependent variables (pre-test/post-test change, and pre-test/delayed post-test change).

6.3.2 Participants and Educational Context

Before any questionnaire measures were administered to students, school and parental consent were obtained following the ethical guidelines set by the University of Edinburgh and the British Psychological Society (see Appendix A). Questionnaires were initially piloted with 20 students matching the target population (S2, 12-13 years of age), reviewed by two science teachers, and piloted for a second time with another 40 students. In an attempt to ensure that the programme was similarly implemented among classes, the piloting process also involved observing how teachers at the school implemented the programme with groups of students the previous academic year. As described in the previous two empirical chapters (Chapters 4 & 5), these observations included recording the amount of time spent on the CREST programme, documenting the nature of teacher versus student control, observing the types of projects conducted, as well as discussing programme administration with the Head of Department.

Power calculations were carried out using the G*Power 3.1 programme developed by Faul *et al.* (2009). To observe a medium effect size at an alpha value of .05 and achieve a power of .80, a minimum sample of 111 was required to detect differences between the three groups by implementing the analyses of variances used in this study. To ensure that appropriate power was achieved, data were collected from an entire year-group of students (n=240) from an independent school in Edinburgh in a high socio-economic catchment area. However, only students who completed both the pre-test and the post-tests were included in the analyses.

Due to absences during class, only 194 students completed both pre- and post-test questionnaires. Of the students who completed both questionnaires, 6 students did not finish the questionnaires in the allocated time leaving a total of 188 students (45.2% male, 54.8% female) in the study. All students involved in the study were judged by teachers to have adequate reading levels to work through the intervention materials. As with Study 2, a six-month delayed post-test was not available for this sample of students. The school and teachers communicated concern over committing to participate in the project the following academic year due to administrative shifts. Therefore, it was decided to obtain a three-month delayed post-test before the summer break.

Table 6.1 on the following page shows a breakdown of the gender make-up and student numbers in the three groups included in the present study design. Contrasting to the student sample in Study 2 presented in the previous chapter, which contained a larger proportion of male students, Table 6.1 shows that females were slightly overrepresented in Study 3. These sample differences will be considered in the final discussion chapter (Chapter 7) when synthesising the results from the three empirical studies presented in this thesis. Table 6.1 also shows the mean age of the students included in the sample in both years and months. Over the course of 12 weeks, students worked on their CREST projects once a week; completing a total of 12 CREST sessions, each 55 minutes long (total hours on CREST≅11 hours).

Table 6.1. Student numbers, gender split with percentages, and mean ages (standard deviations) for the three groups included in Study 3.

Group	Boys	Girls	Total	Mean Age Y	Mean Age M
S1 CREST	32 (46.4%)	37 (53.6%)	69	13.40 (.329)	160.75 (3.95)
S2 CREST	29 (45.3%)	35 (54.7%)	64	13.46 (.352)	161.54 (4.22)
No CREST	24 (43.6%)	31 (56.4%)	55	13.43 (.334)	161.21 (4.02)
Total	**85 (45.2%)**	**103 (54.8%)**	**188**	**13.43 (.338)**	**161.17 (4.06)**

Note. Y= in years, M= in months.

6.3.3 Pre-, Post-, and Delayed Post-test Measures

Student Measures

The three self-report measures implemented in both Studies 1 and 2 were also chosen for Study 3. These included: the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich & De Groot, 1990); the modified Five Component Scale of Self-Regulation (FCSSR, MacLellan & Soden, 2006); and the Science Motivation Questionnaire (SMQ, Glynn *et al.,* 2009). As the reliability and implementation of the above measures proved useful in addressing the research questions for Studies 1 and 2, it was decided that these measures were also appropriate in order to address the research aims of the present study. These measures were also chosen in order to make cross-study interpretations possible, which will be presented in the final chapter of this thesis (Chapter 7).

As with the previous two studies presented, a score for each subscale was generated by computing a mean for the items relating to each subscale. The following three tables (6.2, 6.3, & 6.4) present summaries of the subscales with example items making up each scale. The calculated scale reliability results assessed with Cronbach's alpha are presented alongside the reliabilities reported in the literature for each measure in order to demonstrate the internal consistency of the measures.

Table 6.2. Example items and internal consistency (reliability) coefficients for the MSLQ subscales.

Subscale	n	Example Item	α	α (1990)*
Motivation Scales				
Self-Efficacy	9	I expect to do very well in science class	.93	.89
Intrinsic Value	9	Understanding this subject is important to me	.90	.87
Test Anxiety	4	I am so nervous during a test that I cannot remember facts I have learned	.90	.75
Cognitive Scales				
Cognitive Strategies Use	13	I outline the chapters in my book to help me study	.85	.83
Self-Regulation	9	I ask myself questions to make sure I know the material have been studying	.77	.74

*Published alpha values from Pintrich and De Groot (1990) for the subscales on the MSLQ.

Table 6.3. Example items and internal consistency (reliability) coefficients for the FCSSR subscales.

Subscale	n	Example Item	α	α (2006)*
Goal Setting	10	When doing my academic work, I always set goals to guide me in my efforts	.92	.88
Strategy Implementation	4	I take notes during class	.88	.90
Strategy Monitoring	15	I compare the strategy to other strategies to see which is more effective	.86	.92
Total	45		.95	-

*Published alpha values from MacLellan and Soden (2006). *Note:* no published alpha value available for the total self-regulated learning composite.

Table 6.4. Example items and internal consistency (reliability) coefficients for the SMQ subscales.

Subscale	n	Example Item	α	α (2009)*
Intrinsic Motivation Personal Relevance	10	The science I learn is more important to me than the grade I receive	.88	.91
Self-Efficacy	4	I believe I can master the knowledge and skills in the science course	.84	-
Test Anxiety	5	I become anxious when it is time to take a science test	.82	-
Self-Determination	4	I put enough effort into learning the science	.51[a]	.74
Career Motivation	2	I think about how learning the science can help my career	.89	.88
Grade Motivation	5	Earning a good science grade is important to me	.49[b]	.55
Science Motivation	30		.86	.91

*Published alpha values from Glynn *et al.* (2009). [a] Mean inter-item correlation between .2 and .4 which is acceptable according to Briggs and Cheek (1986). [b] Mean inter-item correlation= .16 which is not acceptable according to Briggs and Cheek (1986). *Note:* self-efficacy and test anxiety are included in analyses as two separate composites so no published alpha value available.

Teacher Measures

As outlined in the introduction previously, the present study also aims to investigate changes in teacher perceptions of student self-regulated learning following participation in the CREST programme. For the present study, these perceptions were measured using the *Rating Student Self-Regulated Learning Outcomes: A Teacher Scale* (RSSRL) developed by Zimmerman and Martinez-Pons (1988).

While there are several measures available in the literature that assess teachers' perceptions of self-regulated learning as a construct and document teachers' use of self-regulated learning within their classroom practices (Lombaerts, Engels, & Athanasou, 2007; Mikroyannidis, Connolly, & Law, 2012), there are few tools that quantify teachers' perceptions of self-regulated learning strategy use among their students. Zimmerman and Martinez-Pons (1988) developed a measure made up of 12 items (presented in Table 6.5 on the following page) relating to students' use of self-regulated learning strategies easily observable by classroom teachers (completing assignments on time, reviewing notes independently, being prepared for class etc.). Items were rated along a 5-point scale (1=never, 2=sometimes, 3=fairly often, 4=very often, and 5=always). The Cronbach's alpha for the total scale calculated for the present study was .90, which was similar to the value of .92 published by Zimmerman and Martinez-Pons (1988). This provides support for using this measure and demonstrates excellent reliability for the published RSSRL scale.

Table 6.5. A summary the items for the RSSRL questionnaire.

Item number	Item description
Seeking Information	
1	Does this student solicit additional information about the exact nature of forthcoming tests or quizzes?
2	Does this student solicit additional information about your expectations or preferences concerning homework assignments?
Self-Evaluation Activities	
3	Does this student display awareness concerning how well he/she has done on a test or quiz before you have graded it?
8	Will this student seek assistance from you on his/her own when he/she is having difficulty understanding schoolwork?
12	Does this student solicit further information regarding your grades or evaluations of his or her schoolwork?
Goal Setting and Planning	
4	Does this student complete assignments on or before the specified deadline?
5	Is this student prepared to participate in class on a daily basis?
Intrinsic Motivation	
6	Does this student express interest in course matter?
10	Will this student volunteer for special tasks, duties, or activities related to coursework?
Unconventional Comments	
7	Does this student offer relevant information that was not mentioned in the textbook or previous class discussions?
9	Will this student ask unusual or insightful questions in class?
11	Does this student express and defend opinions that may differ from yours or those of classmates?

Academic Performance

Similar to Study 1, in order to control for prior academic performance and investigate its potential influence on students' self-regulatory processes and related motivations, the present study included academic performance marks in science obtained before the study began. Pre-test academic performance measured by student performance marks on a science test (marked out of 100) completed by all students was included in the analyses.

6.3.4 Procedure

The pre-test questionnaires were administered by classroom teachers during regular scheduled classes and students were given 40 minutes to complete the questionnaires. As outlined in Chapter 3 Section *3.7*, the administration procedure involved teachers reading out a pre-determined script in order to ensure similar implementation among the 12 teachers involved in the present study (see Appendix C). The script also involved communicating to students the voluntary nature of participation in the project. Questionnaires were administered to all classes before, after, and three months after students participated in the CREST programme.

After the pre-test questionnaires were administered, the S2 CREST condition took part in the CREST programme over the course of 12 weeks while students in the other two conditions carried on with regular classes with no significant pedagogical events documented. Between the immediate post-test and delayed post-test, all students continued through the regular school term with no significant pedagogical interventions or influential events noted.

In addition to the student measures administered, copies of the teacher measure described earlier (the RSSRL) were distributed to the 12 classroom teachers (8 males, 4 females) while the students were completing the questionnaires. These questionnaires were administered to all 12 teachers within a week before, after, and three months after students in the second intervention condition (S2 CREST) completed the CREST programme. The Cronbach's alpha reliability for the scale for the RSSRL was .90, indicating excellent internal consistency. All post- and delayed post-tests used the same materials and procedures as the pre-tests.

6.3.5 Analysis

Similar to Studies 1 and 2, parametric statistics were employed to provide the power required to answer the research questions and examine interactions between key variables (see Chapter 3 for a full justification of the appropriateness of parametric analyses for this research). Before the parametric analyses were conducted, missing data analysis was performed in SPSS 19.0. As there were no questions with more than 5% missing values, all questions on the questionnaires were included in composite scoring. Similar to Studies 1 and 2, the results from Little's MCAR test for each of the questionnaires showed that any missing data was missing completely at random. At this point, it was deemed appropriate to use listwise deletion of cases for analysis and that no imputation was necessary. Preliminary analyses also involved ensuring no serious violations of the normality and follow-up non-parametric tests were performed if any doubt existed. Analyses exploring gender differences were also conducted to determine whether gender should to be included as a covariate.

In order to address the first research question, one-way ANOVAs were run on all pre-test scores to investigate any differences between groups present at the outset of the study. As outlined in Chapter 3, repeated measures ANOVAs were avoided as the F test for treatment main effect is too conservative as pre-test scores are not affected by the intervention (Dimitrov & Rumrill, 2003; Matthews *et al.,* 2009). Therefore, following the suggestions of Dimitrov and Rumrill (2003) as well as Bonate (2000), one-way ANOVAs using the change scores of student and teacher self-reports while controlling for pre-test academic performance were conducted in order to address the remaining research questions of this study. To obtain a measure of change on each self-report scale, *change* scores were calculated by subtracting pre-test scores from post-test scores, as well as pre-tests from delayed post-test measurements.

Additional analyses were performed in order to contextualise the change scores and build on the correlation analyses presented in Study 1, Chapter 4 Section *4.4.1* on page 110. This section of analyses involved grouping students based on pre-test scores on each measured variable (categorised as low pre-tests, medium pre-tests, high pre-tests). MacCallum, Zhang, Preacher, and Rucker (2002) state that there is a risk of losing power and the ability to detect small effect sizes when dichotomising quantitative variables in this way. However, in the present study these 'costs' were perceived as benefits as detection of any significant findings will be even more impressive with this conservative test (MacCallum *et al.,* 2002). MacCallum and colleagues (2002) also outline that performing this analysis is appropriate when it is likely that distinct groups naturally exist on the variables. In the case of the present research, for self-regulated processes and related motivations this is a definite possibility (Gangestad & Snyder, 1985), providing evidence for the appropriateness of this analysis.

As multiple measures were used for several constructs in this study, data were analysed for these variables using MANCOVAs on the change scores described earlier. Running these multivariate ANOVAs is not only in line with the conceptual framework this research is based on (outlined in Chapters 1 & 2), but also reduces the chances of Type 1 errors occuring by lowering the number of univariate ANOVAs conducted (see Chapter 3 Section *3.9.2* for a more detailed justification).

For all multivariate tests reported in Study 3, preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, with no serious violations noted unless otherwise stated. To simplify the analyses and make results more manageable, results will be presented in sections relating to the three research questions outlined at the beginning of this chapter. Table 6.6 on the following page provides an overview of these sections and the corresponding analyses that will be conducted.

Table 6.6. An overview of results sections included in Study 3.

Part 1: Preliminary Analysis	
	A: Gender differences in key variables at pre-test • Independent-samples *t-tests* and multivariate analyses on key outcome measures
	B: Correlations between key variables at pre-test • Bivariate correlations between dependent variables
Part 2: Main Analyses	
RQ 1	A: Investigating pre-test group differences and retention effects using student self-reports • One-way ANOVAs with post-hoc tests
	B: Investigating pre-test group differences and retention effects using teacher data • One-way ANOVAs with post-hoc tests
RQ 2	A: Investigating group differences in pre- to post-test change using student self-reports • MANCOVAs and ANCOVAs on pre/post-test change with post-hoc tests
	B: Investigating group differences in pre-to post-test change scores using teacher data • ANCOVAs on pre/post-test change with post-hoc tests
RQ 3	A: Investigating retention effects of group differences using student self-reports • MANCOVAs and ANCOVAs on pre/delayed post-test change with post-hoc tests
	B: Investigating retention effects of group differences using teacher data • ANOVAs on pre/delayed post-test change with post-hoc tests

As with Studies 1 and 2, effect sizes will be presented alongside significance values. For ANOVAS, the partial eta squared ($\eta\rho^2$) statistic will be included and Cohen's (1988) guidelines for interpretation, shown in Table 6.7 below, will be followed. In addition, Cohen's d statistic will be used for any *t-test* comparisons presented.

Table 6.7. Guidelines for interpreting effect sizes (Cohen 1988, p. 284-287).

Cohen's d	Size of Effect	$\eta\rho^2$	Size of Effect
≥.10	small	≥.01	small
≥.30	medium	≥.06	medium
≥.80	large	≥.14	large

6.4 RESULTS

6.4.1 Preliminary Analysis A: Gender Differences in Key Variables at Pre-test

Results from the preliminary independent-samples *t-tests* exploring gender differences for the entire student sample on all variables measured at pre-test (student self-reports, pre-test academic performance, and teacher ratings), showed some significant differences between boys and girls at an adjusted alpha level of .01. Differences were found for cognitive strategies use measured on the MSLQ as well as for test anxiety measured on the SMQ, with girls reporting higher self-reported levels on these measures. To explore these differences further, similar tests were run on the post-test and delayed post-test data. As significant differences on cognitive strategies use and test anxiety were maintained at both post-test and delayed post-test and as further preliminary multivariate analyses revealed no main effects of gender on any of the variables used, gender was not included as a covariate in the main analyses.

6.4.2 Preliminary Analysis B: Correlations Between Key Variables at Pre-test

To evaluate the redundancy of the outcome measures, bivariate correlations between dependent variables were investigated. While multiple measures were correlated (MSLQ & SMQ), which may provide justification for the creation of new composites by converting raw scores into standardised scores and the summing the z scores of the related scales, a comparison of the correlation *between* scales to the correlation *within* each scale needs to be addressed. While the correlations between multiple measures (MSLQ test anxiety & SMQ test anxiety) were significant, when compared to the correlations within each scale (correlation between the five test anxiety items on the SMQ), the correlations between different measures were smaller. Therefore, as with Studies 1 and 2, results are presented for the separate scales and the multiple measures were included in the multivariate analyses when appropriate.

6.4.3 RQ 1A: Investigating Pre-test Group Differences and Retention Effects Using Student Self-reports

In order to address the first research question, one-way between-groups ANOVAs were performed on all pre-test variables to explore any differences in self-reported levels of self-regulated processes and related motivations between the three groups at the beginning of the study. No statistically significant differences were found on any pre-test measures at the Bonferroni adjusted alpha level of .01. These results are not in line with the first research prediction that students in the S1 CREST condition who had previous experience with the CREST programme would show significantly higher self-reports on these measures. Therefore, relating to the first research question regarding retention effects, these results suggest that students in the S1 CREST condition did not retain any developed benefits in self-reported levels of these measured variables nine months following CREST programme completion. The means and standard deviations of these pre-test results are presented in Table 6.8 on page 185 alongside the main variance analyses.

6.4.4 RQ 1B: Investigating Pre-test Group Differences and Retention Effects Using Teacher Data

Variance analyses were also conducted to address the second part of Research Question 1 regarding whether pre-test teacher ratings of self-regulated learning were higher for the group that had participated in the CREST programme before coming into the study (S1 CREST condition). The results from a one-way ANOVA on pre-test teacher ratings with group as the independent variable showed that the three groups were not significantly different on pre-test teacher ratings of self-regulated learning ($F(2,181)=1.462$, $p=.235$, $\eta\rho^2=.0161$). These non-significant results are not in line with research prediction 1B and suggest no longer-term (nine-month) impact of the CREST programme on teachers' perceptions of student self-regulated learning. Considering these results together with the student data presented above relating to Research Question 1A provides further support for the lack of longer-term (nine-month) retention effects in this sample. The means and standard deviations of the above pre-test results are presented in Table 6.10 on page 188 alongside the main variance analyses.

As academic performance was not included in the above variance analyses due to violation of the homogeneity of regression slopes assumption, the relationship between pre-test academic performance and pre-test teacher rated self-regulated learning was investigated using the Pearson product-moment correlation coefficient. After ensuring no violations of the assumptions of normality, linearity, and homoscedasticity, a positive correlation was found between the two variables ($r=.219$, $p<.01$), with high pre-test student academic performance associated with higher teacher ratings of self-regulated learning. These results will be discussed further in relation to the student self-report results in the final section of this chapter.

6.4.5 RQ 2A: Investigating Group Differences in Pre- to Post-Test Change Using Student Self-reports

Self-Regulated processes

To detect group differences in pre- to post-test change on the standardised measures used in this study, between groups MANCOVAs were conducted exploring the effect of the intervention on the three conditions included in the study design. For self-regulated processes, a one-way between-groups (S1 CREST, S2 CREST, No CREST) multivariate analysis of covariance was performed on pre- to post-test change scores, controlling for pre-test academic performance. Similar to both Studies 1 and 2, four dependent variables were used: MSLQ self-regulation, MSLQ cognitive strategies use, FCSSR total self-regulated learning, and SMQ self-determination mapping on to the theoretical framework presented in Chapter 1. The independent variable for this analysis was *group* and the covariate used was pre-test academic performance in science.

There was a statistically significant difference between groups on the combined self-regulated process dependent variables ($F(8,272)=2.392$, Wilks' Lambda=.873, $p=.017$, $\eta\rho^2=.066$) and no significant multivariate test was found for pre-test academic performance. The result relating to academic performance suggests that lower-achieving students were no different in their changes in self-reported levels of self-regulated processes compared to higher-achieving students.[10]

When considering the results for the four dependent variables separately, the only difference to reach statistical significance, using a Bonferroni adjusted alpha level of .01, was the self-regulation change score on the MSLQ ($F(2,142)= 5.186$, $p=.007$, $\eta_p^2 =.069$). An inspection of the mean change scores indicated that both the No CREST and S1 CREST conditions decreased in self-reported levels of self-regulation (No CREST, $M_{change}=-.193$, SD=.493; S1 CREST, $M_{change}=-.0786$, SD=.639) while the S2 CREST condition increased ($M_{change}=.174$, SD=.583). Further inspection of the 95% confidence intervals around each mean change score indicated that there was a significant increase in self-regulation for the S2 CREST condition only. These results are in line with research prediction 2A suggesting that students taking part in the CREST programme, at the time of the study, experienced positive changes in their levels of self-reported self-regulation, while students in the other two groups not taking part in CREST showed decreases in these self-reports. Figure 6.1 below illustrates these significant findings.

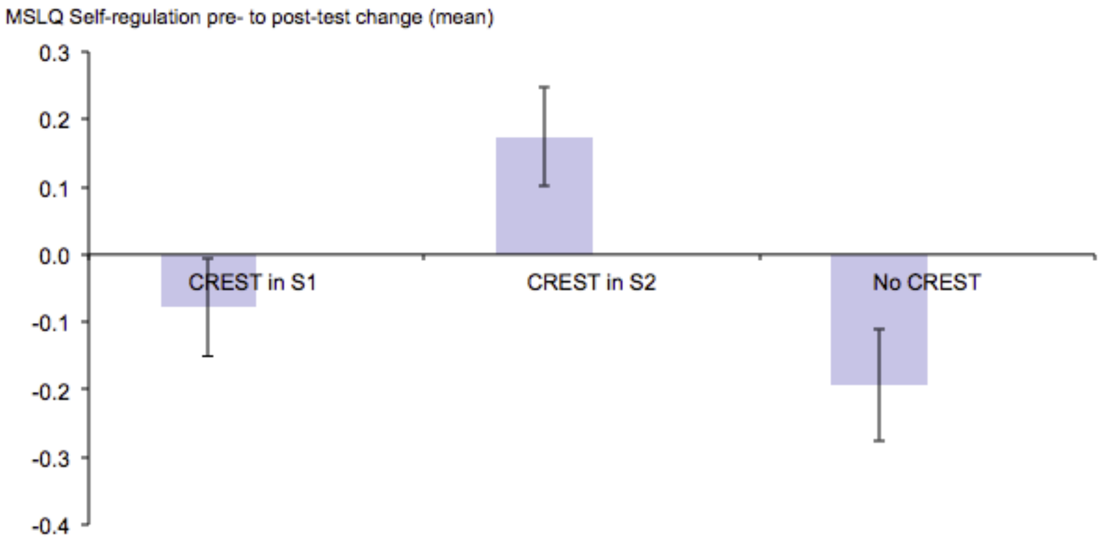

Figure 6.1. Pre- to immediate post-test change in MSLQ self-regulation

[10] For the remainder of this chapter, the results from the multivariate tests for pre-test academic performance will not be presented unless significance is found in order to focus the results.

The univariate tests relating to self-regulated learning, cognitive strategies use, and self-determination were not significant, therefore showing that the three groups did not differ in their self-reported changes on these measures from pre-test to post-test. As no significant changes in cognitive strategies use from pre-test to post-test were documented in either Studies 1 or 2, this result does not necessarily contradict the research prediction 2A made in Study 3 relating to this construct. However, as significant changes were expected for self-regulated learning and self-determination (documented in both Studies 1 & 2), these results are not in line with the research prediction 2A made in Study 3 relating to these two constructs. Table 6.8 on page 185 presents a summary of the pre-test, post-test, and change score means and standard deviations for these variables as well as for all other variables measured in this study.

Related Motivations

MANCOVA results investigating group differences in self-efficacy scores on the MSLQ and SMQ showed no statistically significant difference between the three groups on the combined dependent variables ($F(4,350)=.413$, $p=.799$, Wilks' Lambda= .991, $\eta_p^2=.005$) while controlling for academic performance in science. Similarly, while controlling for academic performance at pre-test, there were no group differences in pre- to post-test change in intrinsic motivation scores on the MSLQ and SMQ combined dependent variables ($F(4,344)=1.612$, $p=.171$, Wilks' Lambda= .964, $\eta_p^2=.018$). Multivariate results investigating group differences in the test anxiety change scores on the MSLQ and SMQ also showed no statistically significant group differences on the combined dependent variables after controlling for pre-test academic performance ($F(4,354)=.614$, $p=.663$, Wilks' Lambda= .986, $\eta_p^2=.007$).

