Developing Information Technology learners' critical thinking skills: Implications for Self-Directed Learning

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DECLARATION

I the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature

___26/10/15__

Date

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ABSTRACT

DEVELOPING INFORMATION TECHNOLOGY LEARNERS' CRITICAL THINKING SKILLS: IMPLICATIONS FOR SELF-DIRECTED LEARNING

Critical thinking in the Information Technology classroom is a concept of importance in this day and age where learners are bombarded with information and faced with a subject that is constantly changing. This study focused on the development of critical thinking skills in the Information Technology classroom and the influence of critical thinking development on learners' Self-Directed Learning. Self-Directed Learning is described by Knowles (1975:18) as a process where an "individual takes responsibility for his/her own learning by taking initiative in diagnosing his/her learning needs, formulating learning goals, identifying human and material resources needed for learning, choosing and implementing appropriate learning styles and evaluating the learning outcomes". In an era where learners need the ability to think critically about information and keep up with the changes that surround them in the Information Technology subject (where computer programming makes up 60% of the subject and is generally seen as difficult), Self-Directed Learning and critical thinking increase learners' likelihood of succeeding in the subject.

To investigate the development of critical thinking in the Information Technology classroom and its effect on Grade 10 Information Technology learners' Self-Directed Learning, a quasi-experimental study was conducted among Grade 10 Information Technology learners from three provinces in South Africa. The study consisted of four groups (one control group and three experimental groups) all of which were randomly selected from the schools who opted to participate in the study. At the beginning of the study, all four groups in the study completed the Cornell Critical Thinking Test – Level X as well as the Self-Directed Learning Instrument by Cheng *et al.* (2010). During the intervention, experimental group one (critical thinking instruction [CTI] group) implemented deliberate critical thinking strategies, experimental group two (critical thinking instruction infused into pair programming [CTI+PP] group) implemented critical thinking strategies infused into PP, and experimental group three ([PP] group) only implemented pair programming in the class. After approximately six weeks, the two questionnaires given at the onset of the study were once again distributed. The Grade 10 learners completed narratives during the post-test phase of the study. Grade 10 Information Technology teachers participated in semi-structured interviews at the onset of the study as well as at the end of the study in order to establish their experiences of the suggested strategies to develop critical thinking.

The results yielded from the study showed that pair programming (as a cooperative learning strategy) holds the greatest advantages regarding critical thinking and Self-Directed Learning development for Grade 10 Information Technology learners. Success, for any teaching–learning strategy, is however dependent on the implementation and willingness of teachers.

Key words:
Critical thinking, Socratic Method, pair programming, Information Technology education, Computer Science education, cooperative learning, Self-Directed Learning

OPSOMMING

ONTWIKKELING VAN INLIGTINGSTEGNOLOGIE-LEERDERS SE KRITIESE DENKVAARDIGHEDE: GEVOLGE VIR SELF-GERIGTE LEER

Kritiese denke in die Inligtingstegnologie-klaskamer is ŉ waardevolle begrip in die moderne lewe waar leerders oorval word met inligting en waar die vak voortdurend besig is om te verander. Hierdie studie was op die ontwikkeling van kritiese denkvaardighede in die Inligtingstegnologie-klaskamer gefokus en wou vasstel wat die invloed van die ontwikkeling van kritiese denke op leerders se self-gerigte leer is. Self-gerigte leer word deur Knowles (1975:18) gedefinieer as ŉ proses waar ŉ individu verantwoordelikheid aanvaar vir sy/haar leer deur die inisiatief te neem om sy/haar leerbehoeftes te identifiseer, leerdoelwitte te formuleer, gepaste hulpbronne en gepaste leerstyle te kies en leeruitkomste te evalueer. In ŉ era waar leerders oor die vermoë moet beskik om krities met inligting om te gaan en by te bly met die veranderinge wat hulle omring in die Inligtingstegnologie-vak (waar programmering 60% van die vakinhoud uitmaak en oor die algemeen as moeilik beskou word), sal self-gerigte leer en kritiese denke leerders se kanse op sukses verbeter.

Om die ontwikkeling van kritiese denke in die Inligtingstegnologie-klaskamer en die uitwerking daarvan op graad 10 Inligtingstegnologie-leerders se self-gerigtheid te ondersoek, is ŉ kwasi-eksperimentele studie onderneem. Graad 10 Inligtingstegnologie-leerders van drie provinsies in Suid-Afrika het deelgeneem. Die studie het uit vier groepe bestaan (een kontrolegroep en drie eksperimentele groepe) wat almal ewekansig gekies is uit die skole wat ingestem het om aan die studie deel te neem. Aan die begin van die studie is al vier groepe gevra om die Cornell Critical Thinking Test – Level X-vraelys en die Self-Directed Learning Instrument-vraelys van Cheng *et al.* (2010) te voltooi. Gedurende die intervensie het eksperimentele groep een (betrokke by die onderrig van kritiese denke) doelbewuste kritiese denkstrategieë geïmplementeer, eksperimentele groep twee (betrokke by die onderrig van kritiese denke gepaard met paarprogrammering) het kritiese denkstrategieë geïntegreer met paarprogrammering geïmplementeer, en eksperimentele groep drie (paarprogrammeringgroep) het slegs paarprogrammering geïmplementeer. Ná sowat ses weke is dieselfde twee vraelyste weer voltooi. Die graad 10-leerders het ook narratiewe gedurende die na-toetsfase voltooi. Graad 10-onderwysers in die eksperimentele groepe het aan semi-gestruktureerde onderhoude deelgeneem om sodoende hulle ervaring van die voorgestelde strategieë vas te stel.

Die studie het bewys dat paarprogrammering (as ŉ koöperatiewe leerstrategie) die meeste voordele rakende die ontwikkeling van kritiese denke en selfgerigte leer vir graad 10

Inligtingstegnologie-leerders inhou. Die sukses van enige onderrig–leerstrategie is afhanklik van die implementering en gewilligheid van die onderwyser.

Sleutelwoorde:
Kritiese denke, Sokratiese Metode, paarprogrammering, Inligtingstegnologie-onderwys, Rekenaarwetenskaponderwys, samewerkende leer, self-gerigte leer

TABLE OF CONTENTS

CONTENT

CHAPTER 1: INTRODUCTION

CHAPTER 2: CRITICAL THINKING SKILLS: A THEORETICAL APPROACH

CHAPTER 3: TEACHING–LEARNING STRATEGIES CONDUCIVE TO THE DEVELOPMENT OF CRITICAL THINKING SKILLS IN THE INFORMATION TECHNOLOGY CLASSROOM

CHAPTER 4: SELF-DIRECTED LEARNING: A NECESSITY FOR INFORMATION TECHNOLOGY TEACHING AND LEARNING

CHAPTER 5: RESEARCH DESIGN AND METHODOLOGY

CHAPTER 6: DATA ANALYSES AND RESEARCH RESULTS

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

ASCSC	Australian Schools Computer Skills Competition
CAPS	Curriculum and Assessment Policy Statement
CCTDI	California Critical Thinking Disposition Inventory
CCTST	California Critical Thinking Skills Test
CCTT	Cornell Critical Thinking Test
CIQ	Critical Incident Questionnaire
CL	Cooperative Learning
CT	Critical Thinking
CTD	Critical Thinking Dispositions
CTI	Critical Thinking Instruction
CTS	Critical Thinking Skills
DVD	Digital Video Disc
e-SOLMS	e-Student-Oriented Learning Management System
ICAT	International Centre for the Assessment of Thinking
IPIP	International Personality Item Pool
IT	Information Technology
LTIQ	Level of Technology Implementation Questionnaire
MSLQ	Motivated Strategies for Learning Questionnaire
NCS	National Curriculum Statement
PP	Pair Programming
PRO-SDLS	Personal Responsibility Orientation to Self-Direction in Learning Scale
SCT	Socio-Cognitive Theory
SDL	Self-Directed Learning
SDLI	Self-Directed Learning Instrument
SRSSDL	Self-Rating Scale of Self-Directed Learning
TER	Test of Everyday Reasoning
W–G CTA	Watson–Glaser Critical Thinking Appraisal

CHAPTER 1
INTRODUCTION

1.1. BACKGROUND TO PROBLEM STATEMENT AND INTELLECTUAL CONUNDRUM

Critical thinking (CT) has been coined as one of the most important life skills needed to be successful in life, and subsequently it has gained great emphasis in educational discourses (Hyslop-Margison, 2003). CT is associated with all levels of education (Tiwari *et al*., 2006) and is a prime objective of education worldwide (Fahy, 2005) in order to assist learners with becoming lifelong learners (Paul & Elder, 2005).

One of the main reasons provided as to why CT is of vital importance is the fact that we live in an Information Age where individuals are daily confronted by a magnitude of information and therefore need to know how to distinguish between truths and untruths (Lorenzo & Dziuban, 2006). Paul and Elder (2005) note that accelerating changes in the world and intensifying complexities of life necessitate the importance of critical thinking skills (CTS) development.

Several studies (Paul & Elder, 2005; Stupnisky *et al*., 2008; Tiwari *et al*., 2006) have been conducted regarding the measurement of CT as well as students' critical thinking disposition (CTD) (whether students know when to apply CTS); however, few empirical studies have been conducted regarding the effectiveness of critical thinking instruction (CTI) (Lampert, 2007). In a study conducted by Innabi and Sheikh (2007) in Jordan with secondary school Mathematics teachers, they found that teachers agree with the importance of CT and claim that they are supposed to teach CT, yet do not do so.