These results regarding related motivations are not in line with research prediction 2A that students in the S2 CREST condition would experience more development of these measured outcomes compared to student in the two other conditions included in the study design (S1 CREST and No CREST).

Science-Specific Motivations

One-way between-groups ANCOVAs were performed to investigate group differences in the science-specific motivations measured on the SMQ. For the career motivation analysis, the independent variable was group and the dependent variable was the career motivation change score from pre-test to post-test. After adjusting for pre-test academic performance marks, there was no significant difference between the three groups on the career motivation change scores ($F(2,187)= 1.979$, $p=.141$, $\eta\rho^2 =.021$). In addition, no strong relationship was found between the change scores and the pre-test academic marks as indicated by the $\eta\rho^2$ value of .004.

For overall science motivation, the independent variable was group and the dependent variable was the pre- to post-test change score for overall science motivation on the SMQ. Results showed that after adjusting for pre-test academic performance marks, no significant differences were found between the three groups on overall science motivation change scores ($F(2,168)=.122$, $p=.885$, $\eta\rho^2 =.001$). Similar to the analysis for career motivation, no strong relationship was found between pre-test academic performance and overall SMQ change scores ($\eta\rho^2 =.003$). The pre-test, post-test, and change score means for the science-specific measures for each CREST condition are presented in Table 6.8 on the following page.

These results relating to the science-specific measures are not in line with research prediction 2A. This hypothesis suggested that students taking part in CREST at the time of the study (the S2 CREST condition) would show more positive changes in the science-specific motivations measured, compared to students in the other two conditions (S1 CREST & No CREST) who were not participating in CREST during the course of the study.

Table 6.8. A summary of the pre-test-test and immediate post-test means (standard deviations) of the three groups for all measures included in Study 3.

Variable	Pre-test	Immediate Post-test	Change Score
Self-Regulated Processes			
MSLQ Self-Regulation			
S2 CREST	4.47 (.641)	4.65 (.696)	.174 (.583)
S1 CREST	4.62 (.823)	4.51 (.749)	-.0786 (.639)
No CREST	4.58 (.918)	4.37 (.839)	-.193 (.493)
MSLQ Cognitive Strategies Use			
S2 CREST	4.84 (.639)	4.86 (.695)	.0248 (.557)
S1 CREST	4.83 (.791)	4.82 (.775)	.0084 (.655)
No CREST	4.76 (.923)	4.77 (.784)	-.0355 (.682)
FCSSR Total SRL			
S2 CREST	2.45 (.476)	2.50 (.430)	.0331 (.342)
S1 CREST	2.61 (.423)	2.48 (.441)	-.106 (.398)
No CREST	2.45 (.461)	2.42 (.423)	.0497 (.357)
SMQ Self-Determination			
S2 CREST	3.75 (.595)	3.74 (.624)	-.0159 (.611)
S1 CREST	3.85 (.553)	3.83 (.548)	-.0147 (.583)
No CREST	3.75 (.499)	3.76 (.477)	.0049 (.465)
Related Motivations			
MSLQ Self-Efficacy			
S2 CREST	4.68 (1.04)	4.67 (1.03)	.108 (.783)
S1 CREST	4.71 (.928)	4.83 (.931)	.0166 (.743)
No CREST	4.47 (.985)	4.44 (.952)	-.0370 (.637)
SMQ Self-Efficacy			
S2 CREST	3.72 (.686)	3.76 (.732)	.0159 (.512)
S1 CREST	3.61 (.731)	3.63 (.749)	.0441 (.532)
No CREST	3.43 (.737)	3.45 (.736)	.0185 (.596)
MSLQ Intrinsic Value			
S2 CREST	4.91 (.885)	5.06 (.873)	.155 (.682)
S1 CREST	5.14 (.874)	5.02 (.960)	-.106 (.827)
No CREST	4.95 (.872)	4.94 (.859)	-.0101 (.851)
SMQ IMPR			
S2 CREST	3.62 (.708)	3.64 (.619)	.0295 (.470)
S1 CREST	3.81 (.562)	3.73 (.695)	-.0868 (.553)
No CREST	3.56 (.574)	3.60 (.545)	.0519 (.545)
MSLQ Test Anxiety			
S2 CREST	3.31 (1.45)	3.61 (1.40)	.298 (1.05)
S1 CREST	3.28 (1.42)	3.35 (1.47)	.0672 (1.29)
No CREST	3.61 (1.70)	3.71 (1.64)	.100 (1.25)
SMQ Test Anxiety			
S2 CREST	2.80 (.855)	2.66 (.865)	-.141 (.562)
S1 CREST	2.82 (.891)	2.83 (.941)	.00896(.581)
No CREST	2.73 (.920)	2.70 (.930)	-.03704 (.679)
Science-Specific Motivations			
SMQ Career Motivation			
S2 CREST	3.62 (1.12)	3.91 (.928)	.297 (.876)
S1 CREST	3.80 (.968)	3.84 (.980)	.0435 (.980)
No CREST	3.67 (1.07)	3.65 (.902)	-.0182 (1.06)
SMQ Overall Science Motivation			
S2 CREST	105.95 (15.0)	105.79 (14.2)	-.288 (9.66)
S1 CREST	108.55 (13.5)	109.94 (14.5)	.677 (11.6)
No CREST	104.18 (14.5)	104.62 (13.0)	-.292 (10.9)

Note. SRL= self-regulated learning, IMPR= intrinsic motivation and personal relevance.

6.4.6 Contextualising Changes in Students' Self-Reported Levels on Key Variables

As with Study 1, while the use of change score analysis was justified for the present study, an appreciation of where students were on the scales at both pre-test and post-test is important in order to understand the influence of pre-test scores on student change scores and to contextualise any changes observed. Without drawing focus away from the main analyses in the present study, building on the exploratory correlational analysis presented in Study 1, Chapter 4 Section *4.4.1* on page 110, participants were split into three groups based on pre-test variable scores for the self-regulated processes and related motivational measures (categorised as low pre-tests, medium pre-tests, and high pre-tests) for the analysis reported in this section.[11] One-way ANCOVAs on the change scores of the self-regulated processes and related motivational outcome measures, while controlling for pre-test academic performance, were then conducted for each variable measured in the present study.

Results showed statistically significant differences between the change scores for the three groups created on each variable with effect sizes indicated by Cohen's d ranging from medium to large (see Table 6.9 on the next page). From Table 6.9 it can be seen that students with low pre-test scores on each variable experienced increases from pre-test to post-test while students showing high pre-test scores experienced slight decreases. Meanwhile, students in the middle range in terms of pre-test scores on the key constructs included in this study, experienced very slight increases and decreases. As contextualising the change scores included in this study was not an explicit research question, no research predictions were made here. However, these results have important implications for the interpretation of the findings presented and will be carefully considered in the final discussion section of this chapter.

[11] This constructed grouping is not to be confused with the three experimental conditions (S1 CREST, S2 CREST, & No CREST) included for the main analyses.

Table 6.9. A summary of one-way ANCOVA analyses for the contextualisation of change scores on all measured variables.

Variable	Pre-test	Immediate Post-test	Change Score	F	df	*p**	ηρ²	Post hoc
MSLQ Self-Regulation								
Low	3.79 (.540)	4.00 (.683)	.213 (.504)					L vs. H
Medium	4.51 (.150)	4.58 (.551)	.0687 (.554)					M vs. H
High	5.39 (.450)	5.05 (.631)	-.344 (.594)	16.8	2,177	.000	.162	
MSLQ CSU								
Low	4.02 (.400)	4.29 (.659)	.271 (.587)					L vs. H
Medium	4.78 (.219)	4.79 (.543)	.00769 (.566)					M vs. H
High	5.67 (.416)	5.39 (.625)	-.275 (.617)	12.0	2,178	.000	.121	
FCSSR SRL								
Low	2.04 (.262)	2.24 (.382)	.196 (.393)					L vs. M
Medium	2.49 (.210)	2.42 (.344)	-.0691 (.299)					M vs. H
High	2.96 (.284)	2.78 (.356)	-.174 (.329)	15.8	2,155	.000	.172	
SMQ Self-Determination								
Low	3.26 (.291)	3.50 (.563)	.240 (.515)					L vs. M
Medium	3.90 (.449)	3.89 (.449)	-.00862 (.456)					M vs. L
High	4.48 (.255)	4.08 (.459)	-.406 (.517)	23.7	2,181	.000	.210	L vs. H
MSLQ Self-Efficacy								
Low	3.53 (.631)	3.84 (.761)	.315 (.549)	12.7	2,182	.000	.123	H vs. L
Medium	4.64 (.254)	4.73 (.748)	.0868 (.710)					M vs. H
High	5.70 (.429)	5.39 (.781)	-.306 (.770)					
SMQ Self-Efficacy								
Low	2.86 (.602)	3.03 (.734)	.170 (.552)	2.95	2,181	.077	.028	_____
Medium	3.64 (.473)	3.67 (.653)	.0253 (.545)					
High	4.13 (.579)	4.05 (.554)	-.0848 (.511)					
MSLQ Intrinsic Value								
Low	4.01 (.434)	4.39 (.782)	.380 (.715)					L vs. H
Medium	5.07 (.294)	5.08 (.694)	.00868 (.685)					M vs. H
High	5.96 (.398)	5.59 (.809)	-.377 (.801)	18.3	2,184	.000	.169	M vs. L
SMQ IMPR								
Low	3.06 (.431)	3.30 (.491)	.237 (.488)					
Medium	3.67 (.351)	3.59 (.611)	-.0845 (.563)					
High	4.24 (.382)	4.08 (.524)	-.164 (.441)	10.9	2,181	.000	,110	L vs. M M vs. H
MSLQ Test Anxiety								
Low	1.76 (.518)	2.46 (1.16)	.706 (1.11)					L vs. H
Medium	3.27 (.433)	3.38 (.919)	.109 (.888)					L vs. M
High	5.17 (.807)	4.81 (1.35)	-.357 (1.33)	13.624	2,184	.000	.131	
SMQ Test Anxiety								
Low	1.87 (.450)	1.98 (.629)	.105 (.595)					L vs. H
Medium	2.78 (.407)	2.72 (.648)	-.0606 (.579)					
High	3.76 (.515)	3.54 (.712)	-.221 (.610)	4.48	2,184	.013	.047	
SMQ Career Motivation								
Low	2.43 (.609)	3.26 (.826)	.833 (.877)					L vs. M
Medium	3.78 (.250)	3.76 (.877)	-.0234 (.902)					M vs. H
High	4.81 (.244)	4.38 (.770)	-.430 (.695)	36.8	2,187	.000	.286	L vs. H
SMQ Overall Science Motivation								
Low	90.0 (7.57)	95.2(11.7)	5.27 (10.0)					L vs. M
Medium	107 (3.66)	105 (11.4)	1.74 (10.7)					L vs. H
High	121 (6.91)	118 (10.7)	-3.57 (9.50)	12.9	2,168	.000	.135	

Note. *two-tailed significance values presented. CSU= cognitive strategies use, SRL= self-regulated learning, IMPR= intrinsic motivation and personal relevance.

6.4.7 RQ 2B: Investigating Group Differences in Pre- to Post-test Change Using Teacher Data

Returning to the main research questions, in order to investigate differences in teachers' ratings of self-regulated learning between the three groups (S1 CREST, S2 CREST, & No CREST) before and immediately after participation in the CREST programme, a one-way ANCOVA controlling for pre-test academic performance was performed on the change scores of the teacher questionnaire results from pre-test to post-test. Results showed that Levene's test of homogeneity of variances assumption was violated. However, ANCOVAs are robust to violations of this assumption provided that the ratio of the largest group variance is no larger than three times the smallest group variance (Field, 2009, 2013). As this was the case for the present results, the ANCOVA approach was deemed appropriate.[12]

The results from the above ANCOVA showed no significant differences between the three groups regarding the pre- to post-test change scores of teacher ratings of student self-regulated learning. In addition, no strong relationship was found between the covariate of academic performance at pre-test and the change scores, as indicated by the $\eta\rho^2$ value of .016. Table 6.10 below shows a summary of these results, which are not in line with the research prediction 2B that teacher ratings of self-regulated learning would increase the most for the S2 CREST condition. These results are also not in line with the increases seen from pre-test to post-test in the student data relating to self-regulation for the S2 CREST condition presented earlier on page 182 while addressing Research Question 2A.

Table 6.10. A summary of the changes seen from pre-test to post-test using the teacher data.

Variable	Pre-test	Immediate Post-test	Change Score	F	df	p*	$\eta\rho^2$
Teacher SRL							
S2 CREST	2.70 (.773)	2.66 (.708)	-.0685 (.643)				
S1 CREST	2.93 (.787)	3.04 (.855)	.105 (.920)				
No CREST	2.84 (.742)	3.01 (.812)	.1635 (.566)				
One-way ANCOVA				1.96	2, 180	.144	.022

Note. *two-tailed significance values presented. SRL= self-regulated learning.

[12] For the present results, the described ratio is $\left(\frac{SDS1CREST^2}{SDNoCREST^2}\right)$=2.64 as Variance=$(Standard\ Deviation^2)$.

6.4.8 Part 3A: Investigating Retention Effects of Group Differences Using Student Self-Reports

Self-Regulated processes

The analysis reported earlier investigating pre- to post-test change using the student data was repeated comparing the change scores from pre-test to three-month delayed post-test of the three groups (S1 CREST, S2 CREST, & No CREST) in order to investigate retention. For self-regulated processes, the multivariate results showed that there was a statistically significant difference between groups on the combined dependent variables after controlling for pre-test academic performance ($F(8,236)=2.497$, Wilks' Lambda=.850, $p=.013$, $\eta_p^2=.078$). When results for the dependent variables were considered separately, the only difference to reach significance using a Bonferroni adjusted alpha level of .01, was the self-regulation change score measured on the MSLQ ($F(2,125)= 5.723$, $p=.004$, $\eta_p^2=.086$). An inspection of the mean change scores indicated that both the No CREST and S1 CREST conditions decreased in self-reported levels of self-regulation (No CREST, $M_{change}=-.116$, SD=.531; S1 CREST, $M_{change}=-.195$, SD=.771), while the S2 CREST condition increased. Further inspection of the 95% confidence intervals around each mean change score indicated that there was a significant increase in self-regulation for the S2 CREST condition from pre-test to three-month delayed post-test ($M_{change}=.162$, SD=.730). Figure 6.2 below illustrates these significant results.

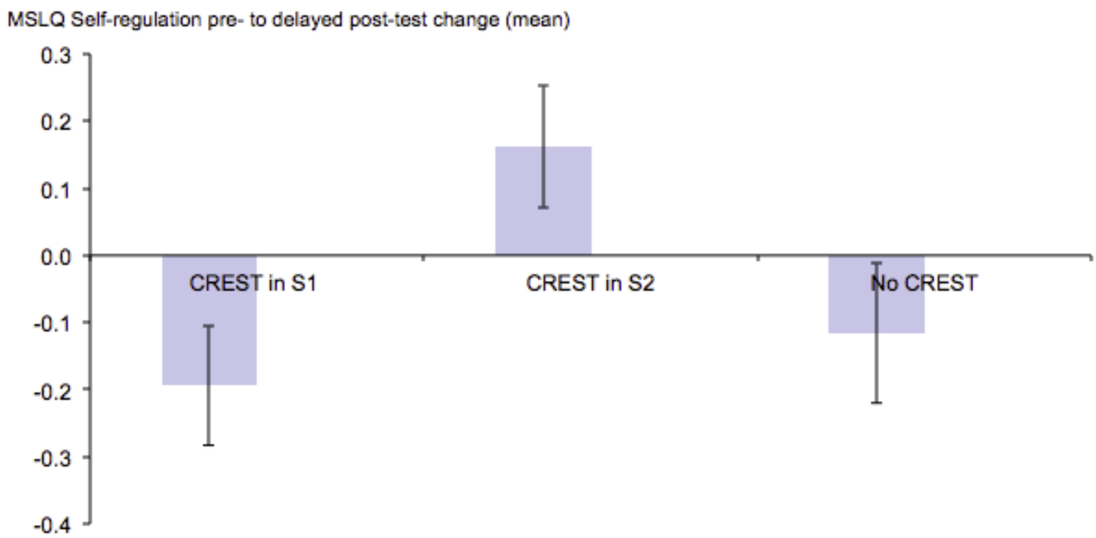

Figure 6.2. Pre- to delayed post-test change in MSLQ self-regulation

These results relating to self-regulation are in line with the research prediction 3A that any positive changes in self-regulated processes observed at immediate post-test would be retained at delayed post-test for the S2 CREST condition. As no significant differences were reported relating to self-regulated learning, cognitive strategies use, and self-determination while addressing Research Question 2A earlier in Section *6.4.5*, the non-significant results relating to these variables from pre-test to three-month delayed post-test are not surprising. The results here showed that the three groups did not differ in their self-reported changes on these measures from pre-test to three-month delayed post-test. Table 6.11 on page 192 presents a summary of the pre-test, delayed post-test, and change score means and standard deviations for these variables as well as for all other variables measured in Study 3.

Related Motivations

Similar multivariate tests reported earlier in Section *6.4.5* for Research Question 2A were run on the motivational measures using the delayed post-test minus pre-test change scores. MANCOVA results investigating group differences in the self-efficacy change scores on the MSLQ and SMQ showed no statistically significant differences between the three groups (S2 CREST, S1 CREST, & No CREST) on the combined dependent variables ($F(4,320)=.498$, $p=.737$, Wilks' Lambda= .988, $\eta\rho^2 =.006$). Similar results were found on the multivariate tests for intrinsic motivation post-test to delayed post-test change scores on the MSLQ and SMQ, with no statistically significant difference between the three groups on the combined dependent variables ($F(4,320)=.477$, $p=.775$, Wilks' Lambda= .989, $\eta\rho^2 =.006$). Multivariate tests run on the test anxiety change scores from pre-test to three-month delayed post-test also showed no significant difference between groups ($F(4,332)=.743$, $p=.563$, Wilks' Lambda=.982, $\eta\rho^2 =.009$). Relating back to research prediction 3A regarding retention, these results suggest that while no group differences were reported between the three groups from pre-test to post-test, no further consolidation of effects occurred in the three months following CREST participation for the S2 CREST condition. In other words, for these motivational variables, which showed no immediate group differences or intervention effects, no delayed impact was reported for the intervention.

Science-Specific Motivations

For the career motivation ANCOVA, after adjusting for pre-test academic performance marks, there was no significant difference between the pre- to delayed post-test change scores of the three groups ($F(2,175)= .415$, p=.661, $\eta\rho^2$ =.005) and no strong relationship was found between the change scores and pre-test academic marks, as indicated by the $\eta\rho^2$ value of .00. For overall science motivation, ANCOVA results showed that after adjusting for pre-test academic performance marks, no significant differences were found between the three groups (S2 CREST, S1 CREST, & No CREST) on total science motivation change scores on the SMQ ($F(2,154)$=.595, p=.553, $\eta\rho^2$ =.008) and no strong relationship was found between the covariate academic performance at pre-test and the pre- to delayed post-test change scores ($\eta\rho^2$ =.011). The pre-test, delayed post-test, and change score means and standard deviations for these variables are presented in Table 6.11 on the following page. As with the related motivational constructs, relating back to research prediction 3A, the results for the science-specific motivations at three-month delayed post-test provide no evidence of delayed impact for the CREST programme, as no group differences were reported.

Table 6.11. A summary of the pre-test-test and delayed post-test means (standard deviations) of the three groups for all measures included in Study 3.

Variable	Pre-test	Delayed Post-test	Change Score
Self-Regulated Processes			
MSLQ Self-Regulation			
S2 CREST	4.47 (.641)	4.62 (.844)	.162 (.730)
S1 CREST	4.66 (.843)	4.47 (.896)	-.195 (.771)
No CREST	4.58 (.918)	4.46 (.891)	-.116 (.531)
MSLQ Cognitive Strategies Use			
S2 CREST	4.84 (.639)	4.95 (.776)	.115 (.652)
S1 CREST	4.83 (.791)	4.81 (.760)	-.0076 (.704)
No CREST	4.76 (.923)	4.73 (.953)	-.0936 (.764)
FCSSR SRL			
S2 CREST	2.45 (.476)	2.52 (.490)	.0280 (.385)
S1 CREST	2.61 (.423)	2.44 (.454)	-.181 (.368)
No CREST	2.45 (.461)	2.42 (.447)	-.0361 (.340)
SMQ Self-Determination			
S2 CREST	3.75 (.595)	3.64 (.625)	-.138 (.588)
S1 CREST	3.85 (.553)	3.70 (.652)	-.181 (.638)
No CREST	3.75 (.495)	3.60 (.689)	-.214 (.732)
Related Motivations			
MSLQ Self-Efficacy			
S2 CREST	4.65 (.929)	4.74 (.880)	.0952 (.777)
S1 CREST	4.69 (.1.03)	4.68 (.991)	-.0106 (.935)
No CREST	4.47 (.985)	4.42 (.941)	-.0556 (.639)
SMQ Self-Efficacy			
S2 CREST	3.55 (.744)	3.61 (.735)	.0483 (.655)
S1 CREST	3.71 (.684)	3.64 (.708)	-.0796(.514)
No CREST	3.45(.742)	3.40 (.716)	-.0441 (.653)
MSLQ Intrinsic Value			
S2 CREST	4.90 (.920)	4.85 (1.02)	-.0507 (1.00)
S1 CREST	5.15 (.851)	4.91 (.840)	-.233 (.737)
No CREST	5.01 (.880)	4.82 (.987)	-.191 (.639)
SMQ IMPR			
S2 CREST	4.90 (.920)	4.85 (1.02)	-.0507 (1.00)
S1 CREST	5.15 (.851)	4.91 (.840)	-.233 (.737)
No CREST	5.01 (.880)	4.82 (.987)	-.191 (.639)
MSLQ Test Anxiety			
S2 CREST	3.36 (1.48)	3.65 (1.62)	.285 (1.35)
S1 CREST	3.31 (1.45)	3.65 (1.62)	.344 (1.35)
No CREST	3.64 (1.75)	3.67 (1.75)	.0294 (1.22)
SMQ Test Anxiety			
S2 CREST	2.82 (.875)	2.77 (.966)	-.0552 (.813)
S1 CREST	2.84 (.891)	2.84 (.963)	.000 (.687)
No CREST	2.75 (.956)	2.78 (.953)	.0353 (.660)
Science-Specific Motivations			
SMQ Career Motivation			
S2 CREST	3.62 (1.12)	3.58 (1.02)	-.0517 (.926)
S1 CREST	3.80 (.968)	3.70 (.966)	-.119 (1.01)
No CREST	3.67 (1.07)	3.50 (.964)	-.226 (1.02)
SMQ Overall Science Motivation			
S2 CREST	106.25 (15.5)	104.40 (15.7)	-1.85 (12.0)
S1 CREST	109.23 (13.2)	105.32 (14.4)	-3.92 (10.9)
No CREST	105.20 (14.5)	101.25 (14.6)	-3.95 (13.9)

Note. SRL= self-regulated learning, IMPR= intrinsic motivation and personal relevance.

6.4.9 RQ 3B: Investigating Retention Effects of Group Differences Using Teacher Data

For the pre-test to three-month delayed post-test change score analyses using the teacher data, the assumption of homogeneity of regression slopes was violated and the covariate of pre-test academic performance was therefore not included in the one-way ANOVA conducted. Results showed no significant differences between the three intervention conditions on pre-test to delayed post-test change scores for teacher rated self-regulated learning. Table 6.12 below presents a summary of these results.