The case in South Africa is not much different as illustrated by Lombard and Grosser (2008) where first-year education students' CTS were tested to see whether the outcomes-based education ideology (with its emphasis on CTS) had been realised. What Lombard and Grosser found, however, was that the students produced by the outcomes-based education system did not display CTS. Other studies regarding the accomplishment of CT and the outcomes-based education system in South Africa have also been conducted (Belluigi, 2009; Chabeli, 2006). The aforementioned studies were all conducted at tertiary level without a tangible contribution to high school application of the development of CTS, leaving a gap in CT research at high school level.

In South Africa, Information Technology[1] (IT) is one of the many elective subjects Grade 10 learners may select. The IT syllabus consists of five main topics of which software development/computer programming makes up 60% of the subject matter (Department of Basic Education, 2012). Computer programming has been noted as being difficult (Teague & Roe, 2008) whether at high school level or tertiary level. In order to foster successful programming skills, teachers need to shift the focus of their classes from teaching the memorisation of programming syntax to the facilitation of the development of skills conducive to successful programming. One of the skills proposed to contribute to the success of programming was CTS. Fagin *et al.* (2006) note that when assisting learners with the development of CTS, computer programming skills increased significantly. One method proved to assist learners in their acquisition of CTS was that of cooperative learning (CL) (McWhaw *et al*., 2003). Not only does CL assist in the development of CTS, but also in the acquisition of computer programming skills (Mentz *et al*., 2008).

In the past few years alone, the programming language had changed several times, access to information for assignments had grown and most importantly, the computer science world had never and would never be stagnant. IT learners should be self-directed in order to keep up with these changes. It was therefore important to foster CTS in the IT classroom and ultimately contribute to more Self-Directed Learning (SDL).

The problem to be addressed was whether the intentional development of CTS of IT learners had an influence on their self-directedness.

To address this intellectual conundrum pose, the study was directed by the following primary research question:

How can critical thinking be fostered in the Information Technology classroom and what is the influence on learners' Self-Directed Learning?

The primary research question was answered by focusing on several secondary research questions. These questions were:

1. What do CT and SDL entail?
2. What is the importance of CT and SDL in education and specifically in the IT classroom?
3. How can CTS be developed in the IT classroom?

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[1] Information Technology as school subject can be seen as synonymous with Computer Science Education

4. What is the influence of a CL environment on the development of CTS?
5. What is the influence of the intentional development of CT in the IT classroom on IT learners' CTS?
6. To what extent, if any, do CTS foster SDL?
7. How should the IT teacher support learners to develop CTS?

To address these questions, a brief review of scholarly literature will follow. In Chapters 2, 3 and 4, an in-depth investigation of the body of scholarship regarding the key concepts of the study will be presented, while section 1.2 briefly analyses and considers the three main concepts of the study in an attempt to bring them in relation to one another to establish a conceptual framework.

1.2. CONCEPTUAL FRAMEWORK

The conceptual framework provides a theoretical clarification of what one wants to study, what one wants to achieve and how this will be achieved (Trafford & Leshem, 2008). For this study, the three main concepts were CT, SDL and CL as illustrated in Figure 1.1, which presents an adaption of Trafford and Leshem's (2008) figure on the conceptual framework. These concepts were integrated to form the conceptual framework for this study, based in the socio-cognitive theory (SCT) and are discussed in sections 1.2.1–1.2.3.

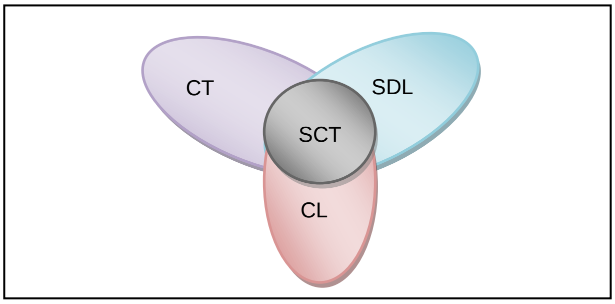


Figure 1.1 Adaption of Trafford and Leshem's (2008) figure on the conceptual framework

1.2.1. Critical thinking

CT is one of the oldest approaches to thinking, dating back to the times of philosophers like Socrates (the father of CT) and Aristotle (Alazzi, 2008). Defining CT can be a difficult task (Halpern, 2003); however, several definitions could be found in the body of scholarship.

In 1941, Glaser moved beyond John Dewey's 'reflective thinking', and added components of reasoning when he defined CT as an approach to thinking where one considers all aspects of an experience by making use of certain methods of inquiry and knowing how to utilise these methods of inquiry appropriately to either solve a problem, reject or accept an experience (Glaser, 1941). Facione (1990) conducted a Delphi study where a panel of 46 experts were interviewed in six rounds to establish various aspects regarding CT. Regarding the definition of CT, Facione's Delphi report states that experts concluded that CT includes application of cognitive skills (interpretation, analysis, evaluation, inference, explanation and self-regulation) (Facione, 1990). Scriven and Paul (2004) in their attempt to define CT noted CT as a mode of thinking where cognitive structures are utilised by imposing specific intellectual standards upon them – regardless of the subject matter. Halpern's (2003) definition of CT coincides with Scriven and Paul's definition in that she regards CT as a cognitive process used to achieve the most desirable outcome. In her development report on CT, McAllister (2009) summarises all these definitions and accepts Facione's definition of CT by stating that CT is a "purposeful and self-regulatory cognitive process" where one makes use of "higher-order thinking skills" (interpretation, analysis, evaluation and inference) to "make a judgement" and in doing so state the "explanation of evidence, methods, criteria and contextual considerations" which influence this judgement. This definition was the accepted definition in the current study.

With the definition of CT in mind, it is important to take note that CT does not only include cognitive and metacognitive skills but also self-regulation, an aspect necessary for a self-directed learner.

1.2.2. Self-Directed Learning

The most commonly used definition of SDL is that of Knowles (1975:18), who describes SDL as a process where an "individual takes responsibility for his/her own learning by taking initiative in diagnosing his/her learning needs, formulating learning goals, identifying human and material resources needed for learning, choosing and implementing appropriate learning styles and evaluating the learning outcomes".

In his book, *The Self-Directed Learning handbook*, Gibbons (2002) describes six skills needed for SDL. A self-directed learner should be able to ask questions, find relevant information, analyse a situation, make thoughtful decisions, determine his/her own point of view (based on judgement) and test if the point of view/judgement is correct (Gibbons, 2002). In addition to Gibbons' description of skills, Long *et al*. (2005) in their study found that professors in Hong Kong, interviewed in their study, noted seven tasks for which learners are responsible in an SDL setting. These tasks are that the learner should understand the coursework, attend classes, actively participate in lectures, execute assignments, be prepared for class, engage in small group discussions and participate in the field of study (Long *et al*., 2005).

From the definitions of SDL (noted earlier), two aspects are clear. Firstly, SDL, as defined by Knowles, correlates with aspects from CT, e.g. higher-order thinking skills, decision-making skills and reflection skills (Aksal *et al*., 2008), and secondly, SDL does not stand in solitude (Peters & Gray, 2005) and is better achieved through collaborative/CL (Donaghy, 2005).

During CL, individuals can share their ideas allowing them to process several points of view thoughtfully, argue with each other leading to the use of higher-order thinking skills, gather the necessary information from each other to complete a task successfully and reflect on how they (as a group) came to the conclusions and judgements made. Although these skills are correlated with CTS, they also correlate with Gibbons' view of what a self-directed learner should be able to do (Gibbons, 2002).

The following section reports on CL as an attempt to place it within the study's conceptual framework.

1.2.3. Cooperative learning

The terms 'cooperative learning' and 'collaborative learning' have often been used interchangeably in many studies regarding group work (McWhaw *et al*., 2003). McWhaw *et al*. further mention that CL is described as structured group work, whereas collaborative learning is often unstructured group work (a characteristic which often causes group work to fail). Johnson and Johnson (2008) describe CL as the use of group work where students work together to maximise not only their own learning but also the learning of others.

After much study in the field of group work and CL, Johnson and Johnson (2009) contend that there are five basic elements to be adhered to for successful CL:

- positive interdependence – where the individuals in the group realise that "we all sink or swim together"; therefore, the group's success also reflects the individual's success (Johnson & Johnson, 2009:107);
- individual accountability – where the individual realises that he/she has an individual responsibility towards the group and that he/she will be held accountable as an individual in the group (Johnson & Johnson, 2009:110);
- promotive face-to-face interaction – where group members assist one another by providing guidance and resources as well as challenging each other's reasoning and judgements (Johnson & Johnson, 2009:111);

- appropriate use of social skills – an attempt to assist group members in the acquisition of social skills (communication skills, praising skills, supporting skills, etc.) in order to contribute to the success of the group (Johnson & Johnson, 2009:111);
- group processing – the metacognitive factor in the group work process where the group has the opportunity to assess and evaluate their progress, strengths and weaknesses and identify aspects which could have been done better or were executed well (Johnson & Johnson, 2009:112).

The above-mentioned five basic elements of CL not only promotes student learning but also CTS and the transfer of learning (McWhaw *et al*., 2003).

In the previous paragraph, the conceptual framework for this study was explained in terms of CT, SDL and CL. CT is an important concept in education and in IT specifically. SDL can be seen as the educational outcome of this study as IT learners need to be equipped to cope with the changes brought about in this subject and take responsibility for their own learning. CL is conducive to both CT and SDL development as learners have the opportunity to argue with one another and learn to take individual responsibility for learning (enforced by the positive interdependence and individual accountability). In the light of the five elements of CL it is viable to position the three concepts within a SCT of learning. SCT can be defined as a social approach that extends beyond the social learning theory in that it "acknowledges the joint roles of cognitive factors, self-beliefs, and environmental factors in human learning" (Winne & Hadwin, 2011:34) and can be seen as the crystallisation of the three concepts as CL is seen as conducive to CT and SDL development.