Considering the results presented above relating to student self-reported changes in self-regulation from pre-test to three-month delayed post-test, it was expected here that teacher ratings in the S2 CREST condition would increase significantly while teacher ratings for the other conditions might decrease (No CREST & S1 CREST). As these trends were not found, the results presented here are not in line with the research prediction 3B.

However, it should be noted that while no differences were found between the three intervention conditions in terms of changes in teacher ratings of self-regulated learning from pre-test to delayed post-test, significant increasing trends were found in all groups. In addition, from Table 6.12 below it can be seen that the teacher perceptions self-regulated learning increased the most for the S2 CREST condition. This result will be discussed in the final section of this chapter regarding the changes in self-regulated learning from the teachers' perspectives mirroring the student self-regulation trends presented earlier relating to Research Question 3A.

Table 6.12. A summary of the means (standard deviations) of the teacher self-regulated learning ratings for the three groups at pre-test and delayed post-test and the variance analyses results.

Variable	Pre-test	Delayed Post-test	Change Score	F	df	*p**	$\eta\rho^2$
Teacher SRL							
S2 CREST	2.68 (.796)	3.67 (.617)	.981 (1.00)				
S1 CREST	2.92 (.755)	3.69 (.520)	.767 (.790)				
No CREST	2.85 (.738)	3.57 (.568)	.716 (.843)				
One-way ANOVA				1.37	2,167	.257	.016

Note. *two-tailed significance values presented. SRL= self-regulated learning.

6.4.10 Exploring the Relationship Between Teacher Ratings of Self-Regulated Learning and Student Self-Reports on Related Motivational Constructs

As the results addressing Research Question 3B showed that teacher ratings were not in line with student self-reports relating to the self-regulated processes measured, further investigation is needed to identify whether teacher ratings of self-regulated learning are correlated with any other student self-report outcome measures.

While the results presented in this chapter thus far have investigated group differences in student and teacher self-reports on key outcome measures, additional insight can be gained by extending the investigation further to the relationship between teacher ratings and student self-reports on the other motivational variables measured. While not outlined above as a specific research prediction for the present study, it is expected here that teacher ratings may be correlated with some of the other motivational constructs measured. The previous finding that teacher results did not match those observed for the student self-reports relating to self-regulated processes, and the literature discussed in Chapter 1 regarding the role related motivations play in the self-regulatory process, provided rationale for this prediction.

For the present study, the relationships between teacher-rated self-regulated learning at pre-test and student pre-test self-reports on all outcome measures included in this research were investigated using Pearson product-moment correlation coefficients. These analyses were repeated to investigate the relationships between teacher perceptions of self-regulated learning and student self-reports on all outcome variables at post-test as well as delayed post-test. Preliminary analyses were performed to ensure no violations of the assumptions of normality, linearity, and homoscedasticity. Partial correlations were also run to test the influence of controlling for pre-test academic performance on the relationships studied in each group with no significant differences from the zero order correlations noted.

Table 6.13 on page 196 presents a summary of the above analyses, conducted firstly on the entire sample of students included in the study at pre-test, post-test, and three-month delayed post-test (rows 1, 2, & 3), and then on each of the three groups of students at the three time points (S2 CREST= rows 4, 5, & 6; S1 CREST= rows 7, 8, & 9; No CREST= rows 10, 11, & 12). The correlations presented in Table 6.13 were also compared to the partial correlations described above and an inspection of the zero order correlations suggested that controlling for academic performance had very little effect on the strength of the relationships between the measured outcome variables presented.

From rows 1 and 2 presented in Table 6.13, it can be seen that no significant correlations were found between teacher rated self-regulated learning and student self-reports of self-regulated learning and self-regulation for all students included in the study at pre-test and post-test. These results provide further support for the findings presented earlier rejecting the second research prediction (2B).

However, significant correlations were found between teacher ratings of self-regulated learning and student self-reports of self-determination at pre-test, post-test, and delayed post-test for the entire sample. Significant correlations were also found between teacher ratings of self-regulated learning and student self-reports of self-efficacy, intrinsic motivation, and test anxiety. Results showed that teachers rated students higher on levels of perceived self-regulated learning when students had higher self-reports of self-determination, self-efficacy, intrinsic motivation, and reported lower levels of test anxiety. Therefore, while the results presented in this chapter showed that changes in teacher ratings of self-regulated learning from pre-to post-test did not match the changes in student self-reports relating to self-regulated processes, they are in line with the changes observed on the related motivational outcome measures.

The results for the delayed post-test correlations (rows 3, 6, 9, & 12 in Table 6.13 on the following page) showed that teacher ratings of self-regulated learning were significantly correlated with all outcome measures. These results will be discussed further in the final section of this chapter as they contribute to understanding the results presented earlier relating to Research Question 3B.

Table 6.13. Correlations between student and teacher outcome measures at pre-test, post-test, and delayed post-test.

	SR	SRL	CSU	SD	MSLQ SE	SMQ SE	MSLQ IV	SMQ IMPR	MSLQ TA	SMQ TA	CM	SMQ Total
1	.069	.052	.025	.23**	.23**	.21**	.090	.11	-.25**	-.15*	.036	.18*
2	.078	.004	.035	.18*	.21**	.146*	.13	.32**	-.18*	-.094	-.008	.23**
3	.55**	.51**	.56**	.76**	.41**	.41**	.68**	.83**	-.15	-.31**	.76**	.74**
4	-.082	-.17	-.053	.20	.23	.098	.10	.11	-.22	-.11	.030	.13
5	-.19	-.18	-.16	-.039	.22	.14	.047	-.044	-.19	-.13	-.14	.033
6	.59**	.45**	.51**	.81**	.50**	.44**	.71**	.80**	**.061**	**.34***	.82**	.76**
7	.082	.096	.019	.16	.11	.17	.026	.090	-.22	-.20	.094	.18
8	.23	.14	.17	.20	.23	.41**	.15	.24*	-.16	-.051	.13	.29*
9	.49**	.61**	.50**	.75**	.30*	.33**	.61**	.83**	.24	**.28***	.73**	.71**
10	.16	.18	.59**	.37**	.42**	.37**	.13	.084	-.33*	-.13	-.053	.20
11	.22	.064	.080	.43**	.30*	.42**	.23	.20	-.19	-.080	-.010	.38**
12	.60**	.50**	.67**	.71**	.44**	.43**	.72**	.86**	.15	.34*	.73**	.75**

1. Teacher SRL at pre-test for all students 2. Teacher SRL at post-test for all students. 3. Teacher SRL at delayed post-test for all students. 4. Teacher SRL for S2 CREST at pre-test. 5. Teacher SRL for S2 CREST at post-test. 6. Teacher SRL for S2 CREST at delayed post-test. 7. Teacher SRL for S1 CREST at pre-test. 8. Teacher SRL for S1 CREST at post-test. 9. Teacher SRL for S1 CREST at delayed post-test. 10. Teacher SRL for No CREST at pre-test. 11. Teacher SRL for No CREST at post-test. 12. Teacher SRL for No CREST at delayed post-test. *Note.* *Correlation is significant at p<.005 level (2-tailed). ** Correlation is significant at the .05 level (2-tailed). SR= self-regulation, SRL= self-regulated learning, CSU= cognitive strategies use, SD= self-determination, SE= self-efficacy, IV= intrinsic value, IMPR= intrinsic value and personal relevance, TA= test anxiety, CM= career motivation, SMQ Total= overall science motivation.

6.5 DISCUSSION

The results from Studies 1 and 2 indicated that the CREST programme led to measurable positive changes in students' self-reported levels of some measured self-regulated processes and related motivations. Study 3 aimed to replicate these findings in a different sample of students, provide more insight into the long-term retention of these changes, and also investigate whether these changes were observed from the teachers' perspectives. These results will now be discussed in relation to the findings presented for Studies 1 and 2 (in Chapters 4 & 5) as well as in relation to relevant literature in the field. The discussions will be focused around the three research questions.

6.5.1 RQ 1: Investigating Pre-test Group Differences and Longer-term Retention Effects

As outlined in Chapter 1 Section *1.2*, the cognitive and metacognitive processes required in science learning are not only vital during school scholarship, but are life-long skills learners can sustain after graduation and for self-education later in life (Abdullah & Lee, 2007; Boekaerts, 1997; Kaplan, 2008; Kistner *et al.,* 2010). While the previous two empirical studies presented in this thesis investigated the presence of retention effects six months (Study 1) and four months (Study 2) after participation in the CREST programme, Study 3 explored whether retention was possible on a longer-term basis. As both Studies 1 and 2 documented that any developments in self-regulated processes and related motivations were maintained at the delayed post-tests (with the exception of intrinsic motivation in Study 2), it was predicted in the present study that students in the S1 CREST condition, with previous CREST experience nine months before taking part in the study, would show higher self-reported levels on the outcome measures included than students in the other two conditions who had no CREST experience (S2 CREST & No CREST). While an inspection of the trends showed that the S1 CREST condition had the highest pre-test scores on all self-regulated processes and motivational measures (with the exception of test anxiety), no significant pre-test group differences were found. Therefore, the results of the present study reject the first research prediction and suggest that any developments in self-regulated processes and related motivations in the S1 CREST condition who participated in the CREST programme the previous year were not retained.

The lack of longer-term retention effects reported in Study 3 in terms of the results relating to the S1 CREST condition, are however, in line with the findings documented by Montalvo and Torres (2004), who suggest that it is necessary for students to have frequent opportunities to practice any developed self-regulated learning strategies through being given opportunities in the classroom in order to maintain them over time. Glaser and Brunstein (2007) also adopt this view and suggest that explicit self-regulation instruction is needed for lasting effects of writing interventions targeted at performance. Extending these results further, it might also be necessary for students to practice self-regulated strategies outside the classroom as research has shown that teachers and parents can foster autonomous motivation by giving students opportunities to be autonomous in their learning and have psychological freedom (Vansteenkiste *et al.,* 2009).

The results relating to Research Question 1 may also be explained from another perspective. As the nine-month delayed post-test was the first measurement obtained for the S1 CREST condition, it is not possible here to understand whether these students experienced any significant change in self-reported levels of self-regulated processes and related motivations measured immediately following CREST participation.

Similar analyses were also run to explore differences in teacher rated self-regulated learning among the three groups in order to understand if any changes in teacher perceptions of student self-regulated learning developed following CREST programme participation were retained at the nine-month delayed post-test for the S1 CREST condition. As with the student self-report results, while the trends in the teacher data indicated that the group of students with previous CREST experience (S1 CREST) had higher teacher ratings of self-regulated learning, no significant group differences were found. These results therefore also reject the first research prediction relating to retention effects from the teachers' perspectives (1B). However, as with the student data results presented earlier, it is also possible that teachers' perceptions did not change following CREST programme participation and therefore, there were no developments to retain. Further research collecting more data from the S1 CREST condition is needed in order to generate stronger conclusions regarding this effect. The shorter-term (three-month) retention effects for the S2 CREST condition will be discussed later relating to the third research question of the present study.

6.5.2 RQ 2A: Investigating Group Differences in Pre- to Post-test Change Using Student Data

Section *6.4.5* of the results above reports the findings of the analyses that were conducted to address the second research question. This second research question refers to whether students in the S2 CREST condition taking part in the CREST programme during the course of the study experienced significantly different changes at immediate post-test in their self-reports compared to the other two groups. The results relating to self-regulated processes showed that the three groups were significantly different in their pre- to post-test change scores. While the S2 CREST condition, who took part in the CREST programme during the course of the study, experienced significant increases in their self-reported levels of self-regulation, the other two groups decreased. These results are in line with the research prediction that students in the S2 CREST condition would experience positive changes in the outcome measures, providing support for the influence of the CREST programme on students' self-reported levels of self-regulation at immediate post-test.

While studies have documented increases in self-regulation following intervention programmes, several are limited due to the lack of appropriate control groups (Butler, 1998). As the present study followed a quasi-experimental design including two intervention conditions (S2 CREST & S1 CREST) in addition to a control group (No CREST), the threats to the external validity of the results are reduced. The above results contribute to the debate in current educational literature as to whether direct strategy instruction is necessary for the development of self-regulation in young students. Some researchers believe that strategy instruction needs to involve teachers modeling behaviours as well as explicitly explaining the strategies, how to use them, and what skills are required from the student (Boekaerts & Corno, 2005; Zimmerman, 2008). The present findings provide evidence against researchers possessing the view that self-regulation cannot be developed by exposing students to active learning environments, and that explicit strategy instruction is necessary (Hartman, 2001; Kramarski & Michalsky, 2009; Schraw *et al.,* 2006). The results presented here however, substantiate previous research findings on the other side of the debate, suggesting that curriculum embedded self-regulated learning interventions can lead to improvements in self-regulation among students (Butler, 1998; Perels, Gurtier, & Schmitz, 2005). Study 3, along with Studies 1 and 2, suggest that by creating an environment in the classroom that fosters self-regulation, students can develop these learning processes further.

As significant increases were predicted and observed for students in the S2 CREST condition who were participating in the CREST programme at the time of Study 3, it was expected that group differences might also be observed on the related motivational constructs measured. However, the findings reported earlier in Section *6.4.5,* showed no significant differences between the three groups on self-efficacy, intrinsic motivation, test anxiety, and career and overall science motivation change scores. As these results were present for both the MSLQ and the SMQ on several of the variables, further support for the internal validity of these findings is provided.

The findings above relating to these motivational constructs are surprising considering the significant changes documented in both Studies 1 and 2 relating to these motivational constructs measured. However, De Corte and colleagues (2004) conducted a similar intervention study in mathematics with 5^{th} grade students receiving the intervention from their classroom teachers and found only small effect sizes relating to related motivations. De Corte *et al.* (2004) suggested that even young students have years of experience in traditional classrooms that may need to be deconstructed before the potential benefits of new environments for learning can be realised. In addition, considering that smaller effect sizes are common in studies including a control group in the research design (Hattie, Biggs, & Purdie, 1996), the non-significant findings may also be explained by the tight control achieved in the present research design, which involved two intervention conditions (S1 CREST & S2 CREST).

These results are, however, not in line with research suggesting that changes in self-regulation are associated with changes in related motivations (Ahmed, Van der Werf, Kuyper, & Minnaert, 2013). Study 3 results relating to these motivational constructs are also not in line with research that has documented increases in self-efficacy and intrinsic motivation in students following participation in interventions aimed at developing self-regulated learning (Fuchs *et al.,* 2003; Stoeger & Ziegler, 2005, 2008, 2010). However, with regards to these non-significant findings, it is possible that in the broader sense, students do increase in these related motivations, but not with regards to their learning specifically in science. While they may not be experiencing significant changes in their self-efficacy and motivations towards their science learning, they might be becoming more confident and motivated as a result of CREST participation in their other school subjects. However, further research incorporating classroom data from other school subjects is required to investigate this possibility.

In addition, as explained in relation to Study 1, the CREST programme presents a unique and challenging learning situation to students who may not be experienced in dealing with this amount of control for their learning. As a result, it is possible that students have low self-judgments of their abilities in science immediately after taking part in CREST, and that any benefits related to improved self-efficacy would only be seen on the delayed post-tests. Results from the delayed post-tests showed that students in the S2 CREST condition, who participated in the programme during the course of the study, increased in their self-reported levels of self-efficacy three months after taking part in the CREST programme, while the other two groups decreased (S1 CREST & No CREST). It is therefore possible that participation in the CREST programme does influence the development of self-efficacy among students, but that these benefits may take time to surface.

As with Study 1, the analyses included in Study 3 also involved controlling for student academic performance marks at the beginning of the study. In each of the analyses carried out on the outcome variables included in this study, no significant interaction was found for pre-test academic performance. In other words, the amount of change experienced on each variable measured was not related to student pre-test academic performance marks. Additionally, for the group of students taking part in CREST during the course of this study (S2 CREST), the benefit experienced (measured by change scores on the outcome measures) was not predicted by their academic performance marks at the beginning of the study. Replicating the findings of Study 1, these results provide further support for the utility of the CREST programme, as students from a wide spectrum of achievers in science classrooms can benefit from participation. These findings relating to academic performance also have implications in terms of implementation strategies for the CREST programme, as they reveal that the programme does not need to be targeted towards lower-achieving students.

6.5.3 Contextualising Change Scores: Validation of RQ 1A

While *change* score analysis was deemed appropriate in order to address the specific research questions for the present study (as well as Studies 1 & 2 presented in Chapters 4 & 5 of this thesis), additional analyses were conducted to provide further insight into the nature of the changes experienced. While change score results may show that students in the three groups differed significantly in their pre- to post-test change scores on certain measures, it is important to understand and contextualise these scores among students relating to their pre-test levels on the self-report measures. The contextualisation analyses presented in Section *6.4.6* of this chapter therefore explored whether students who began with higher pre-test self-reports experienced smaller gains than students who came into the study with lower self-reports on the variables measured (as documented in the correlational analyses in Chapter 4 Section *4.4.1*). The results from these analyses demonstrated that students with low pre-test self-reported levels on the self-regulated processes and related motivational variables measured, experienced significantly larger gains than students who reported high and medium self-reported levels for the constructs at pre-test.

Research has documented that differences in intervention effects may be related to pre-test self-reported levels of the constructs that interventions are trying to change, however the results are mixed (Van Horn *et al.,* 2008). Hu and colleagues (2011) found that medium scorers at pre-test received the most benefit from thinking skills interventions based on metacognitive and self-regulated learning theories. The meta-analysis of self-regulated learning intervention studies conducted by Hattie *et al.* (1996) similarly showed that student ability influenced the impact they received among the 51 studies investigated. These researchers concluded that the effect sizes for performance, study skills, and affect were largest for the medium ability group. In contrast, Young (1996) reported that students low in self-regulated learning experienced less gains than medium and high self-regulating students following participation in a programme aimed at developing self-regulated learning. The results presented in Study 3 are not in line with any of the above research findings.

The findings of the present study are however in line with research looking at general academic performance, as well as self-regulated learning interventions, documenting that higher scoring students make lower gains than lower and middle achieving students (Chiu 1998; Wright, Horn, & Sanders, 1997). Wright and colleagues (1997) explained the possibility that higher achievers were not challenged enough as the focus of classes was on lower achieving students. The present results may therefore highlight the need for special programmes to be designed and targeted for students demonstrating high and medium levels of self-regulatory and motivational processes in order to ensure that they are pushed even further and obtain the same benefits experienced by students beginning the programme with lower self-reported levels on these variables.

However, these results may be interpreted in several different ways; each providing different sets of implications for practice. Intuitively, the results discussed above are obvious as students who are already demonstrating high levels of regulatory processes and who possess strong motivations for their learning in science, may not have room to develop these skills further as they are already functioning at ceiling level on these variables. However, these results may also be explained in relation to the specific self-report measures used in Study 3. If a student indicated a score of 5 on a 5-point question at pre-test, they may also indicate a 5 on the post-test even if they felt they had developed on the measure throughout the study. Therefore, it is possible that students at the top end of the self-regulatory and motivational spectrums were not able to report the increases they felt they had experienced at post-test. From this perspective, the present results may suggest that the CREST programme does not need to be administered or targeted to specific groups of students as benefits are provided to students demonstrating lower self-regulatory processes and motivations, and no significant detriment was observed for students at the middle and higher ends of the spectrum. This explanation implies that the results documented here were due to the limits of the particular measurement instruments included in the study design and not underlying student differences on pre-test scores. And finally, statistical regression to the mean should not be ignored as a possible explanation for the observed pattern of results in this contextualisation analysis.

6.5.4 RQ 2B: Investigating Group Differences in Pre- to Post-test Change Using Teacher Data

In order to address the second aspect of the second research question, an analysis of covariance was conducted on the pre- to post-test change scores of the teacher self-regulated learning for the three groups, controlling for pre-test academic performance. The results showed no significant differences between the three groups immediately following CREST programme participation. This result was not in line with the research prediction that the group participating in the CREST programme during the study (S2 CREST) would have higher post-test teacher ratings of self-regulated learning than the other two groups not participating in the programme at the time of the study (S1 CREST & No CREST). The lack of significant correlations between post-test teacher and student ratings reported in Table 6.13 on page 196 provides additional support for this finding. Therefore, while students reported that they were demonstrating higher levels of self-regulation in the science classroom immediately after taking part in the CREST programme (as presented in the previous results section), this development was not perceived by the teachers involved in the present study.

As students gain control in the classroom through conducting CREST investigations, which aim to answer a scientific question that is personally relevant to them, teachers need to facilitate this learning by supporting students in the development and utilisation of effective strategies. However, it is possible for an individual student to self-regulate toward his or her own criteria and personal goals, which may be different from the teacher's set of perceived goals (Winne, 1995). While the students may indeed be self-regulating, it is possible that they are not regulating the way in which teachers intend them to or in the particular direction to achieve the goals assumed by the teacher. This may explain the absence of a correlation between teacher and student self-reports of self-regulated learning at immediate post-test.

While the corroboration of teacher and student perceptions of self-regulated learning may have strengthened the validity of the measurement tools utilised, as well as the thesis findings presented thus far, the lack of agreement between teacher and student reports of self-regulated learning provide important insight into the particular measurement tools employed and contribute to literary discussions regarding self-regulated learning theories. Different results from the teachers' perspectives may also highlight the difficulty for teachers to measure and quantify internal processes such as self-regulation and motivation among their students while also exposing the difficulty for students to perceive and record these internal processes within themselves.

6.5.5 RQ 3: Investigating Group Differences in Overall Change Using Student Data

As a third research question, this study explored whether any developments in the self-regulated processes and related motivational variables measured were retained three months following CREST programme completion. To achieve this, analyses of variances were conducted looking at the pre-test to delayed post-test change scores for the three groups included in the study. Results relating to self-regulation addressing the second research question, discussed earlier in Section *6.5.2,* demonstrated that students in the S2 CREST group experienced significant increases in their levels of self-regulation from pre-test to immediate post-test. Aligning with the third research prediction that any developments would be retained three months following CREST participation, the results presented in Section *6.4.8* showed that overall, students in the S2 CREST group experienced significant increases in self-regulation from pre-test to delayed post-test while students in the other two groups (S1 CREST & No CREST) experienced decreases throughout the course of the study. In other words, three months after taking part in the CREST programme, students in the S2 CREST group retained the higher levels of self-regulation they had developed through participating in the CREST programme.

In a meta-analysis looking at 95 studies of self-regulated learning in maths, reading comprehension, writing, and science in primary and secondary schools, De Boer, Donker-Bergstra, and Kostons (2012) found only 17 studies that demonstrated long-term analyses of retention effects. The infrequency of studies reporting longer-term retention of intervention effects highlights the importance of the results presented in the present chapter relating to Study 3. With delayed post-tests on average 12 weeks after the intervention took place, De Boer *et al.* (2012) discovered that maintenance effects were actually higher than the immediate post-test results in several of the self-regulated learning interventions included. The results of Study 3 are in line with the findings documented by De Boer *et al.* (2012), as the effect size for self-regulation at three-month delayed post-test ($\eta\rho^2$ =.078) was larger than at immediate post-test ($\eta\rho^2$ =.066).

The delayed post-test results for the related motivational constructs showed that the three intervention conditions (S2 CREST, S1 CREST, & No CREST) did not differ in their self-reported changes on these measures from pre-test to delayed post-test. However, as no significant group differences were reported relating to the motivational variables measured in the present study, the non-significant results relating to these variables from pre-test to delayed post-test are not surprising.

6.5.6 RQ 3B: Investigating Group Differences in Overall Change Using Teacher Data

The above analyses were repeated on the pre-test to delayed post-test change in teacher ratings of student self-regulated learning in order to test the prediction that any changes in teacher ratings would be maintained three months after completion of the CREST programme. The results from the analysis of variance conducted showed no group differences regarding changes in teacher ratings of self-regulated learning, which was not in line with the research prediction made at the outset of the study. Therefore, the overall significant increases seen from the student self-report results were not mirrored on the teacher ratings of self-regulated learning. However, teacher ratings did increase the most in the S2 CREST condition who experienced the programme during the course of the study.