With the conceptual framework for the study established, the following section describes the body of scholarship consulted regarding these three main concepts.

1.3. REVIEW OF SCHOLARLY LITERATURE

Many researchers have attempted to design appropriate methods for the development of CTS and, although most agree that teaching CT is a good idea, it remains hard work to develop CT appropriately (Dunn *et al.*, 2008). CT, however, can be taught (Lai, 2011).

In her book, *Critical thinking*, Dr Jennifer Moon describes several activities, which she designed to stimulate CT in various representations (Moon, 2008). These activities include making use of direct methods, research-based activities, real-life scenarios, out-of-class activities, reflection activities, assessment activities, oral activities, writing and reading activities, critical analysis of others' work, argument activities, reasoning and logic activities. Similar to Moon's suggested activities for the development of CTSs, McAllister (2009) notes that the activities conducive to the development of CTSs are reading activities, writing activities, direct coaching, mentoring of students and group work activities, which all contribute to the successful development of CTSs. Fagin *et al*. (2006) describe how programming skills are improved through the development of CTSs.

Although computer programming was traditionally viewed as a solitary activity where an individual struggles through coding alone, the necessity of programmers to have the skills to work with others has been said to be a prerequisite stemming from the computer programming industry (Balijepally *et al*., 2009). Researchers like Williams and Kessler (2003) and Mentz *et al.* (2008) have proved that the application of collaborative and CL in computer programming significantly increases the success of programmers.

During pair programming (PP), two programmers work together on one computer to execute a programming task (Williams & Kessler, 2003). One of the programmers serves as the 'driver' and the other serve as the 'navigator' (Williams & Kessler, 2003). The driver's role is to type and write all the code necessary, whereas the navigator is responsible for gathering information and resources and assisting the driver in the coding process. Mentz *et al*. (2008) applied PP in a computer programming module at tertiary level, which did not result in an increase in successful programming; however, when the five basic elements of CL were embedded in the PP intervention, the success of the programming module increased significantly.

Few studies have been conducted regarding the use of PP in an educational setting in South Africa. Mentz *et al*. (2008) applied PP in an introductory programming course where pre-service teachers were involved. Breed (2010) applied PP in the South African high school context where she tested the application of metacognitive strategies combined with PP and its effect on knowledge productivity. Another study regarding PP in the South African high school context was that of Liebenberg (2010) who determined IT learners' (specifically girls taking IT as a subject) enjoyment of the subject when PP was implemented. All of these studies indicated that PP, even in a teaching–learning setting proved to be a successful strategy; however, all of these studies implemented PP in the manner set out by Mentz *et al.* (2008), where the elements of CL, as determined by Johnson and Johnson, were incorporated – a vast difference from how PP is implemented in the programming industry (which is done in a collaborative way, namely unstructured).

No studies regarding the effect of PP on CTSs at high school level or of the effect of incorporating deliberate CT instruction in conjunction with PP have been found. Taking into consideration how important it is for learners to possess the ability to be self-directed also necessitates research into the effect of deliberate CTSs within a CL environment on SDL.

In order to investigate the development of CTSs and its implication on SDL further, a more in-depth investigation into the body of scholarship was executed. This was done by making use of several literature databases such as EBSCOHost, Google Scholar, Science Direct, Web of Science and JSTOR. The investigation was directed by the following keywords: Critical thinking, Socratic Method, pair programming, Information Technology education, Computer Science education, cooperative learning, Self-Directed Learning. These keywords were the main keywords used; however, secondary terms were added to widen the search and to ensure that the greatest scope of literature possible was covered.

1.4. PURPOSE OF THE STUDY

The purpose of this study was to determine how CT can be developed in the IT classroom and what the influence of this development is on Grade 10 IT learners' SDL.

1.5. RESEARCH DESIGN AND METHODOLOGY

In order to demonstrate the research design and methodology successfully, an illustration regarding the current study was developed. Figure 1.2 illustrates the study process as a whole, including the research design and methodology. From this illustration, it is evident that the body of scholarship (literature) and the research questions set out for the study informed each process of the study. By completing the different sections, the researcher aimed at contributing to the body of scholarship as well as to answer the research questions, illustrated by the arrows running from the findings to the body of scholarship as well as the research questions.

In the empirical study, a control group and three experimental groups were used. A pre-test for CT and SDL as well as a post-test for CT and SDL was distributed. An intervention between the pre-test and post-test in the experimental groups was done. One group received only the deliberate CTI (Exp Group 1: CTI), one group received both CTI and CL (Exp Group 2: CTI+PP) intervention and one group received only the CL (Exp Group 3: PP).