As with the immediate post-test teacher results presented and discussed earlier, the different results from the teachers' perspectives may expose the difficulty for teachers to measure and quantify internal processes such as self-regulation among their students, while also exposing the difficulty for students to perceive and record these internal processes within themselves. As these results were more in line with the research predictions than the teacher results at immediate post-test, one possible explanation for this finding is that teachers become more comfortable with the measure and are more able to match student perceptions as time goes on throughout the school year. However, through speaking with teachers in a post-study debrief, it was apparent that the teachers involved in the present study perceived students as maturing over the course of the academic year, and the results for teacher rated self-regulated learning may be due to this fact. Additionally, it is difficult to ask teachers to rate an instantaneous process when the measure used is relative to a recent time period.

6.5.7 The Relationship Between Teacher Ratings of Self-Regulated Learning and Student Self-Reports on Related Motivational Constructs

The present study also explored the correlations between teacher rated self-regulated learning and the other related motivational constructs measured. The findings presented in Table 6.13 on page 196 provided further support for the lack of agreement between the student and teacher data relating to changes in self-regulated processes from pre-test to post-test, as no significant correlations were found between teacher ratings at post-test and student self-reports of self-regulation. However, while the results between teacher and student self-reports do not appear to agree relating to self-regulated learning and self-regulation in the science classroom, significant positive correlations were found between teacher ratings of self-regulated learning and student self-reports of self-determination, self-efficacy, and intrinsic motivation.

One possible explanation for this finding could be that when teachers are judging self-regulated learning among their students, they may actually be looking at these related motivational variables. In other words, when teachers try to determine the extent to which students are regulating their own learning in the science classroom, they may actually be judging self-determination, self-efficacy, and intrinsic motivation. In addition, teacher ratings of self-regulated learning were negatively correlated with student self-reports of test anxiety. In line with the other motivational variables just discussed, it is possible that when attempting to evaluate self-regulated learning among their students, teachers view students who demonstrate more anxiety towards taking tests as showing less self-regulation.

These results also demonstrate the possibility that these motivational variables are more externally visible to teachers compared to self-regulated learning, which is sometimes interpreted in the literature as an internal process. While part of self-regulated learning is the ability to monitor and regulate one's surroundings, it is possible that it is too internal to be seen by teachers who are not trained as educational researchers studying observational methods for self-regulated learning.

These correlational findings highlight the potential difficulty of using observational measures of student self-regulation in natural classroom settings by classroom teachers, and the importance of training teachers to measure these constructs among their students.

In addition, the correlational results showed that at three-month delayed post-test, the teacher and student self-report results were significantly correlated, providing further support for the finding that the S2 CREST condition had the largest increase in teacher self-regulated learning ratings. In debriefing sessions with the teachers involved in this study, the possibility that teachers get to know students over the course of the year was discussed. This suggests that teachers become more familiar with what 'self-regulated learning' entails through participation in the CREST programme and therefore report more occurrences of regulatory processes. It is also possible that students naturally progress through the academic year and develop self-regulated learning skills that teachers can see. However, the results relating to retention effects using the student data, which are in line with published research findings, did not demonstrate that students in all three groups increased in levels of self-regulated learning, making this explanation unlikely.

It is interesting to also note that the majority of significant correlations in the separate group analyses at pre-test and post-test came from the No CREST condition (rows 10 & 11), and that this pattern was maintained before and after participation in the CREST programme. This removes the possibility that both teachers and students taking part in CREST are more aware of these perceptions than students not taking part in the CREST programme at the time of the study. This also suggests that teacher variation may be an issue and highlights the importance of replicating this research with a larger sample of students.

6.5.8 Methodological Limitations and Future Research

As with the previous two empirical chapters presented in this thesis (Chapters 4 & 5), the present study does not escape the limitations of quasi-experimental research conducted in natural classroom settings. While several of these limitations were discussed in Chapter 3 Section *3.3.2*, some additional methodological considerations will be discussed before concluding this chapter and outlining the thesis implications of the results presented in this final empirical chapter.

In addition to the limitations regarding student self-report measures, the generalisability of the study results is limited to the particular school setting and student year-group included in Study 3. However, through replicating some of the trends reported in the previous two studies presented in this thesis (Chapters 4 & 5), the generalisability of the results presented in this chapter may be widened. As with Studies 1 and 2 presented in this thesis, school contamination may also be an issue for the present study, as students in the two intervention conditions and the control group attended the same school. Another limitation of Study 3 relates to the academic performance marks that were included in the analyses as covariates. While it is appreciated that a more complete picture of assessment (including investigation/lab marks, daily quizzes, as well as presentation and homework marks in other science subjects) would be desired, the performance marks available were utilised. It was decided that this initial test was sufficient to obtain a general sense of student ability in science and contribute to the internal validity of this study.

While the results discussed in this chapter provide support for the influence of the CREST programme on students' levels of self-regulation, as with Studies 1 and 2, it is not possible in the present study to unpack which aspects of the CREST programme contributed to the changes seen on the measured outcome variables in the present study. Similar issues have been documented in intervention studies regarding the difficulty in determining which aspects are necessary for improvements (De Corte *et al.,* 2004; Glaser & Brunstein, 2007; Williams & Binnie, 2003). Further observational and quantitative research is needed in order to fully address this issue. However, De Corte and colleagues (2004) state that the high degree of ecological validity is defensible and appropriate when looking at evaluating a classroom curriculum-embedded programme.

As with the other questionnaires used in this thesis, the teacher self-report questionnaire administered does not escape the limitations of other self-report measures. Similar to the researchers who developed the measure used in this study, the present research was conducted under the assumption that teachers are able to observe students' use of several self-regulated learning strategies as well as the outcomes of students' use of these strategies. It is possible however that this assumption was not met, which would provide further threats to the internal validity of this study. In addition, considering that observer bias in the teacher measures of self-regulated learning has been documented recently in the literature (Matthews *et al.,* 2009), appreciating that these biases may have affected the results presented in this chapter seems appropriate. Even further, as teachers' post-test questionnaire responses were retrospective, it is possible that post-test results may have included their perceptions of the results of their implementation of the CREST programme (Rozendaal *et al.,* 2005). In regards to the method that teachers used to measure the self-regulatory processes among their students, it is also possible that the teachers were rating students based on the norms of other students in a ranking process, which would also affect the validity of the results presented in this chapter.

This study has documented fascinating discrepancies between student and teacher self-reports of the impact of the CREST programme on self-regulation. Future research incorporating teacher data as a control in variance analyses in order to investigate which students are further away from the teacher measures may provide insight into this issue. The results of the present study have highlighted the difficulties of administering this measure to teachers and the importance of either developing teachers' understandings of the constructs further before administering the questionnaires, or having trained researchers make the observations directly. Incorporating observational measures completed by parents into the study design may provide further insight into the results presented in this study. A final limitation of this study is due to the small sample size of 12 teachers involved. While the student data from each teacher is considerable, variation is expected between and within teacher measurements at the three different time points, and may have contributed to the results presented in this chapter.

6.6 CHAPTER SUMMARY AND CONCLUSIONS

The primary aim of this chapter was to present results from the last of the three empirical studies included as part of this thesis. The purpose of Study 3 was to investigate the impact of the CREST programme on students in a different school setting, building on the results of both Studies 1 and 2. Through implementing a more rigorous quasi-experimental research design using two intervention conditions and one control group with immediate as well as three-month delayed post-test data, the results documented both the immediate and longer-term impact of CREST participation on students' self-reported levels of self-regulation.

In addition to investigating changes in student self-reports, the present study also aimed to explore changes in teachers' perceptions of students' self-regulated learning through CREST participation. By collecting data from the 12 teachers involved for each of their students at three time points, this study investigated the changes in student self-regulated learning from the teacher perspective, contributing to an area not yet explored in the literature. The group differences regarding changes in student self-reported self-regulation were not matched when looking at the teacher self-regulated learning results at both immediate post-test and delayed post-test. However, delayed post-test results indicated that the largest increase was found in the S2 CREST group that experienced the programme during the course of the study. By also investigating the correlations between teachers' ratings of self-regulated learning and the other related student self-reported motivational variables measured, additional insight into the relationship between these variables and the potential difficulty for teachers to quantify self-regulated learning among their students was gained.

6.6.1 Thesis Implications

Through replicating some of the findings and trends documented in Studies 1 and 2, Study 3 has provided further support for the practical utility of the CREST programme as a strategy to promote self-regulation among science students. The research presented in this chapter has also addressed several issues highlighted in the literature as needing further research. Firstly, this study investigated the retention of developed self-regulation among adolescent students specifically within a science inquiry-based learning context; exposed as an area needing more research attention. Additionally, as major career and educational decisions are made during the school years (Steffens, Jelenec, & Noack, 2010), understanding the potential impact of strategies aimed at developing these self-regulated processes and related motivations in young students is an important contribution to knowledge in this field of educational research. The difficulty and complexity of creating environments that promote these processes among young students further highlights the importance of understanding how to appropriately support teachers in conducting these learning tasks with their students (Boekaerts & Niemivirta, 2000).

The next, and final, chapter of this thesis presents a comprehensive discussion of the key findings of the three studies presented (Chapters 4, 5, & 6) in relation to relevant literature (Chapters 1, 2, & 3). Going beyond merely repeating the discussions presented thus far relating to each of the three empirical chapters, the final chapter aims to bring together the empirical findings in order to provide further insight into their direct implications for theory, policy, and practice.

7

General Discussion:
A Synthesis of Empirical Findings and Implications

Chapter Objectives

This final chapter aims to synthesise the findings across the three empirical studies (presented in Chapters 4, 5, & 6) in order to understand the overall impact of the results and the distinctive contributions they offer. Through bringing the key findings together, this chapter will begin by highlighting some broad themes that have emerged from the results presented. The issues that have arisen from the results also have several theoretical, practical, and policy implications. As such, a secondary aim for this chapter is to present an overview of the impact of the research presented with a focus on drawing conclusions regarding specific recommendations for the CREST programme. The chapter will then conclude with a critique of the methodology and a discussion of some future research needed before drawing final conclusions.

7.1 INTRODUCTION

As previously discussed, much self-regulated learning research has taken a cross-sectional design approach and there are few studies documenting changes in students' self-regulated learning within natural classroom settings. In addition, recent downward trends in self-regulated processes and related motivations documented among young science students highlight the need for research in this field to be targeted at investigating viable strategies to develop these constructs in a science-learning context (Archer *et al.,* 2010; Awan *et al.,* 2011; Bennett & Hogarth, 2009; Van der Veen *et al.,* 2005). As such, the overarching aim of this thesis was to investigate the impact of a curriculum-embedded inquiry-based learning programme - *the CREST programme* - on students' self-regulated processes and related motivations toward their science learning. In order to achieve this, the CREST programme was situated within a framework of self-regulated intervention research (Chapter 2) and a series of three empirical intervention studies employing controlled quasi-experimental designs (Chapter 3) were conducted (Chapters, 4, 5, & 6).

While Study 1 was concerned mainly with the differences in changes in students' self-regulated processes and related motivations immediately following participation in the programme compared to a control group, Study 2 also focused on looking at class differences in response to programme participation. Study 3 included in this thesis built on the findings that came from the previous two empirical chapters and looked at longer-term retention effects within a more complex experimental design involving two intervention conditions, as well as teacher data.

The self-regulatory process constructs investigated across the three empirical studies were self-regulation, self-regulated learning, self-determination, and cognitive strategies use (see Chapter 1 for the conceptual framework). The research presented also explored some related motivational constructs within the framework adopted including self-efficacy, intrinsic motivation, test anxiety, science-specific career motivation, and overall science motivation (Chapter 1). The next section will present a comprehensive overview of the key findings of the research conducted and will be structured according to the above constructs measured in the three empirical studies.

7.2 Summary of Key Empirical Findings

This section will present a summary of the key findings across the three empirical studies and discuss the consistency of the results presented, providing explanations, where appropriate, in relation to relevant research in the area. In addition, implications relating specifically to the CREST programme will be outlined in this section among the discussions of the key empirical findings.

7.2.1 The Impact of CREST Programme Participation on Self-Regulated Processes

Self-Regulation and Self-Regulated Learning

The task of creating environments in the classroom that promote and encourage self-regulated learning for a range of different learners, each with individual needs, is complex, even for experienced teachers (Zumbrunn, Tadlock, & Roberts, 2011). Self-regulation is additionally hard to achieve in classrooms as a learning episode has to take place where the student is given enough motivation to begin the process in order to engage in the activity, but also be provided with appropriate support while they work towards personally set goals (Boekaerts & Niemivirta, 2000). Through placing a curriculum-embedded inquiry-based learning programme currently being implemented in classrooms throughout the UK within the context of self-regulated learning intervention and science education research (Chapter 2), it was predicted that CREST participation would increase students' self-reported levels of self-regulation and self-regulated learning in each of the three empirical studies conducted.

One of the most prominent findings documented across the three studies presented in this thesis was the influence of participation in the CREST programme on students' self-reported levels of self-regulation and self-regulated learning. As predicted, the three studies together documented significant increases in these constructs from pre-test to post-test for students taking part in the programme that were not observed in the control group. The magnitude of the effect relating to self-regulated learning was large in both Study 1 and Study 2, while no effect was found relating to self-regulated learning in Study 3. For self-regulation, while no significant increases were reported in Study 1, large and medium effects were seen in Studies 2 and 3. Together, these results suggest that giving students the opportunity to control and evaluate their learning and work collaboratively with peers toward personally set goals appears to influence their ability to self-regulate their learning in science.

It is necessary at this point to translate what these effects mean for teachers and why they are impressive in the context of the three studies presented in this thesis, as well as the wider literature in the area. Considering the above results in the light of downward trends in self-regulation and self-regulated learning over a school term, as reported by Berger and Karabenick (2011), highlights the potential significance of these findings. In more technical terms, the research evidence outlining that smaller effect sizes are documented in controlled studies that use standardised measurement tools underlines the statistical significance of these results for educational practice (Chiu, 1998; Hattie *et al.*, 1996, 2009). Finally, as Hattie and colleagues (1996) outlined that medium effect sizes (d=.4) should be used as a benchmark for discussing research findings as educationally significant, the practical implications of the work presented in this thesis are clear.

In addition to discussing the educational significance of the effects sizes reported above, it is important to discuss why the results were different across the three empirical studies presented. Firstly, why were results significant for self-regulated learning in Studies 1 and 2 and not in Study 3? Equally, how can the lack of significant findings relating to self-regulation in Study 1 be explained when significance was reported in the other two empirical studies? It was discussed in Chapter 4 Section *4.5.1* that the lack of significance on the MSLQ self-regulation scale in Study 1 could be due to the fact that the FCSSR self-regulated learning measure is more sensitive as it has an entirely self-regulated learning focus. However, the results from Study 3 documenting significant impact relating to self-regulation on the MSLQ with no significance reported for self-regulated learning on the FCSSR, suggests the unlikelihood of this explanation. As outlined in Chapter 3, the self-regulation scale on the MSLQ includes components of metacognitive strategies as well as management and control of effort, while the FCSSR self-regulated learning scale includes items relating to planning, monitoring, and modifying metacognitive strategies. It is therefore possible that students in Study 3 also developed more capacity to manage and control their efforts on tasks. However, a deeper understanding is needed through future research in order to appreciate the multifaceted nature of self-regulatory processes and the specific aspects of the constructs being measured by each tool available in the literature.

Secondly, it is important to discuss possible explanations for the presence of large effects in both Studies 1 and 2 while only medium effects were reported in Study 3. While these results may be explained by the particular research design of each of the three studies, with the lack of an appropriate control in Study 2 and the tighter control provided in Study 3 with two intervention conditions, considering the results in relation to relevant literature may provide further insight. Dignath and Büttner (2008) conducted research investigating the influence of the length of similar interventions in maths and found that interventions with more sessions had an increased impact on academic performance in both secondary and primary schools. Considering the findings presented in this thesis in relation to this research may provide some insight into the larger effect sizes found in Study 2 (total of ≅22 hours on CREST) compared to both Studies 1 (≅10 hours) and 3 (≅12 hours). In addition, Chiu (1998) found that less intense interventions were more effective (with intensity measured as the average number of days a week spent participating in the programme). From this perspective, it would be expected that Study 3 (12 sessions over 12 weeks) would have larger effect sizes than both Study 1 (10 sessions over 5 weeks) and Study 2 (24 sessions over 8 weeks) and considering the additional control provided in Study 3, this explanation is possible.

The above interpretation provides support for teachers and administrators to conduct the CREST programme over longer periods of time instead of condensing the programme and shortening the implementation period. It is necessary however to understand that this might provide important limitations regarding the nature of the student investigations possible. However, Haller *et al.* (1988) reviewed 20 studies with school children between grades 2 and 12 (aged 6-18) developing metacognitive strategies and found that instruction even as short as 10 minutes per lesson was effective in increasing reading comprehension. Therefore, it may be more effective to have less intense CREST programme work and structure sessions as only a small component of the classroom period over several weeks. This section will now move on to discuss the other two self-regulated process constructs measured in this thesis.

Self-Determination and Cognitive Strategies Use

As outlined in Chapter 1 Section *1.5*, self-determination was included in the framework for understanding student self-regulatory processes in this thesis as it has been shown to be an important factor in fostering self-regulated learning (De Bilde *et al.,* 2011; Deci *et al.,* 1991; Greene & Azevedo, 2007). As with self-regulation and self-regulated learning, it was predicted in each of the three empirical studies that self-determination would also increase following participation in the CREST programme. The final construct included among the self-regulated process variables was cognitive strategies use. As the CREST programme does not involve direct instruction of cognitive strategies, it was hypothesised that smaller increases would be observed in the cognitive strategies use measure included.

While Study 1 reported large effects relating to self-determination and showed that CREST students experienced no changes in self-reported levels of the construct while the control group decreased significantly, Study 2 reported small effects demonstrating that the students taking part in CREST experienced significant increases while a reference class showed no change. In contrast, no significant differences were found between the groups in Study 3 regarding changes in self-determination from pre- to post-test. Again, the lack of significant findings relating to self-determination in Study 3 may be explained by the tighter control provided by the study design. Further, while no significant increasing trends were documented in Studies 1 and 3, remembering the downward trends reported in the literature relating to self-regulated processes and motivation (Berger & Karabenick, 2011; Fredricks & Eccles, 2002; Ryan & Deci, 2000), it is possible that decreases in self-determination are also likely over the course of a school term without intervention, and that CREST reduced these decreases.

Relating to cognitive strategies use, no significant findings were documented across the three studies. As stated above, due to the nature of the CREST programme, large significant changes relating to this construct were not expected. However, an alternative explanation is possible considering these results in relation to the work conducted by Van der Veen and Peetsma (2009). While these researchers reported values for cognitive strategies use on the MSLQ between 2.5 and 3.5 rated on a 7-point scale, the values reported across the empirical work presented in this thesis were between 4.2 and 5.3. These results may suggest that the students attending the three schools involved in the research presented may be generally using more strategies even before coming into the intervention and therefore, may have less scope to improve. The results from the change score contextualisation analyses presented in Chapter 4 Section *4.4.1* and Chapter 6 Section *6.4.6* may therefore provide insight into the lack of significant findings relating to cognitive strategies use across the three studies. As the contextualisation analyses reported that students on the higher end of the self-reported scales coming into the studies experienced less development compared to students at the lower end, the relatively high values reported may explain the lack of significant increases documented. These contextualisation analyses as well as the finding that academic performance at pre-test had no influence on the amount of change experienced by the students, also have implications relating to CREST administration strategies that will be discussed further when outlining specific recommendations for the programme.

7.2.2 The Impact of CREST Programme Participation on Related Motivations

Self-Efficacy and Intrinsic Motivation

It has been highlighted in the literature that self-efficacy and intrinsic motivation are important factors in students' abilities to regulate their learning and that they have high predictive power in relation to self-regulatory behaviour, as they determine both what goals are set and how they are attained (Chularut & DeBacker, 2004; Gaskill & Hoy, 2002; Greene & Azevedo, 2007; Miller & Brickman, 2004; Pintrich, 1999, 2003). These related motivational constructs were therefore included in the theoretical framework outlined in Chapter 1 Section *1.9*. As research has shown that participating in open-inquiry learning activities, giving students opportunities to be autonomous in their learning and have psychological freedom, can increase intrinsic motivation and self-efficacy, it was predicted that CREST participation would also have this effect (Dillon, 2008; Vansteenkiste *et al.,* 2009). However, due to the complexity of the relationships between these constructs and the self-regulated processes measured, these research predictions were made tentatively.

Results presented in this thesis showed that while no significant effects relating to self-efficacy were found in both Studies 1 and 3, significant increasing trends were documented in Study 2 for students participating in the CREST programme. Significant increasing trends were also found in Study 2 relating to intrinsic motivation, while Study 3 reported no effects for this motivational variable. In contrast, Study 1 showed group differences for intrinsic motivation change scores from pre-test to post-test with no changes noted in the CREST group but significant decreases found in the control. While the inconsistency of these results may be explained by the lack of an appropriate comparison group of equal size (n=160) for Study 2, it is important to consider them in relation to available research in the area.

As research has highlighted the domain-specific nature of these motivational constructs, the research presented in this thesis included measures of domain-specific science self-efficacy and intrinsic motivation. In relation to the inconsistency across the three studies regarding these constructs, it is possible that students in Studies 1 and 3 developed self-efficacy and intrinsic motivation toward their learning in other school subjects that were not measured. In addition, as the self-evaluation aspect of self-regulated learning programmes has been highlighted as playing a crucial role in developing high self-efficacy (Schunk & Ertmer, 2002; Zimmerman, 2000), it is possible that students in Study 2 performed more evaluation and self-monitoring behaviours than students in both Studies 1 and 3.

Another explanation for the inconsistency of the findings across the three studies relating to self-efficacy and intrinsic motivation, may be due to how interested the students were in performing their CREST projects and how much success they perceived. Students are like scientists in that their self-regulated learning research has limitations, and task-difficulty perceptions are among these limitations (Winne, 1997). Research has shown that providing students with opportunities for success and ensuring that students find tasks personally meaningful, influences the development of self-efficacy and intrinsic motivation (Pintrich, 2003; Schunk & Miller, 2002). Specifically in a science-learning context, giving students more responsibility, and providing them with opportunities to plan and evaluate their learning and develop practical skills in science, builds self-confidence and subject interest and can help maintain high levels of self-efficacy and intrinsic motivation (Black & Deci, 2000; Pintrich, 2003; SCORE, 2009). Researchers have additionally highlighted the importance of ensuring that work is challenging enough for students in order to keep them engaged, but also ensuring that tasks are not overly difficult preventing success which, could result in a potentially negative learning situation (Pintrich, 2003; Urdan & Schoenfelder, 2006; Velayutham *et al.,* 2012; Whipp & Chiarelli, 2004).

Considering the literature above, it is possible that significant increases were not seen in either of Studies 1 or 3 relating to these constructs due to the fact that the students did not perceive enough personal interest in their projects and that the CREST programme was too challenging for them. In contrast, students in Study 2 may have been provided with more choice regarding their investigations and were therefore more personally engaged in their projects. In addition, as students in Study 2 participated in the CREST programme later in the year compared to students in both Studies 1 and 3, it is possible that Study 2 students had more science investigation experience and therefore, more confidence for their learning in science.

Further support for this explanation is provided by research evidence showing that past performance has the most powerful influence on these motivational constructs (Urdan & Schoenfelder, 2006). This explanation may highlight the importance of early inclusion of self-regulated learning and autonomy promoting learning opportunities in the classroom, providing support for the work Whitebread and colleagues (2009) are conducting to integrate these strategies in primary students.

These results also highlight the potential benefits that may be seen through the addition of the new *CREST Star* programme aimed at primary school students between the ages of five and 11 years.