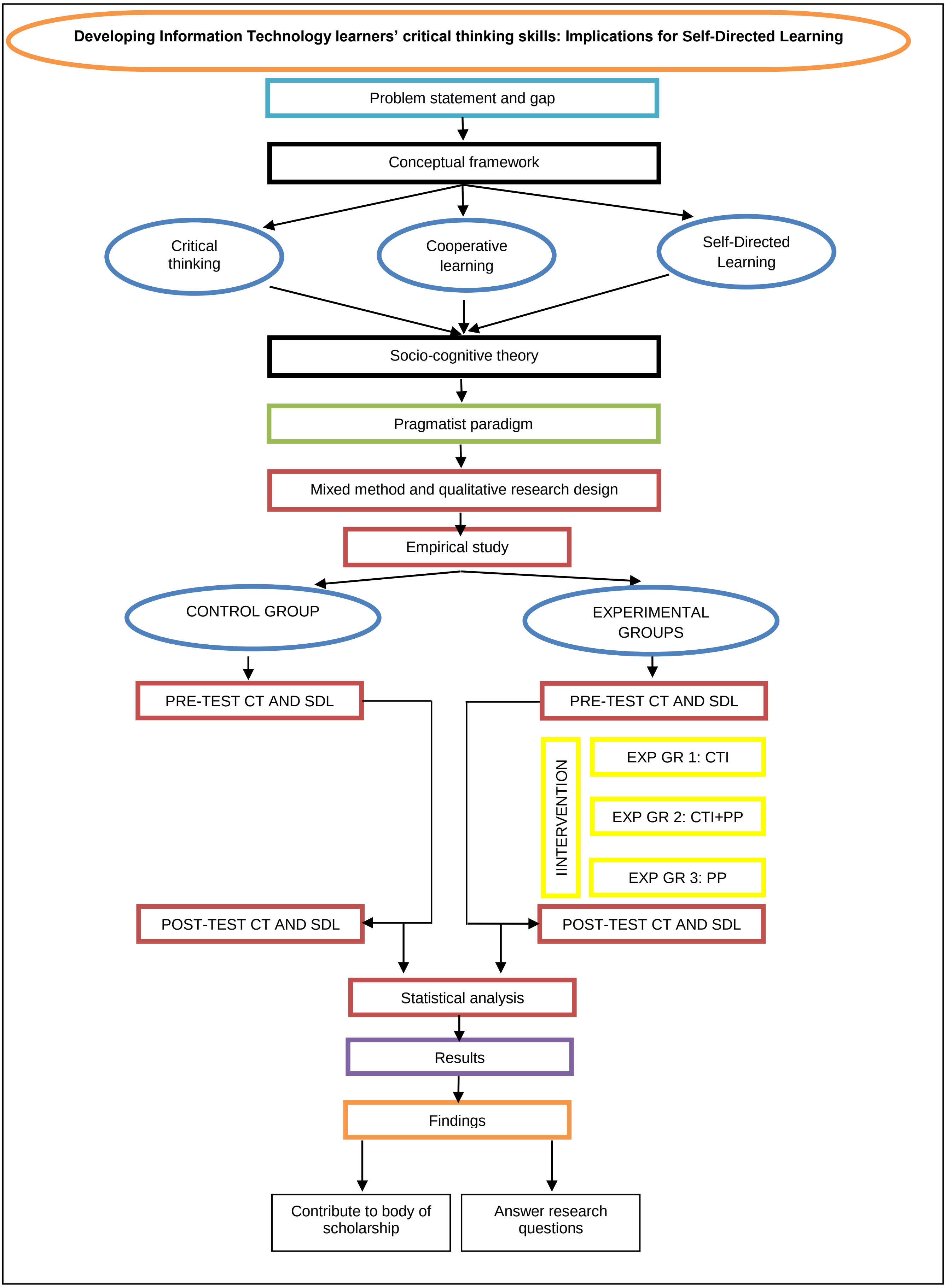


Figure 1.2 Research process of the current study

1.5.1. The empirical study

Creswell (2009) focuses on four different paradigms for conducting research: post-positivism, constructivism, advocacy and participatory paradigm and pragmatism. In the pragmatist research paradigm, the focus is placed on 'what works' and the research is not necessarily bound to specific methodologies. Considering the complexity of this study, which focused on effectively two samples (Grade 10 IT learners and Grade 10 IT teachers) situated in a real-life context (the school and IT class), several methods were necessary to answer the research problem stated; therefore, qualifying why a pragmatist research paradigm is sufficient.

Within the pragmatist paradigm, a mixed method design (for IT learners) and qualitative design (for IT teachers) were followed.

Singh (2007) describes the quantitative research design as having two research strands, namely exploratory research (focusing on understanding the problem through, for instance, a literature review) and conclusive research (which is focused on answering the research problem/question). Conclusive research is further divided into descriptive research, which includes case studies and longitudinal studies, and causal studies which are focused on the cause-and-effect relationship therefore testing an intervention and assessing the effect thereof on certain variables (Singh, 2007). The current study was directed by the quasi-experimental causal study design as it made use of an intervention and verified the effect thereof on certain variables. The qualitative investigation of this study (in both the mixed method design (for learners) and the qualitative design (for teachers)) made use of an interpretivist methodology, as the aim was to gain understanding from the investigation.