Test Anxiety

It has been argued that affective factors have been neglected in research on learning and instruction (Boekaerts & Boscolo, 2002). In contrast to the confidence that can come from developments in self-efficacy and intrinsic motivation, student anxiety towards taking tests has been a topic of recent concern (Pekrun *et al.,* 2002). The results from Study 1 showed that CREST students significantly increased in levels of self-reported test anxiety compared to control students. Rozendaal *et al.* (2005) similarly found that self-regulated learning-based innovation programmes may not be able to solve student problems with anxiety. Research has documented that test anxiety is influenced by situational factors including low confidence, heightened self-awareness, and low preparation (Kurosawa & Harackiewicz, 1995; Zohar, 1998). As results for self-regulated learning in Study 1 demonstrated that participation in CREST makes students more aware of their learning, this elevated awareness might help explain the increase observed in students' levels of test anxiety (Kurosawa & Harackiewicz, 1995; Zohar, 1998). These results may also be explained in relation to the self-efficacy findings documented in Study 1, as Pajares (1996) documented that low self-efficacy can lead to higher levels of anxiety towards taking tests in the classroom learning environment.

The significant increases relating to test anxiety in Study 1 were not replicated in Studies 2 and 3. A previous explanation for the lack of significant changes in test anxiety outlined in Chapter 5, concerned the fact that the time interval used in the design of Study 2 (8 weeks) may have been too short to detect intervention effects (Berger & Karabenick, 2011). However, as Study 1 documented significant increasing trends over the course of only five weeks, this explanation was revoked. An alternative explanation for the inconsistencies across the three studies may be the age differences between the samples. While Study 1 included S1 students (11-12 years of age) transitioning from primary school and in their first year of senior school, the latter studies involved older S2 students (12-13 years of age). Therefore, the older students included in the latter studies (Studies 1 & 2) may have had a chance to become more acquainted with the educational atmosphere in secondary school with more emphasis on test-taking than the first year students included in Study 1.

7.2.3 The Impact of CREST Programme Participation on Science-Specific Motivations

As outlined in Chapter 2, another aim of this thesis was to build on the findings of Grant (2007) regarding students' experiences in the CREST programme. Through administering self-report questions to students (512), Grant (2007) found that 50% reported more interest in science following participation, 33% were more interested in pursuing postgraduate study in science, and 30% were more interested in pursuing science careers. Results relating to science career motivation reported in this thesis provide further support for the findings documented by Grant (2007) as significant increases were found among CREST students in Study 1 that were not seen in the control group, and overall science motivation increased significantly in Study 2 for students taking part in the programme. These results are also in line with the research conducted by Wai and colleagues (2010) who tracked almost 1,500 students from the age of 13 over the course of 25 years and found that students with more STEM educational experiences that were intellectually challenging and offered opportunities for monitoring, planning, and reflecting were more likely to pursue STEM careers. However, these results were not replicated in Study 3, which, again, may be due to the tighter methodological control provided by the study design. Student motivation for obtaining high grades in science was also measured following CREST participation and significant decreases were reported in Study 2 among the CREST students. While this again may be due to the lack of an appropriate control group in Study 2, it is also possible that participating in the CREST programme focused the students' minds on more than just obtaining good marks in science. However, more research is needed to explore this explanation further.

7.2.4 Long-Term Impacts Relating to Self-Regulated Processes and Related Motivations

The three studies documented in this thesis also explored whether developments relating to the key outcome measures discussed above were maintained several months following programme participation. While Study 1 documented retention of the developments in self-regulated learning and career motivation six months following participation in the programme, Study 3 documented retention in the developed self-regulation three months after programme completion for students in the S2 CREST condition who participated in the programme during the course of the study. However, in Study 3, longer-term retention on a 9 month delayed post-test for students in the S1 CREST condition who took part in the programme the previous academic year was not observed. Study 2 documented retention four months following programme completion on all developments except for intrinsic motivation and it was explained that this may be due to the fact that the delayed post-test was measured over the summer break in this sample. Together, these results suggest that while some retention was documented, strategies should be put in place to help maximise the retention of any benefits students receive through taking part in the CREST programme.

7.2.5 Classroom Differences and Teacher Perceptions

Results from Study 2 also investigated classroom differences relating to the impact of the programme on the key outcome variables measured. The findings showed that each of the nine classes taking part in the CREST programme experienced similar changes in their self-regulated processes and related motivations toward their science learning. However, these conclusions were drawn cautiously due to the sensitivity of the analyses, which involved very small group sizes due to the inherent classroom structure.

Study 3 also investigated changes in teachers' self-reports of students' levels of self-regulated learning following CREST programme participation. Results from Study 3, which involved two CREST conditions (S1 CREST & S2 CREST) and one control group (No CREST), showed that the increases in students self-reported levels of self-regulation observed were not matched by the teachers' ratings. These findings highlighted the difficulty for teachers to measure and quantify internal processes such as self-regulation among their students, and also demonstrated that teachers may actually be measuring the related motivational constructs when asked to record self-regulated learning among their students.

7.2.6 Overview of the Empirical Findings

The findings discussed above provide a summary of the broad research results documented in this thesis. Taking a wider view of the research presented in each of the three empirical chapters, it appears that participating in the CREST programme had a significant, positive, impact on self-regulation and self-regulated learning among students as well as on preventing decreases in the related motivational constructs that may have occurred without participation. It was also documented that students entering the study with low self-reported levels on the measured variables experienced the most benefit and that classes were not different in terms of the benefits received. By also investigating teacher reports of students' self-regulated learning, insight was gained into the difficulty of observing these internal processes among students. Through discussing any inconsistencies, as well as relating the findings to relevant literature, the implications are clear and will now be discussed in more detail.

7.3 Implications of the Findings

The strength of the research conducted in this thesis is emphasised by the use of an inter-disciplinary approach, drawing from faculties including education and psychology. As the research crosses several bodies of literature, it provides a variety of original contributions that will be discussed in this section.

> 'Much science education research takes place as if school science occurs in a political and cultural vacuum' (Fensham, 2009, p. 1080).

Fensham (2009) argues that researchers who maintain a naïve view of the politics of science education often overestimate the impact of their findings on educational practice. This highlights the importance of maintaining a sense of realism when discussing the impact of the research findings presented in this thesis. The present research is therefore careful to assume impact on the educational experience of *some* learners in school environments that are open to *change* and have the funds to support this change. In addition, the importance of administrative support and the willingness of teachers are appreciated in order for the impacts to be realised. This section will now continue with a discussion of the main contributions offered by this doctoral research and the literature discussions presented in this thesis.

7.3.1 Theoretical Implications

In a period where educational research appears to be moving away from its ties to psychology, answering theory-based questions with classroom evidence is essential, as psychology can help with the struggles seen in educational reform (Mayer, 2004). Further, Pintrich (2003) highlighted that future use-inspired research including intervention studies needs to understand effective ways to implement psychological theoretical principles into classrooms and to empirically examine how they work. Through situating the CREST programme within the framework of educational psychology and self-regulation intervention research (Chapter 2) and developing research predictions based on Pintrich's (2004) framework and the wider theory-based literature (Chapter 1), the research presented in this thesis was able to explore the influence of CREST participation on the self-regulated processes and related motivations measured. More generally, the results presented in this thesis highlight that social-cognitive models can help researchers in thinking about self-regulated processes in young science students during collaborative inquiry activities, especially as they include a focus on related motivational aspects. In addition, as some researchers feel that motivations and social interactions are underappreciated in self-regulation theories (Baumeister & Vohs, 2007; Gabel & Bunce, 1994; Gaskill & Hoy, 2002; Pintrich, 2003; Zimmerman, 1995) the inclusion of the related motivational constructs in a collaborative learning context provides theoretical implications in this field.

Concern has been voiced in the literature relating to the prevalence of 'one-shot' correlational studies in this area and that more longitudinal, controlled research conducted in natural classroom settings is needed in order to gain insight into attainment and retention of the key constructs studied (Berger & Karabenick, 2011; Fraser, 1994; Pintrich, 2003; Zimmerman, 2008). By evaluating the CREST programme using a quasi-experimental design, this thesis provides longitudinal insight into developing self-regulated processes and related motivations in young students. Further, as the long-term effects of inquiry-based learning programmes on high school science students attitudes, interest, and motivations for pursuing careers is underexplored in the literature (De Boer *et al.,* 2012; Gibson & Chase, 2002), this thesis went beyond exploring the immediate impacts of CREST programme participation on the self-regulated processes and related motivational constructs studied.

Since the constructs studied are applicable to almost every research area, there is little consistency across and within domains regarding clear definitions (Beishuizen & Steffens, 2011; Fox & Riconscente, 2008; Kaplan, 2008). A gap in the saturated research area was identified in Chapter 1 regarding empirical studies that do not outline operational definitions, and whose measurement tools do not link to the theoretical models used to frame the research. Therefore, taking on board the suggestions that came from the research conducted by Dinsmore *et al.* (2008), this thesis was careful to outline the operational definitions assumed and the models used to frame the work in order to avoid further confusion in the literature. In addition, validated standardised measures linking to these understandings were carefully chosen in order to build on the measurement tools and understandings already available.

As outlined in each of the empirical chapters, multiple measurement tools were used in this research. From the results presented, it was apparent that different trends were observed at times across instruments that claimed to be measuring similar outcome variables. It is therefore possible that these measures, which at surface level investigate similar constructs, may be investigating different components within them. These findings provide support for the complexity of the conceptual nature of the self-regulated processes and related motivations studied in this thesis and highlight the need for important discussions of methodological and conceptual issues relating to these constructs.

Remembering the discussion in Chapter 1 *Section 1.5*, Kaplan (2008) concluded that metacognition, self-regulation, and self-regulated learning are not conceptually distinct and should therefore not be treated as such in empirical work. However, while educational theorists have stated that the three constructs are nested within each other (Dismore *et al.,* 2008) and are interdependent (Fox & Riconscente, 2008), many researchers believe that the three terms should also not be treated as similar constructs as they display meaningful differences (Kaplan, 2008). There is an ongoing debate in the literature regarding this issue with researchers striving to reach agreement in order to provide conceptual clarity to inform the empirical work being conducted. Using a multivariate approach to the analyses conducted across the three empirical studies, this thesis offers a solution through investigating the constructs under the umbrella of *self-regulated processes* while also allowing for any changes in the individual constructs to be observed.

7.3.2 Implications for Policy

In addition to being a scientific process, intervention evaluations in educational research are also political undertakings (Boekaerts & Corno, 2005). While studies are finding effective and innovative ways to deliver new curriculum developments, the task of implementing change throughout an educational system and ensuring that the findings of educational research are used to their full potential in order to benefit learners is not an easy feat. Policy issues provide a potential barrier to the uptake of the findings presented in this thesis, as the implementation and effectiveness of CREST will be threatened if a funding policy does not continue to include a budget for the programme. It is hoped however, that dissemination of the research presented in this thesis will have an impact on furthering policy-makers' support for the CREST programme, resulting in wider and more effective implementation of the programme throughout more schools in the UK.

There has been a great deal of support documented in the literature and evidenced in practice by the large presence of science investigation activities in schools around the world. However, inquiry investigations in science do not escape the limitations and barriers any new curriculum strategy faces. While the discussion presented in Chapter 2 provided empirical and theoretical support for the use of science inquiry-based learning programmes in schools, in reality some schools are reluctant to take part in the CREST programme[13]. This concurs with findings in the literature that teachers are resistant to using inquiry-based learning even though results show it can increase academic performance among students (Blanchard *et al.,* 2010). In addition, new evidence, which made news headlines in The BBC, The Times, The Telegraph, and The Guardian, suggests that the provision for practical science activities in both secondary and primary schools in the UK are seriously limited with some schools spending as little as £0.04 per student and teachers paying for materials out of their own pockets (SCORE, 2013). The findings presented in this thesis may help to provide additional awareness and support for CREST and increase the frequency and sustainability of inquiry activities like the CREST programme in science classrooms today.

Researchers have outlined that teachers' professional development needs to be supported when new strategies are implemented in classrooms in general, but specifically for inquiry-based learning activities in the science classroom (Blanchard *et al.,* 2010; Lazarowitz & Tamir, 1994; Léna, 2011). In addition, while self-regulation of learning is a familiar concept in educational research, among teachers, there is little understanding of what the term means and the need for teachers to understand the importance of developing self-regulated processes among their students is being emphasised (Abdullah & Lee, 2007; McKeachie, 2011). Considering the benefits provided to students through performing their science learning in self-regulated and motivationally supportive environments like CREST, may have implications for policy regarding the potential of incorporating these elements into professional development initiatives for practicing and pre-service

[13] This was exposed through discussions with CREST coordinators, staff at the British Science Association, teachers administering the programme, and teachers not taking part in CREST.

teachers, in order to maximise the benefit students experience through participation in the programme.

Recent science education reviews have shown that clear gender differences continue to exist regarding achievement, interest, selection of science courses, and pursuit of STEM careers (Kahle & Meece, 1994; Kerger, Martin, & Brunner, 2011; Velayutham *et al.,* 2011). Research has highlighted that nurturing interest among students and creating learning environments that foster the development of students' personal interest and confidence (particularly in physics) may address the gender differences seen (Deci *et al.,* 1991; Hoffmann, 2002). As the CREST programme involves giving students personal choice, being able to pick projects they are personally interested in, and also provides an opportunity for students to gain confidence in their science investigation skills, the programme may provide the answer for policy-makers aiming to close these gender gaps. In addition, while there is research suggesting that boys are less cooperative and may not benefit from cooperative learning activities as much as girls (Jacobs, 2002), the research presented in this thesis found that the benefits obtained through CREST programme participation were equal for both boys and girls, further supporting the efficacy of this programme. The findings specifically relating to career motivation in science may also be of interest to policy-makers addressing the issue of lower numbers of students pursuing science careers, as major career and educational decisions are made during the school years (Steffens, Jelenec, & Noack, 2010).

Finally, as empirical findings in the literature have shown that the effects of similar self-regulated learning interventions are stronger for younger students than older postsecondary students and adults (Hattie *et al.,* 1996), and considering the large and medium effects relating to the CREST programme documented in this thesis, the results highlight the need for policy makers to focus on promoting programmes like CREST in the early years of students' educational careers.

7.3.3 Implications for Educational Practice

While great effort is being seen in research into science education, Fensham (2009) outlines the importance of maximising the practical uptake of empirical findings into educational practice. As such, the studies presented in this thesis were carefully designed in order to provide a balance between minimal demands placed on the schools, teachers, and students involved while also maintaining a high level of academic rigour. In addition, as the research presented in this thesis investigates the impact of a programme currently being implemented in the UK, the results have direct implications for teachers administering the programme in science classrooms today.

The main findings of the studies undertaken as part of this thesis contribute to the debate in current educational literature as to whether explicit strategy instruction is necessary for the development of self-regulated processes in young students. The results summarised and discussed earlier in Section *7.2* and in each of the three empirical chapters (Chapters 4, 5, & 6), provide evidence that this can be done indirectly through creating an environment in the classroom that fosters the development of self-regulated processes and related motivations, and that direct strategy instruction is not needed. As Zimmerman (2008) states that an emerging issue in self-regulated learning is whether teachers can alter their classroom environments to promote increases in self-regulated learning among students, the research presented in this thesis suggests that the CREST programme can help science teachers in this aim.

Therefore, instead of having outside researchers come to classrooms and 'train' students, or having teachers complete training programmes themselves on how to teach the relevant strategies, teachers can use the CREST programme to help structure an environment in their classrooms that promotes self-regulated learning and encourages autonomous motivations among their students. In this, a distinctive contribution offered by the research presented in this thesis to educational practice is that the CREST programme allows students to develop the above constructs while covering curriculum guidelines, through gaining skills in conducting scientific investigations. Further, while developing the self-regulated processes and motivational constructs studied in this thesis has been shown to improve academic performance and subject interest, the benefits also extend to reducing problems with procrastination and boredom, highlighting the importance of this research (Parjes, 1996; Pekrun, Goetz, Daniels, Stupnisky, & Perry, 2010; Simpkins *et al.,* 2006; Wolters, 2003).

Understanding and developing self-regulated learning at a young age is an essential practical contribution, as effective early education fostering self-regulated learning may have significant developmental and educational implications (Cleary & Chen, 2009). As self-regulation is particularly important at the post-secondary and post-graduate levels due to students being given more control, responsibility, and having less parental support (McKeachie, 2011), and considering the growing concern seen at these educational levels regarding self-regulated learning and autonomous motivations (Perverly, Brobst, Graham, & Shaw, 2003), developing these constructs in adolescent students before entering post-secondary institutions is essential. In addition, the physical, mental, and educational changes experienced during adolescence highlight the importance of building the self-regulation literature in this age group (Cleary & Chen, 2009; Wigfield & Eccles, 2002).

As current publications have stressed the need for self-regulation research to be context-specific, the research presented in this thesis has been conducted in a science-learning context during a student-led inquiry-based programme. The way science is taught in schools around the world is widely contested (Fensham, 2009), which provides further support for the importance for conducting this research exploring the impact of a current strategy aimed at improving science learners' experiences in our educational system today. As previously discussed in this thesis, the need to increase student engagement in science at school is seen internationally in the literature with students in developed countries showing lower interest and less positive attitudes in science than students in developing countries (Archer *et al.,* 2010; Awan *et al.,* 2011). Therefore, these issues are extremely relevant for the UK, the United States, Canada, Japan, and Korea.

7.4 Overview of Recommendations for the CREST Programme

While it is accepted that self-regulated learning is an important facet of science education, and education in general, it has been identified that research is required to ensure that learning strategies are being implemented in the best way possible (Fensham, 2009; Kanter, 2010). Through investigating the impact of the CREST programme on student self-regulated processes and related motivations across three quasi-experimental studies, this thesis offers several specific programme administration suggestions that may increase the 'curriculum potential' of the CREST award scheme.

Section *7.2.1* above outlined some suggestions regarding the timing of the CREST programme in relation to the number of sessions completed. From the results presented in this thesis, it may be useful for schools to implement the programme over an entire school term and even commit only parts of a lesson to completing the CREST projects if possible. Based on the results presented, it is also clear that the CREST programme does not need to be targeted based on science ability or student self-reported levels on the key outcome measures studied, providing support for the current programme administration structure. The results also showed that conducting the CREST projects later in the academic year, after students have gained some experience conducting science investigations, may allow students to get the most out of the programme. In addition, across the three studies presneted in this thesis, it was observed that while the Bronze guidelines prescribe 10 hours of CREST participation, some schools are going above and beyond this requirement. While this is a positive observation, it may warrant further consideration regarding communication of programme guidelines across schools taking part.

The results presented in this thesis also made it clear that in order to develop the self-regulated process and related motivational constructs studied, students need to be personally engaged in their CREST projects. These findings suggest that additional effort may be valuable at the outset of the CREST programme to ensure that students are working effectively in their groups to develop a mutually agreeable project. This also highlights the importance of allowing students to choose their projects; not simply providing them with prescribed options. However, it is appreciated that in schools with limited resources, the flexibility awarded to students to design their projects may be lower. While the schools used in this thesis were fortunate enough to have the necessary materials to perform the detailed science projects with laboratory technicians who could order the materials when needed, CREST projects could be conducted on local university campuses, widening access and providing better facilities for students to use (Gibson & Chase, 2002).

Results presented in this thesis also showed that the CREST programme, while developing inquiry experience and self-regulated learning strategies, may need to prepare students for the transfer back into taking tests, especially students in their first year of senior school. Implementing strategies to help reduce test anxiety following CREST participation would therefore be beneficial. In addition, while some retention was documented in the present research, further strategies aimed at helping students to retain the developments would also be an important addition to the programme in order to extend the observed programme benefits over a long-term basis. This may also provide further support for the structure of the CREST programme with students continuing in more advanced investigations at the Silver and Gold award levels. Building on the current design, with the main difference between the three CREST levels being the time commitment, it would also be beneficial to structure the programme in order to gradually give students more control and explicitly focus on developing these self-regulatory and motivational strategies. The introduction of the Collaborative Hypothesis Tool (Sabb, Van Joolingen, & Van Hout-Wolters, 2012), which helps students work together to formulate appropriate research questions, may be a helpful addition to the early stages of the CREST programme for students completing the Bronze level as making hypotheses is difficult for even experienced researchers.

Through conducting this research it was observed that the majority of projects take place in Biology classrooms. However, considering that internationally, student attitudes are most positive for biology and lower for both physics and chemistry (Awan *et al.,* 2011), promoting CREST programme participation in physics and chemistry classrooms may help increase student interest and positive attitudes towards these subjects. Appreciating the added safety concerns that may come with conducting CREST projects in chemistry, promoting CREST projects in upper year chemistry classes who have successfully completed the Bronze level and have experience conducting investigations as well as more content knowledge in the subject, may provide a solution.

7.5 Limitations and Future Research

While the research presented in this thesis offers several contributions to knowledge, it does not escape the limitations of similar quasi-experimental studies. Among these limitations, practice, maturation, and history effects were carefully considered when interpreting the impact of the findings presented. Pre-test sensitisation may have also been an issue, particularly in Study 1, as the time between pre-test and post-test was only five weeks. However, while pre-test sensitisation may not have been a problem in Studies 2 and 3, the longer interval between administration of the pre-test and post-tests may have increased the probability of external factors influencing any treatment effects (Bonate, 2000). Future research replicating the findings documented in this thesis at different times throughout the school year would increase the confidence of generalisations by making interaction effects of intervention with history less likely (Campbell & Stanley, 1966).

As the research conducted in each of the three studies involved experimental control groups attending the same school as the CREST conditions, spillover effects need to be considered (Schochet, 2008). It is possible that the students taking part in the CREST programme were aware that other students were not taking part and therefore responded more positively, with the reverse being true for students in the control groups. While caution was taken to reduce these reactive effects by not communicating the purpose of this research to the students taking part (Campbell & Stanley, 1966), these effects still need to be considered when interpreting the findings presented in this thesis.

This research was conducted in three school settings with students ranging from 11 to 13 years of age, and therefore, generalisations are limited to these particular UK student samples. The research also appreciates that the schools who consented to participating may be atypical in having higher morale, less fear of inspection, and more desire for improvement and development, which would affect the external reliability of the results (Campbell & Stanley, 1966). The results presented in this thesis are also limited to the cultural context in which the research was conducted. Further research replicating these results in other countries would help to build confidence in the generalisability of the findings. In addition, while the research presented in this thesis investigated classroom effects, future research looking at the effect of CREST participation at the school level would provide an interesting contribution to literature documenting that urban schools have less positive attitudes towards science and benefit more from similar interventions (George, 2000; Haller, Child, & Walberg, 1988; Skibbe *et al.,* 2012).

Relating to the specific self-report measures used, the research presented in this thesis assumes that students have the ability to verbally express their cognitions. However, it is possible that the young students involved in this research were incapable of identifying and recalling their mental processes (Whitebread *et al.,* 2009). This could present a problem for this research as students may be using strategies but not possessing the conscious awareness that they are doing so. In addition, since the present study did not include any measure of students' perceptions of the classroom context, there may be further reason to question the validity of the results. Taking these issues into consideration, structured interview protocols developed by Zimmerman and Martinez-Pons (1986) to assess levels of student self-regulatory processes and related motivations have been piloted. Questions relating to students' perceptions of the CREST programme as a strategy to develop self-regulated processes and related motivations were also included in the interviews. The addition of an observational tool like the Reformed Teaching Observation Protocol (Sawada *et al.,* 2002) would also provide a measure of the different instructional strategies between the intervention and control classes and contribute to the validity of the research findings.

As students participating in the CREST programme are also asked to complete working diaries of their progress, collecting these and analysing them using content analyses would provide for a more qualitative understanding of the impact of CREST participation (Arsal, 2010). Future plans for this research include comparing the student self-report measures with the qualitative results from the interviews, classroom observations, questionnaire results on teacher perceptions of the CREST programme (see Appendix E), and student diaries (Pauli, Reusser, & Grob, 2007).