1.5.2. Experimental design

Babbie *et al*. (2008:351) distinguish between true experimental studies and quasi-experimental studies. In the current study, a non-equivalent control group quasi-experimental study was conducted as the study made use of one control group in the study.

Taking into account the purpose of the study to determine how to develop IT learners' CTSs and the influence thereof on these learners' SDL, certain steps needed to be taken to measure the two components. These steps included pre-tests and post-tests, using generally accepted instruments.

Few schools in South Africa host IT as a subject. Up until 2015 the nine provinces in South Africa had the choice as to which programming language they wanted to use in their classes. The two programming languages used were Delphi and Java. For this study, it was decided to focus on those provinces and schools that used Delphi, as this was the programming language commonly used in South African schools (only two provinces, namely Western Cape and KwaZulu-Natal, hosted Java as the programming language in 2015).

Although a non-equivalent control group quasi-experimental study was used by focusing on three provinces (North West, Free State and Eastern Cape) using Delphi as the programming language, randomisation was done as far as possible to select which schools had to be in the control groups and which schools had to be in one of the three experimental groups.

1.5.3. Population and sample

Singh (2007:88) describes the population as the group of which a sample is taken to conduct research on, while a sample is the part of the population whose results portray a selection of the population or the population in general. For this study aimed at developing IT learners' CTSs to foster SDL, the population was Grade 10 IT learners in South Africa; however, as IT learners were directly connected to the schools hosting the subject, the total number of schools hosting IT as a subject can be seen as the population.

A two-fold sampling strategy was used and this is discussed next.

Firstly, a convenience sample was used due to the distances between schools hosting IT as a subject taking into consideration the provinces in which the schools were teaching Delphi as a programming language at the time of the research. Furthermore, focus was also on the inclusion of rural schools in order to present an equal demographic representation of all schools hosting IT. The selected provinces were North West, Free State and Eastern Cape. The estimated number of schools hosting IT as a subject, taken from previous years' statistics, were:

- North West: 22 schools, with in total about 217 Grade 10 IT learners;
- Free State: 16 schools, with about 233 Grade 10 IT learners; and
- Eastern Cape: 22 schools, with about 258 Grade 10 IT learners.

Secondly, a random sample of each province's total number of schools was taken. For North West, 20 out of 22 schools were randomly selected; in Free State, all 16 schools were selected and for Eastern Cape, 20 of the 22 schools were selected. However, because only a few rural schools hosted IT as a subject at the time of the research, stratification according to this variable assured that the control and all experimental groups represented an equal number of rural schools. Furthermore, the stratification of the rural schools contributed to the empowerment of rural schools by giving them the opportunity to engage in research endeavours. The rural schools, however, were randomly selected for either the control group or one of the three experimental groups. After stratification of the rural schools, the remaining schools (randomly selected from the total number of schools in the province) were randomly assigned to either the control group or one of the three experimental groups. Figure 1.3 illustrates the sampling process including the control group and three experimental groups with the interventions CTI, CTI and CL (CTI+PP) and only CL (PP) each group received.