Obtaining background information regarding parental involvement at home might also increase the generalisability of the results discussed in this thesis, as research has suggested that parental help may explain differences in self-regulated processes, related motivations, and academic performance among students (Grolnick & Ryan, 1989; Purdie, Hattie, & Douglas, 1996; Vansteenkiste *et al.,* 2009; Zimmerman & Martinez-Pons, 1990). It is also important to highlight that the academic performance data included in this thesis related to science unit test results and not inquiry-based laboratory assessments. Inclusion of this data relating to students' performances on their inquiry investigations may provide additional insight, as research has shown that performance in practical skill activities is weakly correlated to academic performance (Hofstein & Lunetta, 1982; Lazarowitz & Tamir, 1994).

One of the main limitations of the research presented relates to the difficulty of unpacking which aspects of the CREST programme led to the developments observed. While randomised experiments with groups using different aspects of the CREST programme (group work, choice of projects) to observe which have the most impact may provide further insight into this issue (De Corte *et al.,* 2004; Levin & O'Donnell, 1999), this analysis would interfere with the natural structure of the CREST programme and was therefore not included in the research presented in this thesis. Another limitation of the research presented was that the time students spent on their CREST projects *between* and *within* schools was not controlled. While this was done in order to minimise interruption of the programme within the natural classroom settings, it does provide limitations regarding the validity of the results discussed.

In addition to regulating their individual learning on tasks, students need to regulate the collaborative activities being planned and performed (DiDonato, 2013; Sabb *et al.,* 2012). Co-regulation has been shown to help students refine and develop their individual self-regulated processes and therefore, future research investigating co-regulation through including the Co-Regulated Learning Questionnaire (DiDonato, 2013) may provide a more complete picture of the impact of the CREST programme on the key outcome measures studied. Measuring the key outcome variables across different school subjects in order to investigate the wider impact of CREST programme participation would also strengthen the research presented in this thesis.

A final limitation worth mentioning here is the presence of power issues in two of the three studies presented in this thesis. It is therefore possible that the samples involved in these studies were not large enough to detect significant trends. However, through dissemination of the contributions offered by this thesis to schools and teachers participating in the CREST programme, it is hoped that more schools will participate in order to build the generalisability of the findings.

7.6 CONCLUSIONS AND FINAL REMARKS

Recent concerns regarding downward trends in self-regulated processes and related motivations among young students toward their science learning highlight the need for research in this field to be targeted at investigating viable strategies that foster the development of these constructs in the science learning context. A solution has been proposed in curriculum reforms through increasing open-inquiry investigations in classrooms (Dillon, 2008; Kalman, 2010). However, while more practical work takes place in science classrooms throughout the UK compared to most other countries around the world, researchers, teachers, and science policy-makers are voicing concern that not enough practical work is happening and that the quality is mixed (BBC News, 2010; Dillon, 2008; Dixon, 2011; Minner *et al.,* 2010; SCORE, 2013, 2008). This highlights the need for academics as researchers and educators to promote and encourage these practices in schools while also ensuring that the science investigations that *are* taking place in our classrooms are working to benefit students as much as possible. As such, the research presented in this thesis investigated the impact of a strategy, currently being implemented throughout the UK, on developing self-regulated processes and related motivations in young science students (11-13 years of age), and offered specific programme administration suggestions based on the empirical findings reported.

Appreciating the concerns voiced in the literature regarding the conceptual clarity of self-regulated processes and related motivations, this thesis began by introducing these constructs and outlining an overall framework, providing a basis for the empirical work conducted (Chapter 1). The initiative studied, the *CREativity in Science and Technology* (CREST) programme, was then introduced and framed within the context of educational intervention research in order to support the research predictions formulated and the implications drawn from the work presented (Chapter 2). This thesis offers several distinctive contributions to knowledge by addressing issues highlighted in the literature as needing further attention.

Firstly, by conducting this series of three quasi-experimental studies in different natural classroom settings (Chapter 3), this thesis builds on the correlational findings present in the literature in this area of educational research and provides ecologically valid insight. As this thesis investigated the retention of developed self-regulated processes and related motivations among adolescent students specifically within a science inquiry-based learning context, the reported findings help to fill a gap identified in a saturated area of research. As research documents that major career and educational decisions are made during the school years (Steffens *et al.,* 2010), understanding the potential impact of strategies aimed at developing these self-regulated processes and related motivations in young students is another important contribution to knowledge in this field of educational research provided by this thesis. And finally, the difficulty and complexity of creating environments that promote these processes among young students further highlights the importance of understanding how to appropriately support teachers while conducting these learning tasks with their students (Boekaerts & Niemivirta, 2000).

The results reported across the three studies (Chapters 4, 5, & 6) provided evidence for both the short and long-term impact of the CREST programme on increasing student self-reported levels of self-regulation, self-regulated learning, and career motivation and that academic performance in science, as well as classroom membership, did not influence the amount of benefit received. The findings provided evidence for the potential of the programme to limit the downward trends seen in the literature relating to the key constructs studied. As students' self-reported levels of the outcome variables depended on the particular measure administered, the results also provided support for the complexity of the conceptual nature of the constructs included in the research. This thesis also documented that the CREST programme did not impact teachers' perceptions of student self-regulated learning, which was not expected and highlighted the potential difficulty for teachers to measure internal processes like self-regulation among their students. Together, the findings presented in this thesis provide clear support for the CREST programme as a strategy to help teachers create supportive learning environments aiming to develop self-regulated processes and related motivations among their students (Chapter 7).

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Appendix A

University of Edinburgh

MORAY HOUSE SCHOOL OF EDUCATION ETHICS COMMITTEE

Confirmation of Ethical Approval Form

Research Support Office
MORAY HOUSE SCHOOL OF EDUCATION

The University of Edinburgh
Old Moray House
Holyrood Road
Edinburgh EH8 8AQ

Direct Dial 0131 651 6388
Switchboard 0131 650 1000
Fax 0131 651 6052
Email
http://www.ed.ac.uk

Julie Moote
c/o Dr John Sproule
SPEHS
St Leonards

26th April 2011

Dear Julie

An Investigation of Self-regulated Learning in Young Students

The School of Education Ethics Sub-Committee has now considered your request for ethical approval for the studies detailed in the above application.

This is to confirm that the Sub-Committee is happy to approve the application and that the research meets the School Ethics Level 1 criterion. This is defined as"'straightforward' non-intervention, observational research (e.g. analysis of archived data, classroom observation, use of standardised questionnaires)".

A standard condition of this ethical approval is that you are required to notify the Committee, of any significant proposed deviation from the original protocol. The Committee also needs to be notified if there are any unexpected results or events once the research is underway that raise questions about the safety of the research.

Yours sincerely

S Cunningham

pp Dr K McCulloch
Convener, School Ethics Sub-Committee

Appendix B

1. Parental Consent Form

Information Sheet and Parental Consent

Who am I?
My name is Julie Moote and I am a PhD student in Moray House School of Education at the University of Edinburgh. With the help of my supervisors Drs. Joanne Williams and John Sproule, I am conducting a research project as part of my PhD thesis and would like to invite your child to take part. Please read the following information carefully before deciding whether to participate in the project.

Why is the research being conducted?
The primary aim of the project is to explore students' ability to control their learning and motivation in science class. The results will be used as part of the PhD thesis and also presented in paper and poster publications.

What will participants be asked to do?
Participating in this research project will involve your child completing a 30-minute questionnaire (administered by their teacher during class) regarding their experience and motivations in science. Sample questions include: 'I like science that challenges me' and 'Understanding science gives me a sense of accomplishment'. The researcher will then analyse these questionnaires and may also ask students to elaborate on their answers in a short interview. The researcher may also be in touch with teachers regarding performance marks.

Will people who see the research be able to identify my child?
No. Your child's identity will be protected at all times and any information they provide as part of this research will be **strictly confidential.**

What if parents and students have questions?
If after reading this information sheet you have further questions regarding this research project, please contact the researchers directly:

Julie Moote	**Dr. Joanne Williams**	**Dr. John Sproule**
s0564634@sms.ed.ac.uk	jo.williams@ed.ac.uk	john.sproule@ed.ac.uk

If you choose to participate, please keep this form for your reference. However, if you **Do Not** wish to have your child take part, please return the slip below to the main office.

Cut along the line

_ _

I **Do Not** give consent for my child to take part in the above study

Name of Student:

Name of Parent/Guardian (please print):

Signature of Parent/Guardian:

Appendix B

2. Child Assent Form

Included at the beginning of the questionnaires

THE UNIVERSITY of EDINBURGH

The following pages contain questions that will help understand your attitudes towards learning in your science class.

Please take the time to read each question carefully and follow the instructions given.

I agree to take part in the project and allow the researcher to analyse my questionnaire results and communicate with my teacher regarding my performance in class. I understand that my identity will be kept anonymous in any presentation of the material and that I am free to leave the project at any time.

Student Name: ________________________________

Student Signature: _____________________________

Date of birth (dd/mm/yyyy): ___ ___ _______

Boy ( ) or Girl ( )

Teacher:_____________________________

Appendix C

1.Questionnaire Procedure

Read to students by classroom teachers prior to administering questionnaires

THE UNIVERSITY *of* EDINBURGH

Questionnaire Procedure

1. Please read the following script to students before they begin the questionnaire:

"The school has agreed to help a researcher at the University of Edinburgh with a project focusing on understanding students' attitudes and learning in science. Today we would like you to fill out a short questionnaire regarding your learning in science class. This is not a test, there are no right or wrong answers, and you may stop at any time and work quietly at your desks. When answering the questions please think about your feelings and learning in science class. Even though many of the questions may sound very similar, please try to answer as many of them as you can. Your efforts are greatly appreciated!"

2. While the students are filling out the questionnaire, if you are willing, please complete a *Student Self-regulated Learning Outcomes* questionnaire for each student in the class. It should take approximately a minute and a half for each student (30mins for the entire class set).

3. Please place all questionnaires in the envelope provided with your name and date and return them to _______________.

Thank you for participating!!!

Appendix C

2. Student Questionnaire Measures

Font size and format altered for presentation in this Appendix

Larger fonts were used in practice

In order to understand what you think and feel about your science class, please put an X in the box you feel applies to you for the statement:
"When I am in a Science Class…….."

1. I enjoy learning the science.

Never	Rarely	Sometimes	Usually	Always

2. The science I learn relates to my personal goals.

Never	Rarely	Sometimes	Usually	Always

3. I like to do better than the other students on the science tests.

Never	Rarely	Sometimes	Usually	Always

4. I am nervous about how I will do on the science tests.

Never	Rarely	Sometimes	Usually	Always

5. If I am having trouble learning the science, I try to figure out why.

Never	Rarely	Sometimes	Usually	Always

6. I become anxious when it is time to take a science test.

Never	Rarely	Sometimes	Usually	Always

7. Earning a good science grade is important to me.

Never	Rarely	Sometimes	Usually	Always

8. I put enough effort into learning the science.

Never	Rarely	Sometimes	Usually	Always

9. I use strategies that make sure I learn the science well.

Never	Rarely	Sometimes	Usually	Always

“When I am in a Science Class……..”

10. I think about how learning the science can help me get a good job.

Never	Rarely	Sometimes	Usually	Always

11. I think about how the science I learn will be helpful to me.

Never	Rarely	Sometimes	Usually	Always

12. I expect to do as well as or better than other students in the science course.

Never	Rarely	Sometimes	Usually	Always

13. I worry about failing the science tests.

Never	Rarely	Sometimes	Usually	Always

14. I am concerned that the other students are better in science.

Never	Rarely	Sometimes	Usually	Always

15. I think about how my science grade will affect my overall marks.

Never	Rarely	Sometimes	Usually	Always

16. The science I learn is more important to me than the grade I receive.

Never	Rarely	Sometimes	Usually	Always

17. I think about how learning the science can help my career.

Never	Rarely	Sometimes	Usually	Always

18. I hate taking science tests.

Never	Rarely	Sometimes	Usually	Always

19. I think about how I will use the science I learn.

Never	Rarely	Sometimes	Usually	Always

“When I am in a Science Class……..”

20. It is my fault if I do not understand the science.

Never	Rarely	Sometimes	Usually	Always

21. I am confident I will do well on the science labs and projects.

Never	Rarely	Sometimes	Usually	Always

22. I find learning the science interesting.

Never	Rarely	Sometimes	Usually	Always

23. The science I learn is relevant to my life.

Never	Rarely	Sometimes	Usually	Always

24. I believe I can master the knowledge and skills in the science course.

Never	Rarely	Sometimes	Usually	Always

25. The science I learn has practical value for me.

Never	Rarely	Sometimes	Usually	Always

26. I prepare well for the science tests and labs.

Never	Rarely	Sometimes	Usually	Always

27. I like science that challenges me.

Never	Rarely	Sometimes	Usually	Always

28. I am confident I will do well on the science tests.

Never	Rarely	Sometimes	Usually	Always

29. I believe I can earn a grade of ‘A’ in the science course.

Never	Rarely	Sometimes	Usually	Always

30. Understanding the science gives me a sense of accomplishment.

Never	Rarely	Sometimes	Usually	Always

Goal Setting

*Some students set goals for themselves when doing their academic work. How often do **you** set goals to perform your academic work?*

*Please put an X in the box that applies to **you**.*

1. When doing my academic work, I always set goals to guide me in my efforts.

Never	Sometimes	Frequently	All the time

2. I check with others (friends, parents, tutors) that the goals I set for myself are realistic.

Never	Sometimes	Frequently	All the time

3. I set clear goals that I can describe without difficulty.

Never	Sometimes	Frequently	All the time

4. I set goals that go beyond what I have already achieved.

Never	Sometimes	Frequently	All the time

5. I set goals that present me with a challenge.

Never	Sometimes	Frequently	All the time

6. I check with others that the goals I set for myself are clear.

Never	Sometimes	Frequently	All the time

7. I give myself plenty of time to achieve the goals I set for myself.

Never	Sometimes	Frequently	All the time

8. I set goals that I think I have a good chance of achieving.

Never	Sometimes	Frequently	All the time

9. I check with others that I give myself enough time to work on my goals.

Never	Sometimes	Frequently	All the time

10. I am able to clearly distinguish my academic goals from one-another.

Never	Sometimes	Frequently	All the time

11. I check with others that my goals involve objectives that I have not yet attained.

Never	Sometimes	Frequently	All the time

12. I make sure that the number of goals I set for myself is manageable.

Never	Sometimes	Frequently	All the time

13. I organize my goals so that attaining one makes it easy to attain another.

Never	Sometimes	Frequently	All the time

14. I set a definite deadline (date, time) for reaching each goal.

Never	Sometimes	Frequently	All the time

15. I can't make sense from one day to the next of my goals.

Never	Sometimes	Frequently	All the time

Using Strategies

*Some students use the following strategies to perform their academic work, while others prefer not to use strategies such as these. How often do **you** use the strategies listed to perform your academic work?*

*Please put an X in the box that applies to **you**.*

1. I get teachers to help me when I get stuck with academic work.

Never	Sometimes	Frequently	All the time

2. I get other students to help me when I get stuck with academic work.

Never	Sometimes	Frequently	All the time

3. I get other adults to help me when I get stuck with academic work.

Never	Sometimes	Frequently	All the time

4. I motivate myself to do academic work when I find the material difficult.

Never	Sometimes	Frequently	All the time

5. I motivate myself to do academic work when I find the material boring.

Never	Sometimes	Frequently	All the time

6. I motivate myself to do academic work when I am tired.

Never	Sometimes	Frequently	All the time

7. I motivate myself to do academic work when there are other interesting things to do.

Never	Sometimes	Frequently	All the time

8. I take notes during class.

Never	Sometimes	Frequently	All the time

9. I use the library to get information for assignments.

Never	Sometimes	Frequently	All the time

10. I organize my academic work.

Never	Sometimes	Frequently	All the time

11. I repeat things over and over in my head to remember information presented in class or textbooks.

Never	Sometimes	Frequently	All the time

12. I continue with my academic work when I find the material very hard.

Never	Sometimes	Frequently	All the time

13. I continue with my academic work when I find the material very boring.

Never	Sometimes	Frequently	All the time

14. I continue with my academic work when I am tired.

Never	Sometimes	Frequently	All the time

15. I continue with my academic work when there are other interesting things to do.

Never	Sometimes	Frequently	All the time

Strategy Monitoring

When using a strategy such as note taking or underlining, how often do ***you*** *do the following things?*

Please put an X in the box that applies to ***you****.*

1. I check to see if I am performing the strategy in the way it is supposed to be carried out.

Never	Sometimes	Frequently	All the time

2. I have alternative strategies available in case the one I use does not work.

Never	Sometimes	Frequently	All the time

3. I compare my performance with that of others to see if I am performing the strategy in the way it is supposed to be carried out.

Never	Sometimes	Frequently	All the time

4. I check my work to see if the strategy is having the desired effect.

Never	Sometimes	Frequently	All the time

5. I compare the strategy with other methods to see which is more effective.

Never	Sometimes	Frequently	All the time

6. I keep records of my performance so I can see how much progress I am making.

Never	Sometimes	Frequently	All the time

7. I try out problems in textbooks to see how well I have mastered the material.

Never	Sometimes	Frequently	All the time

8. I take old tests to see how well I know the material.

Never	Sometimes	Frequently	All the time

9. I adjust my behaviour as necessary to better use the strategy.

Never	Sometimes	Frequently	All the time

10. I switch to a more effective strategy when the one I am using is not working.

Never	Sometimes	Frequently	All the time

11. I review my answers on a test to see if I have made any mistakes.

Never	Sometimes	Frequently	All the time

12. I look for what I did wrong when I find I have not succeeded in mastering the material.

Never	Sometimes	Frequently	All the time

13. I take action to identify the reason why I have made mistakes if I find them.

Never	Sometimes	Frequently	All the time

14. I check to make sure I have fixed the mistakes.

Never	Sometimes	Frequently	All the time

15. I reward myself for correcting the mistake.

Never	Sometimes	Frequently	All the time

General Science Learning

The next section asks you questions in order to understand your thoughts and feelings about your learning in Science class.

*Please put an **X** over the number that applies to **you** in this **science** class.*

1. I prefer class work that is challenging so I can learn new things.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

2. Compared with other students in this class, I expect to do well.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

3. I am so nervous during a test that I cannot remember facts I have learned.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

4. It is important for me to learn what is being taught in this class.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

5. I like what I am learning in this class.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

6. I am certain I can understand the ideas taught in this course.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

7. I think I will be able to use what I learn in this class in other classes.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

8. I expect to do very well in this class.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

9. Compared with others in this class, I think I am a good student.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

10. I often choose assignment or project topics I will learn something from even if they require more work.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

11. I am sure I can do an excellent job on the problems and tasks assigned in this class.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

12. I have an uneasy, upset feeling when I take a test.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

13. I think I will receive a good grade in this class.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

14. Even when I do poorly on a test, I try to learn from my mistakes.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

15. I think that what I am learning in this class is useful for me to know.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

16. My study skills are excellent compared with others in this class.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

17. I think that what we are learning in this class is interesting.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

18. Compared with other students in this class I think I know a great deal about the subject.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

19. I know that I will be able to learn the material for this class.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

20. I worry a great deal about tests.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

21. Understanding this subject is important to me.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

22. When I take a test, I think about how poorly I am doing.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

23. When I study for a test, I try to put together the information from class and from the textbook.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

24. When I do homework, I try to remember what the teacher said in class so I can answer the questions correctly.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

25. I ask myself questions to make sure I know the material I have been studying.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

26. It is hard for me to decide what the main ideas are in what I read.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

27. When work is hard I either give up or study only the easy parts.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

28. When I study I put important ideas into my own words.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

29. I always try to understand what the teacher is saying even if it does not make sense.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

30. When I study for a test, I try to remember as many facts as I can.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

31. When studying, I copy my notes over to help me remember material.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

32. I work on practice exercises and answer end of chapter questions even when I do not have to.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

33. Even when study materials are dull and uninteresting, I keep working until I finish.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

34. When I study for a test I practice saying the important facts over and over to myself.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

35. Before I begin studying, I think about the things I will need to do to learn.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

36. I use what I have learned from old homework assignments and the textbook to do new assignments.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

37. I often find that I have been reading for class but do not know what it is all about.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

38. I find that when the teacher is talking I think of other things and do not really listen to what is being said.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

39. When I am studying a topic, I try to make everything fit together.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

40. When I am reading, I stop once in a while and go over what I have read.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

41. When I read material for this class, I say the words over and over to myself to help me remember.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

42. I outline/summarize the chapters in my textbook to help me study.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

43. I work hard to get a good grade even when I do not like a class.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

44. When reading, I try to connect the things I am reading about with what I already know.

Not at all true of me						Very true of me
1	2	3	4	5	6	7

Appendix C

3. Student Perceptions of Questionnaire

Included in the Pilot Work Conducted

Please take a moment to answer the following general questions about completing this questionnaire.

Were instructions clear?

Were any questions unclear?

Would it have been easier if there was more space between the questions?

Would you prefer the text size to be bigger?

Was the general layout of the questionnaire clear?

Any other comments about your experience completing this questionnaire?

Thank you and enjoy your weekend!!!!!!

Appendix C

4. Teacher Questionnaire Measuring Perceptions of Student Self-Regulated Learning in the Classroom

Rating Student Self-Regulated Learning Outcomes: A Teacher Scale (Zimmerman & Martinez-Pons, 1988)

Student Self-regulated Learning Outcomes

Teacher Name: ____________________________

Student Name: _____________________________

1. Does this student solicit additional information about the exact nature of forthcoming tests or quizzes?

1	2	3	4	5
Never	Sometimes	Fairly often	Very often	Always

2. Does this student solicit additional information about your expectations or preferences concerning homework assignments?

1	2	3	4	5
Never	Sometimes	Fairly often	Very often	Always

3. Does this student display awareness concerning how well he/she has done on a test or quiz before you have graded it?

1	2	3	4	5
Never	Sometimes	Fairly often	Very often	Always

4. Does this student complete assignments on or before the specified deadline?

1	2	3	4	5
Never	Sometimes	Fairly often	Very often	Always

5. Is this student prepared to participate in class on a daily basis?

1	2	3	4	5
Never	Sometimes	Fairly often	Very often	Always

6. Does this student express interest in course matter?

1	2	3	4	5
Never	Sometimes	Fairly often	Very often	Always

7. Does this student offer relevant information that was not mentioned in the textbook or previous class discussions?

1	2	3	4	5
Never	Sometimes	Fairly often	Very often	Always

8. Will this student seek assistance from you on his/her own when he/she is having difficulty understanding schoolwork?

1	2	3	4	5
Never	Sometimes	Fairly often	Very often	Always

9. Will this student ask unusual or insightful questions in class?

1	2	3	4	5
Never	Sometimes	Fairly often	Very often	Always

10. Will this student volunteer for special tasks, duties, or activities related to coursework?

1	2	3	4	5
Never	Sometimes	Fairly often	Very often	Always

11. Does this student express and defend opinions that may differ from yours or those of classmates?

1	2	3	4	5
Never	Sometimes	Fairly often	Very often	Always

12. Does this student solicit further information regarding your grades or evaluations of his or her schoolwork?

1	2	3	4	5
Never	Sometimes	Fairly often	Very often	Always

Appendix D

1. Formal Permission From Publisher to Include Research Article in the Present Thesis

June 17, 2013

Dear Ms. Julie Moote,

Springer Publishing Company's policy permits the authors to: (a) reuse their own material, and (b) use Springer material in a dissertation. Therefore, there is nothing preventing you from using your recent article "When Students Take Control: Investigating the Impact of the CREST Inquiry-Based Learning Program on Self-Regulated Processes and Related Motivations in Young Science Students" in your PhD dissertation.

See the following link for more information if needed:
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Warm regards,

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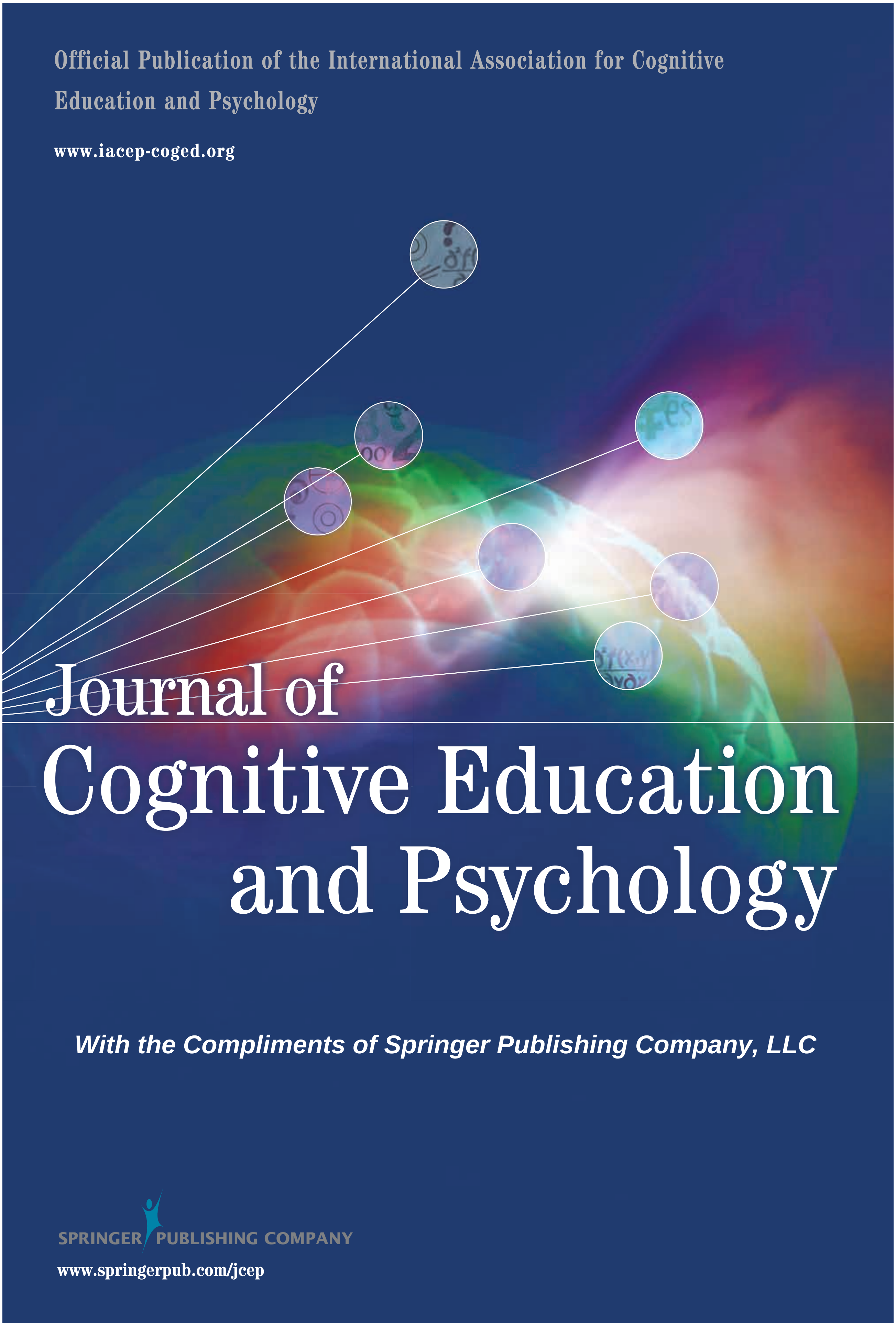
Appendix D

2. Research Publication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Journal of Cognitive Education and Psychology
Volume 12, Number 2, 2013

When Students Take Control: Investigating the Impact of the CREST Inquiry-Based Learning Program on Self-Regulated Processes and Related Motivations in Young Science Students

Julie K. Moote
Joanne M. Williams
John Sproule
University of Edinburgh, Scotland

The CREativity in Science and Technology (CREST) scheme, a student-run science project supported by the science, engineering, and technology network, is currently being implemented in schools across the United Kingdom to increase student engagement and motivation in science. The central aim of this research was to explore the influence of CREST participation on students' self-regulated processes and related motivations. This study followed a quasi-experimental design with a control group ($n = 34$) and a "CREST" group ($n = 39$) of students between the ages of 11 and 12 years from a Scottish school. Because multiple measures were used, this study also provides a contribution to the literature regarding measurement issues relating to self-regulated learning (SRL) and motivation. Covariance analyses controlling for academic performance in science revealed significant effects for the intervention regarding changes in SRL, test anxiety, and career motivation in science. Delayed posttest results for the experimental group are also presented and discussed.

Keywords: self-regulation; self-regulated learning; metacognition; motivation; science

One of the primary goals of educational psychology is to understand the learning process and to provide support for those who struggle with it (Greene & Azevedo, 2007). In the late 1980s, driven by the findings of rigorous educational research, several education systems around the world participated in a movement to encourage learners to become more self-regulated and independent in their learning (Jones & Idol, 1990; Wongsri, Cantwell, & Archer, 2002). Empirical studies have shown the prevalence of poor self-regulation in students today and its detrimental impact on academic achievement (Matthews,

http://dx.doi.org/10.1891/1945-8959.12.2.178

Ponitz, & Morrison, 2009). Self-regulated learning (SRL) has become an important topic between educational and psychological researchers principally because it has been found to enhance learning outcomes (Beishuizen & Steffens, 2011). This cognitive and metacognitive process is not only vital during school learning but is also a lifelong skill that learners can sustain after graduation and for self-education later in life (Abdullah & Lee, 2007; Boekaerts, 1997; Kaplan, 2008). Given the importance of lifelong learning, which is at the forefront of education policy making, fostering SRL remains a primary focus of current research (Beishuizen & Steffens, 2011; Dignath & Büttner, 2008; Zimmerman, 2002).

Alongside recent developments in SRL research, teachers' roles over the last two decades have evolved from simply dispensing knowledge to more integral roles in increasing motivation among students and helping them develop strategies to self-regulate their learning (Abdullah & Lee, 2007; Velayutham, Aldridge, & Fraser, 2012). Zimmerman (2008) states that an emerging issue in SRL is whether teachers can alter their classroom environments to promote increases in SRL among students. Investigating SRL and motivation in real-life learning environments is necessary to further our understanding and provide more realistic information regarding student engagement in these contexts (Gläser-Zikuda & Järvelä, 2008). Without looking at real classroom settings, generalizations concerning the practical implications of research findings are of limited value (Martin & McLellan, 2008).

The study presented here builds on the work of researchers who have been developing our understanding of self-regulation in science classrooms (Adey, 1992; Driver, 1989; Driver & Oldham, 1986; White & Frederiksen, 1998; Zohar, 2004; Zohar & Dori, 2012) through evaluating a science education intervention administered by classroom teachers. This research therefore has direct implications for practice and contributes to the identified knowledge gap relating to self-regulation research in natural settings. Current theoretical discussions regarding science education highlight the benefits of conducting research in science classrooms and improving science learners' experience within educational systems (Fensham, 2009). Moreover, education policy makers have documented concerns regarding the recent decline in engagement in school science and the decreasing number of students pursuing university study in science (Archer et al., 2010). The physical, mental, familial, and educational changes experienced during adolescence also highlight the importance of building on the self-regulation literature relevant to this age group (Cleary & Chen, 2009; Wigfield & Eccles, 2002). Before describing the intervention program and placing it within the context of SRL intervention studies, the theoretical framework adopted for understanding the theoretical constructs of interest will be presented.

THEORETICAL FRAMEWORK FOR UNDERSTANDING SRL

According to social cognitive researchers, SRL involves three or four interdependent phases through which learners manage their academic progression (Pintrich & De Groot, 1990; Wolters, 2010; Zimmerman, 2002). One phase is commonly referred to as the *forethought* phase, which involves planning and setting goals and selecting strategies for a learning activity. During the *monitoring* phase, a student continuously tracks his or her progress and is aware of his or her current performance in relation to his or her goals. The activities involved in the *control* phase refer to implementing and adapting learning strategies to complete the task. Finally, reviewing and responding to the learning experience makes up the *reflection* phase. In his framework, Pintrich (2004) lists the self-regulatory activities involved in each of the phases in four separate areas: cognitive, motivation and affect, behavior, and context. This study adopts this multidimensional framework for understanding SRL, and decisions regarding the measurement tools used in this study were guided by this conceptualization (MacLellan & Soden, 2006). Velayutham et al. (2012) additionally highlight the importance of implementing strategies to develop self-efficacy and motivations when aiming to promote SRL in secondary school science, and the influence of the CREativity in Science and Technology (CREST) program on student beliefs toward his or her science learning was also investigated.

Closely related to the topic of SRL is self-determination, which involves control, choice, and self-initiation of behavior (Glynn, Taasoobshirazi, & Brickman, 2009). This motivational aspect related to SRL has been shown to be important in promoting autonomous learning, which helps students retain an intrinsic sense of learning and fosters SRL (de Bilde, Vansteenkiste, & Lens, 2011; Deci, Vallerand, Pelletier, & Ryan, 1991). Although not included in many studies of SRL among students, we argue that additional insight may be provided through incorporating this construct into our understanding of student self-regulatory processes. The particular science education intervention program of interest will now be presented and placed within this framework for understanding SRL and related motivations in school students.

THE CREST PROGRAM THROUGH THE LENS OF SRL INTERVENTION RESEARCH

Current science curriculum initiatives in the United Kingdom have resulted in the implementation of the British Science Association's CREST award scheme. This inquiry-based intervention program involves a 5-week science project (10 classroom hours—approximately 20 classroom sessions) for students between 11 and 13 years old and is offered to schools as a supplement to the U.K. science curriculum. Led by students and facilitated by teachers, this program focuses on promoting student autonomy and peer collaboration, and on providing students with opportunities to perform self-reflection and self-evaluation. Suggestions in the literature for intervention programs aimed at developing SRL and motivation in young students outline that students should be given choices, allowed to set personally relevant goals, control their learning and progression through the activity, work with peers, and self-assess their performance on the task (Gaskill & Hoy, 2002; Greene & Azevedo, 2007; Schraw, Grippen, & Hartley, 2006). Although the CREST program does not involve direct strategy instruction by trained researchers, the design of the program closely aligns with suggestions outlined in the literature regarding necessary components in SRL interventions. Considering elements of the CREST program within the context of SRL intervention research and connecting aspects of the program to the theoretical framework discussed earlier, this section provides support for the CREST award scheme as a viable pedagogical route through which to gain a better understanding of SRL and related motivations in young science students.

Educational researchers focusing on curriculum design and delivery have documented various strategies that can be employed to influence the self-regulatory behaviors of young students (Schraw et al., 2006). Among these, researchers have highlighted the implementation of inquiry-based programs, which provide students with an opportunity to focus on a process-orientated approach to learning while stimulating active engagement in the classroom (Schraw et al., 2006). Because autonomy and control over the learning process can be seen as conditions for SRL (Bergramin, Werlen, Seigenthaler, & Ziska, 2012), inquiry-based learning opportunities in the classroom may help develop SRL and self-determination in young students. This view is further supported by considering the links between White and Frederiksen's (1998) model of inquiry learning in science and the social cognitive model of SRL adopted in this study. White and Frederiksen outline that students begin the inquiry cycle by formulating a question and generating several predictions and hypotheses. Through planning and carrying out experiments, they are able to test the contradicting predictions and analyze the results. The students then apply their findings to other situations while reflecting on the limitations of what they have learned. This final phase allows students to develop new questions, and the inquiry process begins again through the same cycle of phases. The "apply" stage of White and Frederiksen's model closely aligns with the *reflection* phase of the social cognitive model of SRL described earlier. In addition, White and Frederiksen outline that the entire inquiry process is guided by carefully planned research goals, which is similar to the *forethought* component of the SRL model. Because the CREST program is a student-driven inquiry experience and considering the links between inquiry learning in science and the model of SRL adopted in this study, it is possible that the program fosters the development of SRL and self-determination among students.

Before the CREST program begins, teachers meet with a member of the CREST team (a "mentor") to become familiar with the program and obtain support regarding program administration strategies. Similar to the intervention developed by Boekaerts (1997) to develop cognitive and motivational self-regulation, the teachers in the CREST program are encouraged in this session to refrain from giving explicit procedural help to students and allow them to reflect on their learning. The program begins with teachers introducing students to CREST and allowing students to select groups of three to four peers to work with. At this point, student-led discussions regarding how to work effectively in groups also take place. In a meta-analysis of SRL interventions conducted by Dignath and Büttner (2008), larger effect sizes were found for interventions that also contained an element of group work in the program design. However, although research has shown that working in groups can provide an environment that supports and promotes active reflection, evaluation, and monitoring during inquiry activities (Silver & Marshall, 1990), educators cannot simply place students in science investigation groups and expect positive outcomes (Tobin, Tippins, & Gallard, 1994). As with SRL development, students need to be supported in learning how to work collaboratively and develop the skill set necessary for these specific learning environments (Howe et al., 2007; Tobin et al., 1994). Because the program is explicitly presented to students as a chance to develop their team working skills and effective collaborative learning strategies are discussed, the design of the CREST program seems to be in line with research suggestions regarding the development of students' abilities to reflect, evaluate, and monitor their learning in science and the support of teachers.

During the initial sessions of the program, classroom teachers work with the student groups to explore areas of interest and support students in formulating a scientific question that they are personally interested in. Through allowing students to develop their own project hypotheses and detailed methods, the program introduces students to the investigative nature of science. Relating to the literature, CREST aligns with the Self-Regulation Empowerment Program (SREP) developed by Cleary and Zimmerman (2004) to foster SRL in students. Like the SREP, the CREST program encourages students to set personal goals, monitor and reflect on their performance processes and outcomes, and make adjustments to manage independent projects. Because SRL within the framework outlined earlier involves goal-directed actions, thoughts, and feelings, providing students with opportunities to work toward goals they have set for themselves and devise their own learning experiences as part of the CREST program may also contribute to increases in SRL, particularly in the *forethought* stage (Boekaerts & Niemivirta, 2000).

Students continue to work together in their groups and conduct the experiments while reflecting on their performance and whether they are on track to reach their goals. The experiments are run during classroom teaching sessions and teacher guidance is kept to a minimum, prompting students to think for themselves and manage their projects independently. At the conclusion of the sessions, students are asked to present their projects and results to peers as well as to communicate the real-life implications of what they have found. Assessment of the projects is focused around student self-assessments and reflections. In addition, there was an element of teacher feedback.

Pintrich (2003) highlighted that future use–inspired research including intervention studies needs to understand effective ways to implement psychological theoretical principles into classrooms and to examine empirically how they work. By viewing the CREST program through a lens of educational psychology and understanding the program's influence on student SRL and related motivations, this study provides an original contribution both to educational psychology research and to science education practices. In addition, because much of the previous self-regulation intervention research is correlational (Berger & Karabenick, 2011), through evaluating the CREST program using a quasi-experimental design, this study provides longitudinal insight into fostering SRL and related motivations in young students.

AIM AND RESEARCH QUESTIONS

The central aim of this study was to explore the impact of the CREST inquiry-based learning program on young students' self-reported levels of SRL and related motivations in science. Specifically, this study aims to address two research questions presented in the following text with the corresponding research predictions:

1. Do students taking part in the CREST program during the course of the study experience different changes in self-reported levels of self-regulated processes and related motivations immediately following participation in the program compared to students in the control group?
2. Are any changes in self-reported self-regulated processes and related motivations retained 6 months after participation in CREST?

Relating to the first research question, it was hypothesized that students taking part in the program would increase in self-reported levels of self-regulatory strategies compared to students who were not taking part in the program, owing to the nature of the CREST program discussed earlier. Because the program did not involve direct instruction of cognitive strategies, it was hypothesized that smaller increases would be observed in the cognitive strategies use measure included in this study. Because of the structure of the CREST program allowing students to conduct investigations on topics they are interested in, it was predicted that students would enjoy their science learning more as well as gain a better understanding of its practical uses. These factors, in addition to successfully completing their investigations, might lead to increases in the amount of interest students have for science learning and the importance they place on it as well as their self-efficacy and career motivation in science. However, as the literature highlights the complex nature of the relationships between these constructs and self-regulatory strategies (Berger & Karabenick, 2011), no strong predictions were made.

Given the importance of performance on academic tests and remembering the affect component of the social cognitive model of SRL adopted, the impact of CREST participation on test anxiety was also investigated in this study. Predicting that the CREST program would develop self-regulation and other related motivations, it was hypothesized that taking part in CREST would also lead to reductions in students' test anxiety. Although CREST does not focus on developing test-taking skills, it is designed to impact the academic performance of young students, and, therefore, we expect that levels of test anxiety may lessen.

Because adaptations in response to environment specifically relating to self-regulation and motivation are evolutionary not instantaneous (Winne, 1995), the researchers were also interested in looking at the impact of the CREST program beyond immediate posttest. Relating to the second research question, it was hypothesized that any changes in self-reported outcome measures would be retained at 6-month delayed posttest for the students who took part in the CREST program.

METHOD

Design

This study followed a quasi-experimental design and involved a "control" group and a CREST group of students from four classes in an independent school in Edinburgh. Although all students in the year group at the school participated in the CREST program during the academic year in which this study took place, participation in the program was staggered. Therefore, students participating later in the year provided a control group for comparison. The questionnaires were administered to both groups (four classes) before and after CREST participation. Delayed posttests were administered to the original two classes making up the CREST group 6 months after program completion. Between the posttest and delayed posttest, students in the CREST group continued through the regular school term with no significant pedagogical interventions or influential events noted. The students making up the control group participated in the CREST program after the posttest measures were administered and were therefore no longer a control group.

Participants and Educational Context

Parental consent and child assent were received and data were coded following the ethical guidelines set by the British Psychological Society. Questionnaires were administered to the four classes of 20 students from one school in Edinburgh. Only students who completed both pretest and posttest were included in this study, which left 73 students, 37 (51%) females and 36 (49%) males for analysis. Of these, 39 (53%) students were participating in CREST at the time of this study and 34 (47%) were not and formed a control group. The CREST group was made up of 19 (49%) female students and 20 (51%) male students, whereas the control group comprises 18 (53%) female students and 16 (47%) male students. The mean age for CREST participants was 11.8 years ($SD = 0.4$) and the mean age for control participants was 11.5 years ($SD = 0.5$). The CREST program implementation occurred over the course of 5 weeks at the beginning of the school year.

Pretest and Posttest Measures

Three self-report measures in the field of SRL and motivation were chosen for this study aligning with the framework for understanding the constructs of interest discussed earlier. The Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich & De Groot, 1990) was selected because it has been extensively used in the literature, specifically in adolescent science education and includes scales for the motivational factors of interest. However, the MSLQ was developed more than 10 years before Pintrich finalized his 2004 framework described earlier, and it therefore does not capture the full picture of SRL. Pintrich (2004) suggested that the additional factor of context should be included within models of SRL. Therefore, in addition to using the MSLQ, MacLellan and Soden's (2006) measurement tool (a modified version of the Martinez-Pons' [2000] Five Component Scale for Self-Regulation [FCSSR]) was also included in this study because it focuses additionally on the environmental context students are learning in and has been validated in Scottish schools. Based on a social cognitive model, this modified version of the FCSSR includes goal setting, strategy monitoring, and strategy implementation subscales that together make up the measure of SRL. Both measures include three components, which we propose map well onto each other. The first being metacognitive strategies including planning, monitoring, and modifying; the second being managing and controlling efforts on tasks; and the third being cognitive strategy use.

In addition to the motivational scales on the MSLQ, the Science Motivation Questionnaire (SMQ; Glynn et al., 2009) was also chosen to provide insight into the science-specific motivations of students. Developed to take into account research literature regarding motivational components involved in the self-regulatory process with the help of science teachers and students, this 30-item questionnaire asks students to answer questions on intrinsic motivation, self-efficacy, test anxiety, and career motivation in science. Understanding that the use of self-report measures alone has been criticized pertaining to self-regulation (Winne & Jamieson-Noel, 2002; Winne & Perry, 2000), and appreciating the movement of self-regulation research toward more observational methods led by Whitebread et al. (2009), we argue that there is still value to be gained from implementing these measures when development and change of the constructs are being investigated. All measures are described in the following text relating to specific constructs of interest.

Self-Regulated Processes. The SRL strategies scales from the MSLQ (self-regulation and cognitive strategies use) and the total score on the FCSSR were used to measure self-regulated processes in this study. The self-regulation scale on the MSLQ included nine items relating to metacognitive strategies ("I ask myself questions to make sure I know the material I have been studying") and effort management ("When work is hard, I either give up or study only the easy parts"). For the cognitive strategies use scale on the MSLQ, students completed 13 items relating to the use of rehearsal ("When I read material for science class, I say the words over and over to myself to help me remember"), elaboration ("When I study for a science test, I put important ideas into my own words"), and organizational strategies ("I outline the chapters in my book to help me study"). All items were scored on a 7-point Likert scale (1= *not at all true for me*, 7 = *very true for me*). The Cronbach's alpha coefficients on these scales were .80 and .78, respectively, indicating acceptable internal reliability. The FCSSR comprises 45 items including goal setting ("When doing my academic work, I always set goals to guide me in my efforts"), strategy implementation ("I take notes during class"), and strategy monitoring ("I compare the strategy to other strategies to see which is more effective"). All items on this measure were scored on a 4-point Likert scale (1= *never*, 4 = *all the time*) and the alpha value of .92 was obtained for the overall score from the 45 items indicating excellent internal consistency. The self-determination scale from the SMQ was also included in the self-regulation analysis as described earlier. This scale was made up of four items ("If I am having trouble learning the science, I try to figure out why") that students rated on a 5-point Likert scale (1 = *never*, 5 = *always*). This final scale in the self-regulation analysis had an acceptable alpha value of .70.

Motivational Constructs

Self-Efficacy. Self-efficacy was measured using scales from the MSLQ and the SMQ. The MSLQ scale included nine items ("I expect to do very well in science class") and the alpha coefficient for this scale was .90. The SMQ scale included four items ("I believe I can master the knowledge and skills in this science course"), which students rated on a 5-point Likert scale (1 = *never*, 5 = *always*). The Cronbach's alpha calculated for this scale was .73, indicating acceptable internal reliability.

Task Value. Two measures were also used aligning with task value dimensions defined by Eccles et al. (1983), with the exception of *cost*. The nine-item intrinsic value scale from the MSLQ included items relating to *interest* ("I think what we are learning in this science class is interesting"), perceived *importance or attainment value* ("Understanding this subject is important to me"), preference for *challenge* ("I prefer class work that is challenging so I can learn new things"), and *use* ("I think what I am learning in science is useful for me to know"). The intrinsic motivation and personal relevance (IMPR) scale from the SMQ was also used and included 10 items relating to *interest* ("I enjoy learning the science"), *importance* ("The science I learn is more important to me than the grade I receive"), *challenge* ("I like science that challenges me"), and *use* ("The science I learn is relevant to my life"). The Cronbach's alpha for the MSLQ (.88) and the SMQ (.81) scales indicated good internal reliability.

Test Anxiety. Two measures were used for test anxiety: the four-item scale from the MSLQ ("I am so nervous during a test that I cannot remember facts I have learned") and the five-item scale from the SMQ ("I become anxious when it is time to take a science test") both with a higher score relating to more anxiety for taking tests. The Cronbach's alpha for the MSLQ was .69 with the mean inter-item correlation between .2 and .4, which is acceptable according to Briggs and Cheek (1986). The Cronbach's alpha calculated for the test anxiety scale on the SMQ was .72, which demonstrated acceptable internal reliability.

Career Motivation. The career motivation scale from the SMQ was used in this study and included two items relating to students' motivations to pursue science careers ("I think about how learning the science can help my career"). The Cronbach's alpha for the career motivation scale was .88, which revealed good internal reliability.

Academic Performance. Academic performance measured by the first test of the year in science (marked out of 100) was included in the analyses to investigate whether groups were matched on science achievement at the beginning of this study and to control for any differences present. Although we appreciate that a more complete picture of assessment (including investigation marks, daily quizzes, presentation, and homework marks) would be desired, because of the timing of this study, we used the performance marks available and argue that this data is sufficient to get a general sense of student ability in science and contribute to the internal validity of this study.

Pilot Work

Questionnaires were piloted with 20 students matching the target population. Items were initially reviewed by four science teachers; minor revisions were made and piloted for a second time with another 40 students. In an attempt to ensure that the program was similarly implemented among classes, the piloting process also involved observing how the two teachers implementing the program in this study administered the program with a group of students the previous year. These observations included recording the amount of time spent on the CREST program between the two teachers, documenting the nature of teacher versus student control and observing the types of projects conducted. In addition, the British Science

Association was contacted, and information regarding what quality control measures are in place for the CREST program across schools throughout the United Kingdom was obtained. The researchers felt confident that the two teachers administered the program in very similar ways and no additional teacher data was collected for this study.

Procedure

The pen-and-paper form questionnaires were administered in the classroom to students in both groups immediately prior to the CREST intervention and after its completion. Students were given up to 40 min to complete questionnaires, and completion times ranged between 25 and 35 min. Questionnaires were administered a third time to the CREST group 6 months following program completion.

Analysis

The results from the missing data analysis performed in SPSS, version 19.0, showed that there were no questions with more than 5% missing values. Therefore, no items were removed from the analyses and all composite measures presented are as published in the literature. Results from Little's missing complete at random (MCAR) test for each of the measures at pretest and posttest showed that data was missing completely at random. Therefore, listwise deletion of cases for the analyses was used and no imputation was necessary.

Preliminary analyses involved testing for violations of assumptions of normality and exploring the descriptive statistics to provide further support for parametric treatment of the data. To verify that the two groups were matched on pretest scores and provide justification for interpreting gain scores for the sample, independent-sample t tests were performed comparing the CREST and control group on all pretest measures including science performance. Because no significant differences between groups on any pretest measures were found, gain scores (posttest minus pretest) were calculated and used in the analyses. In addition, because the research questions involved investigating *changes* in student perceptions, gain score analysis was chosen over repeated measures analysis of variance (Dimitrov & Rumrill, 2003; Ganju, 2004).

Because multiple scales for similar constructs were used in this study, scores could have been standardized and collapsed into single composites for each of the constructs. However, because the results of a redundancy analysis showed that correlations between dependent measures were much smaller than the correlations within each measure, it was decided that results would be presented for the separate scales. As a result, the gain scores (posttest minus pretest) on questionnaires mapping onto similar constructs (multiple measures for self-regulated processes, self-efficacy, task value, and test anxiety) were included in multivariate analyses of covariance (MANCOVAs) controlling for academic ability in science. Leaving composite scores as presented in literature also helps to increase the generalizability of the results and the ease of interpretation of the data. Because no multivariate analyses were needed for career motivation in science, results were analyzed for this variable using one-way between-groups analysis of covariance.

Before MANCOVAs were conducted, preliminary analyses exploring gender differences were performed. Gender differences were found for the covariate of science ability, with girls (79.63) performing better on the initial science assessment than boys (71.47), $t(72) = -2.718$, $p = .008$. Because preliminary multivariate analyses revealed no main effects of gender on any of the dependent variables, gender was therefore not included in the MANCOVAs. For all multivariate tests reported in this study, preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance–covariance matrices, and multicollinearity, with no serious violations noted.

To investigate retention effects of the changes in students' self-reported self-regulated processes and related motivations, student scores on the variables at posttest and delayed posttest were compared by performing paired-samples *t* tests with Bonferroni corrections for the CREST group only.

RESULTS

Immediate Posttest Group Comparisons

Self-Regulated Processes. A one-way between-groups MANCOVA was performed to investigate group differences in self-regulatory processes controlling for science performance. Four dependent variables were used: MSLQ self-regulation, MSLQ cognitive strategies use, FCSSR total SRL, and SMQ self-determination gain scores (posttest minus pretest) with the independent variable being group membership (CREST vs. control). Although the multivariate test for the covariate of academic science performance was not significant, a statistically significant difference was found between the CREST and control groups on the combined dependent variables, $F(4, 51) = 2.884$, $p = .031$, Wilks' lamda = .816, partial $\eta^2 = .184$. This result suggests that academic performance in science does not influence the gain scores of students on these variables and that group differences are present when the four variables are considered together. When results for the dependent variables were considered separately, two variables reached statistical significance using a Bonferroni-adjusted alpha level of .013. The univariate test for the SRL gain score measured by the FCSSR was significant, $F(1, 45) = 8.491$, $p = .005$, partial $\eta^2 = .136$. An inspection of mean gain scores indicated that the control group decreased ($M_{gain} = -.120$, $SD = .425$) while the CREST group increased ($M_{gain} = .136$, $SD = .290$) in self-reported levels of SRL. Further inspection of the 95% confidence intervals around each mean indicated that there was a significant increase in self-reports of SRL for the CREST group alone. These results are in line with the first research prediction and suggest that the CREST program may be influencing students' abilities to regulate their own learning processes.

Similar to the results presented earlier for SRL, the SMQ self-determination gain score univariate test was also significant, $F(1, 54) = 6.819$, $p = .012$, partial $\eta^2 = .112$; however, the control group decreased ($M_{gain} = -.307$, $SD = .597$) while the CREST group experienced very slight increases in levels of perceived self-determination ($M_{gain} = .0263$, $SD = .598$). Further inspection of the 95% confidence intervals around each mean indicated that although the control group experienced significant decreases in self-reported levels of self-determination, the increases were not significant in the CREST group. Because it was predicted that participation in the CREST program would increase students' perceptions of control over their learning, these results are not in line with the predictions made. Table 1 shows a summary of the means and standard deviations for the scores involved in these analyses.

Motivational Constructs. MANCOVA results investigating group differences in self-efficacy scores on the MSLQ and SMQ showed no statistically significant difference between the CREST and control groups on the combined dependent variables, $F(2, 65) = 1.745$, $p = .183$, Wilks' lamda = .949, partial $\eta^2 = .051$. In addition, the multivariate test for academic performance was also nonsignificant showing that lower achieving students were no different in their gains in self-reported self-efficacy compared to higher achieving students. Multivariate tests for task value gain scores on the MSLQ and SMQ showed a statistically significant difference between the two groups on the combined dependent variables ($F[2, 64] = 3.229$, $p = .046$, Wilks' lamda = .908, partial $\eta^2 = .092$) and the multivariate test for academic performance showed no significance.

TABLE 1. A Summary of the Means (Standard Deviations) of the CREST and Control Group Scores on Self-Regulatory Measures

Groups	Pretest	Posttest	Gain Score
MSLQ self-regulation			
CREST	4.57 (.72)	4.58 (.74)	.01 (.64)
No CREST	4.62 (.99)	4.45 (.86)	−.17 (.80)
MSLQ cognitive strategies use			
CREST	4.74 (.62)	4.66 (.80)	−.08 (.64)
No CREST	4.81 (.79)	4.53 (1.28)	−.23 (1.11)
FCSSR total SRL			
CREST	2.48 (.35)	2.58 (.44)	.14 (.29)
No CREST	2.56 (.40)	2.44 (.57)	−.12 (.39)
Self-determination			
CREST	3.74 (.72)	3.77 (.62)	.02 (.60)
No CREST	3.91 (.62)	3.61 (.72)	−.31 (.60)

Note. CREST = CREativity in Science and Technology; MSLQ = Motivated Strategies for Learning Questionnaire; FCSSR = Five Component Scale for Self-Regulation; SRL = self-regulated learning.

Results from the univariate test for MSLQ intrinsic value were significant (F[1,65] = 5.316, p = .024, partial η^2 =.076) at the Bonferroni-adjusted alpha level of .025. An inspection of the 95% confidence intervals around each mean shows that although both groups decreased, only the control group experienced significant decreases ($M_{\text{gain}} = -.512$, $SD = 1.21$) in perceptions of intrinsic value. Because Levene's test of equality of error variances was significant for SMQ IMPR, a more conservative alpha level of .01 was used following the recommendations of Tabachnick and Fidell (2007). At this level, a nonsignificant univariate test for this variable was found, $F(1, 65) = 1.028$, $p = .041$, partial $\eta^2 = .063$. These results relating to self-efficacy and task value are not in line with the increases that were predicted in these variables through CREST participation. A summary of the means and standard deviations for all motivational constructs is presented in Table 2.

Multivariate results investigating group differences in test anxiety gain scores on the MSLQ and SMQ while controlling for academic performance in science showed a statistically significant difference between the CREST and control groups on the combined dependent variables, $F(2, 64) = 5.012$, $p = .010$, Wilks' lamda = .865, partial $\eta^2 = .135$. Because Levene's test of equality of error variances on SMQ test anxiety was significant, a more conservative alpha level of .01 was used as earlier. When results for dependent variables were considered separately, the univariate test for SMQ test anxiety reached statistical significance using a Bonferroni-adjusted alpha level of .01/2, $F(1, 65) = 9.305$, $p = .003$, partial $\eta^2 = .126$. With a Bonferroni-adjusted alpha of .05/2, the univariate test for test anxiety as measured by the MSLQ was nonsignificant, $F(1, 65) = 4.776$, $p = .032$, partial $\eta^2 = .068$. The multivariate test for academic performance was also nonsignificant. An inspection of the gain scores shown in Table 2 indicates that the control group decreased in levels of test anxiety on both measures while the CREST group increased. Together, the results from the two measurement scales suggest that, contrary to our prediction, participation in the CREST program resulted in increased levels of test anxiety among students, and this increase was not influenced by pretest academic performance.

A one-way between-group analysis of covariance was also performed investigating group differences in science-specific career motivation measured on the SMQ. After adjusting for

TABLE 2. A Summary of the Means (Standard Deviations) for Self-Efficacy, Task Value, Test Anxiety, and Career Motivation for the CREST and Control Groups

Groups	Pretest	Posttest	Gain Score
MSLQ self-efficacy			
CREST	4.55 (0.76)	4.49 (0.93)	−.06 (0.72)
No CREST	4.64 (0.97)	4.43 (1.31)	−.19 (1.21)
SMQ self-efficacy			
CREST	3.61 (0.51)	3.54 (0.61)	−.08 (0.55)
No CREST	3.71 (0.62)	3.80 (0.64)	.12 (0.47)
MSLQ intrinsic value			
CREST	4.95 (0.76)	4.86 (0.90)	−.06 (0.83)
No CREST	5.08 (1.04)	4.52 (1.31)	−.51 (1.21)
SMQ IMPR			
CREST	3.40 (0.48)	3.55 (0.53)	.14 (0.36)
No CREST	3.46 (0.66)	3.35 (0.85)	−.11 (0.57)
MSLQ test anxiety			
CREST	3.25 (1.04)	3.76 (1.22)	.51 (1.20)
No CREST	3.06 (1.22)	2.94 (1.09)	−.14 (1.24)
SMQ test anxiety			
CREST	2.78 (0.63)	2.99 (0.80)	.27 (0.87)
No CREST	2.69 (0.81)	2.43 (0.78)	−.28 (0.56)
Career motivation			
CREST	3.27 (1.12)	3.71 (0.97)	.43 (0.96)
No CREST	3.06 (1.08)	2.97 (1.22)	−.09 (0.93)

Note. CREST = CREativity in Science and Technology; MSLQ = Motivated Strategies for Learning Questionnaire; SMQ = Science Motivation Questionnaire; IMPR = intrinsic motivation and personal relevance.

academic performance at pretest, there was a statistically significant difference between the CREST and control groups on the dependent variable, $F(1, 70) = 5.498$, $p = .022$, partial $\eta^2 = .073$. Further inspection of the 95% confidence intervals around the means shows that while the CREST group experienced significant increases in levels of perceived career motivation, the control group decreased. These results support our prediction that participation in the CREST program has a positive impact on career motivations in science. A summary of means and standard deviations are also included in Table 2.

Although the use of gain score analysis was justified for this study, an appreciation of where students were on the scales at both pretest and posttest is important to contextualize the gains. Results from correlation analyses investigating the relationships between pretest scores and gains scores for all variables in this study showed that higher pretest scores led to smaller gains. These results will be considered when interpreting the findings.

Delayed Posttest Comparisons for the CREST Group

Table 3 provides a summary of the means on all posttest and delayed posttest measures for the CREST group of students who completed both posttest and delayed posttest questionnaires.

TABLE 3. A Summary of the Means (Standard Deviations) of Scores on Posttest and Delayed Posttests and Paired-Samples *t*-Tests Results

Measure	Score	t	p (two tailed)
MSLQ self-regulation			
Posttest	4.57 (0.77)	1.042	.305
Delayed posttest	4.44 (0.65)		
MSLQ cognitive strategies use			
Posttest	4.60 (0.78)	−1.315	.198
Delayed posttest	4.78 (0.58)		
FCSSR total self-regulation			
Posttest	2.57 (0.44)	−1.310	.022[a]
Delayed posttest	2.44 (0.45)		
SMQ self-determination			
Posttest	3.72 (0.62)	−0.485	.631
Delayed posttest	3.76 (0.59)		
MSLQ self-efficacy			
Posttest	4.43 (0.93)	−1.710	.096
Delayed posttest	4.64 (0.86)		
SMQ self-efficacy			
Posttest	3.53 (0.58)	−1.431	.134
Delayed posttest	3.69 (0.60)		
MSLQ intrinsic value			
Posttest	4.85 (0.92)	−0.638	.528
Delayed posttest	4.93 (0.70)		
SMQ IMPR			
Posttest	3.50 (0.52)	−1.310	.199
Delayed Posttest	3.61 (0.59)		
MSLQ test anxiety			
Posttest	3.70 (1.25)	−1.536	.134
Delayed posttest	3.97 (1.13)		
SMQ test anxiety			
Posttest	3.10 (0.76)	−1.587	.122
Delayed posttest	3.47 (0.74)		
SMQ career motivation			
Posttest	3.67 (1.00)	−0.780	.441
Delayed posttest	3.79 (0.90)		

[a]Nonsignificant at Bonferroni-adjusted alpha value.

Differences between the means were tested using paired-samples t tests with a Bonferroni-corrected significance value and are shown in Table 3. From Table 3, it can be seen that no significant differences were found (at the adjusted alpha value) on any of the variables measured at posttest and delayed posttest. We interpret this result to show that the significant gains in levels of perceived SRL, test anxiety, and science career motivation presented earlier were retained.

DISCUSSION

The Impact of CREST on Student Self-Reports

The results presented in this study regarding SRL align with our prediction that participating in this program fosters the development of this process among students. Giving students the opportunity to control and evaluate their learning and work collaboratively with peers toward their goals seems to influence their ability to self-regulate their science learning. Considering these results in the context of the declining trends in SRL over the school term reported by Berger and Karabenick (2011) highlights the significance of these findings further. Regarding self-determination, although the group of students taking part in the CREST program showed no significant increases in their self-reports, the control group of students experienced significant decreases in self-reported levels of self-determination. Although these results are not directly in line with the research predictions made, they highlight the possibility that self-determination decreases throughout the school year and that participating in the CREST program may help to reduce the likelihood of these decreases. It is important to note at this point that significance was not found on the MSLQ self-regulation scale. Because the FCSSR has an entirely SRL focus, it is possible that it is a more sensitive measure compared to the MSLQ. These findings highlight the need for researchers to appreciate the multifaceted nature of self-regulatory processes and suggest that a deeper understanding of the specific aspects of the construct being measured by each tool is needed. The nonsignificant results relating to cognitive strategies use were in line with our research predictions because the CREST program does not involve direct strategy instruction.

We interpret the lack of significant changes in levels of SRL on the 6-month delayed posttest as evidence that the developments seen at immediate posttest were retained. However, it should be noted that nonsignificant decreasing trends were found. Although decreasing trends over the course of the school year are common (Berger & Karabenick, 2011), this result may suggest that something needs to be in place to build on any developments gained through participation in the CREST program. These findings may also suggest that the self-regulatory skills developed through CREST participation need to be reinforced in other curriculum subjects to improve retention. Although no differences were noted between the school experiences of the control and CREST groups in the 6 months following the program—because no delayed posttest data was available for the control group—the earlier interpretations were made cautiously.

The findings of this study regarding self-efficacy and intrinsic motivation did not align with our predictions. Results showed no significant differences between groups regarding changes in self-efficacy and, although significant differences were found regarding task value, the CREST group of participants did not show any significant increases. One possible interpretation of these results is that the CREST program did not provide an optimal arena in which to develop these motivational capacities. However, as Boekaerts (1997) stated that students cannot become self-regulated and motivated learners overnight, it is also possible that the intervention was successful in creating the learning environment required to develop these processes, but that more sessions were needed. In terms of self-efficacy, the results may also be explained by the fact that CREST presents a unique and challenging situation to students who may not be experienced in dealing with this amount of control for their learning. As a result, it is possible that students have low self-judgments of their abilities in science immediately after taking part in CREST, and that any benefits related to improved self-efficacy would only be seen on the delayed posttests. Results from the delayed posttests showed that although nonsignificant, students did increase in their self-reports of self-efficacy 6 months after taking part in the CREST program. It is therefore possible that participation does influence the development of self-efficacy in students, but that these benefits take a while to come to the surface. Although the results showed no increases in task value for the CREST group, significant decreases were found in the control group. From this, we could infer that like SRL, task value also decreases throughout the academic year for most students, and that the CREST program may help to limit these decreasing trends.

The prediction that the CREST program would reduce students' levels of test anxiety was also not met because the results showed that test anxiety increased for students who participated in CREST. It is possible that the CREST program does not prepare students for the transition back into test taking. Because results for SRL in this study demonstrate that participation in CREST makes students more aware of their learning, this elevated awareness might also explain the increase seen in students' levels of test anxiety (Kurosawa & Harackiewicz, 1995; Zohar, 1998). The results regarding career motivations in science at immediate posttest align with our prediction that taking part in the CREST program increases students' desire to pursue science careers. In addition, considering the results of the delayed posttests for career motivation, we found that these enhanced motivations were retained 6 months after CREST participation. Because the program introduces students to the investigate nature of science and provides them with an opportunity to act as researchers themselves, participation may give students a different picture of what being a scientist would really be like. Together, these findings provide strong support for the efficacy of this intervention as a strategy to encourage postsecondary science enrollment and the pursuit of science careers.

Although gain score analysis was deemed appropriate to address the specific research questions for this study, additional analyses were included to provide more insight into the nature of the gains experienced. The results from these analyses demonstrated that students who came into this study with high self-reported levels on the variables measured experienced smaller gains than students with low pretest scores. These results may be interpreted in several different ways providing different sets of implications for practice. Intuitively, these results make sense given that students who are already demonstrating high levels of regulatory processes and who possess strong motivations for their learning in science may not have as much capacity to develop these further. However, these results may also be explained in relation to the self-report measures used in this study. It is possible that students at the top end of the self-regulatory and motivational spectrums were not able to report the increases they felt. Further research involving median split variance analyses is needed to gain further insight into this issue.

Finally, because groups were matched on science performance at pretest, and because results showed that science performance did not predict how much benefit students received from the CREST program regarding their self-reports of self-regulated processes and related motivations, these results have important implications for designing interventions. A recent trend in educational research highlights the importance of allocating students to different intervention treatment intensities depending on baseline aptitudes (Barnett, Daly, Jones, & Lentz, 2004). The results presented here suggest that this is not necessary regarding the CREST program, and that this program does not need to be adjusted based on student performance levels in science.

Methodological Considerations and Future Research

This study does not escape the limitations of similar quasi-experimental projects in educational research. Although significant findings have been presented, the limitations regarding the practical significance of these findings need to be discussed. First, it is possible that group differences may have resulted from teacher effects and other confounding background factors not explored in this study. Although efforts were made to reduce confounding variables, the authors do not ignore the possibility of differences in treatment compliance between teachers regarding the guidelines for implementing CREST and the internal validity threats because of the lack of other key background variables.

This study involved students from only one school in Edinburgh, and therefore any generalizations need to be made cautiously. In addition, because all students were in the same year group, it is possible that students in both groups communicated with each other regarding the program. Although this might influence the results by reducing intervention effects and therefore providing further support for any significance reported in this study, it is possible that communication between students heightened the CREST students' awareness of the intervention, thus positively affecting their self-reports of self-regulated processes and related motivations.

In using self-report measures, this research assumes that students have the ability to verbally express their cognitions; however, it is possible that young students are incapable of identifying and recalling their mental processes (Whitebread et al., 2009). This could present a problem for this study because students may be using strategies but not possessing the conscious awareness that they are doing so. In addition, because this study did not include any measure of students' perceptions of the classroom context, there may be further reason to question the validity of the results. Taking these issues into consideration, structured interview protocols developed by Zimmerman and Martinez-Pons (1986) and observational tools to assess levels of student self-regulatory processes have been piloted. Questions relating to students' perceptions of the CREST program as a strategy to develop SRL and motivation were also included in the interviews. Future plans for this research include comparing the student self-report measures with the qualitative results from the interviews and classroom observations. A final limitation worth mentioning here is the presence of power issues in this study. It is possible that the sample involved in this study was not large enough to detect significant trends. However, because this study is part of a larger intervention study, the presence of these power issues will—it is hoped—be resolved with the larger sample of more than 500 students.

CONCLUSIONS

The results of this study revealed that participation in the CREST program had a significant impact on students' levels of perceived SRL, test anxiety, and career motivation in science. Although this study, as part of a series of intervention studies, supports the curricular potential of the CREST program both for enhancing SRL and limiting decreases in motivations over the course of the school year, conclusions regarding causal effects are drawn cautiously. The findings also showed that student scores for the specific constructs measured depended on the particular measure administered for that construct. It is therefore possible that these measures, which at surface level investigate similar constructs, are possibly investigating different components within them. These findings provide support for the complexity of the conceptual nature of SRL and highlight the need for important discussions of methodological and conceptual issues relating to self-regulation and the appropriateness of the SRL measurement tools available in the literature. Appreciating the limitations of this quasi-experimental study, the value of this research for pedagogical purposes is clear in terms of helping to persuade teachers and policy makers that the CREST program warrants further study.

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Appendix E

1. Teacher Perspectives of the CREST programme

Administered following participation in the studies

Perspectives of the CREST Programme

Teacher Name: ___________________________

Please put an x beside the number you feel appropriately represents your response for each of the choice questions and type your answers into the space provided for the open answer questions below.

1. Did you enjoy having your students participate in the CREST programme?

1	2	3	4	5	6	7	8	9
Not at all				Somewhat				Extremely

2. What aspect of the programme did you enjoy most?

3. Did you have any difficulty implementing the CREST programme in your classroom?

1	2	3	4	5	6	7	8	9
A little				Moderate				Extreme

4. Do you think the programme benefits students?

1	2	3	4	5	6	7	8	9
Not at all				Moderately				Extremely

5. In what ways do you think it benefits the students? What do they enjoy most about the CREST programme?

6. Where the students resistant at all to the programme?

1	2	3	4	5	6	7	8	9
Not at all				Moderately				Extremely

7. How satisfied are you with the support provided to you on how to administer the programme to your students?

1	2	3	4	5	6	7	8	9
Not at all satisfied				Some what satisfied				Extremely satisfied

8. Do you feel that you followed the guidelines given to you on how to conduct the programme to the standard expected?

1	2	3	4	5	6	7	8	9
Not at all				Some what				Extremely

9. Would you recommend the CREST programme to fellow teachers?

1	2	3	4	5	6	7	8	9
No				Maybe				Absolutely

10. Do you have any recommendations on ways in which the CREST programme can be improved? Either for teacher usability or student enjoyment and benefit?

Thank you for your time!!!