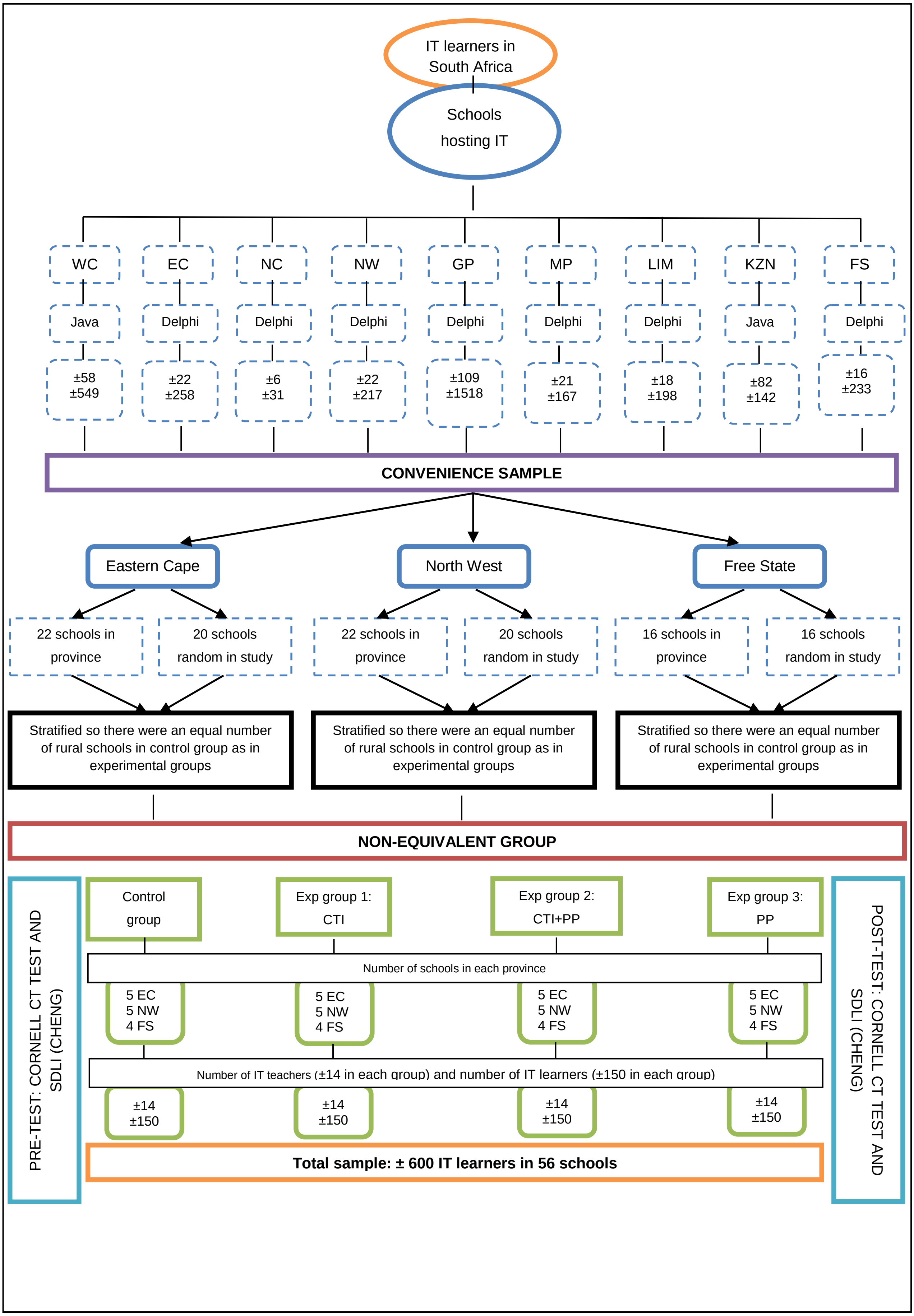


Figure 1.3 Sampling process and division of experimental and control groups

1.5.4. Variables

One of the main items in a quantitative research design is the variables in the study (Creswell, 2009). The variables pertaining to the current study are described briefly below.

- **Independent variables**
  Independent variables are those variables that probably play a role in the outcome of the study. In the current study, the independent variables addressed were CTI intervention, CTI+PP intervention and PP intervention.

- **Dependent variables**
  Dependent variables are believed to be influenced by the intervention and might also depend on the independent variables. Dependent variables are normally the result or outcome of the study. For the current study, the dependent variables were the two aspects being measured, namely IT learners' CTSs and IT learners' self-directedness.

- **Intervening (confounding) variables**
  Intervening variables stand between the independent variables and dependent variables, and for the current study, the intervening variable was the natural progress of the IT learners with regard to CTSs and self-directedness. The presence of a control group where no intervention took place, took this into account.

With the variables determined, the following section is dedicated to explaining the data collection procedures that were followed.

1.5.5. Data collection procedures

The data collection procedures is described as the stage in the study where data is collected in the form of fieldwork (Singh, 2007). In the current study, data collection was done by distributing the measuring instruments at the beginning of the empirical study. Once the intervention had been executed with sufficient time, the same measuring instruments were again used at the end of the empirical study. Learners were asked to complete a narrative on whether they felt their CTSs had improved and how they had experienced the suggested strategies in class. IT teachers also participated in semi-structured interviews at the onset of the study and again at the end of the empirical study in order to determine their experiences of the suggested strategies (only experimental group teachers were involved in the semi-structured interviews).

The researcher was in the field herself distributing the measuring instruments and ensuring that the measuring instruments were appropriately used and that the empirical study was conducted successfully.

1.5.6. Measuring instruments

The first aspect of the study was the CTS of IT learners. Although several CTS tests are available, only two could be found that have been used in the South African context, although at tertiary level. These two instruments are the Watson–Glaser Critical Thinking Appraisal (W–G CTA) and the Cornell Critical Thinking Test (CCTT). The costs incurred for the W–G CTA is extremely high and impossible to cover for a study of this size. The CCTT is not only more affordable but it also focuses specifically on testing CTSs rather than a wider focus on CT as a whole.

The second aspect of the study was IT learners' self-directedness, which was also tested at the beginning and at the end of the empirical study. This was done by using the Self-Directed Learning Instrument (SDLI) developed by Cheng *et al.* (2010).

It is important to note that both the CCTT as well as the SDLI had been implemented at tertiary level in South Africa. A pilot study to determine the validity and reliability of both measuring instruments in the South African context at high school level was therefore conducted. Reliability was determined by calculating the Cronbach's alpha coefficient and the internal validity was determined by performing factor analysis.

1.5.7. Data analysis

The empirical data gathered with the use of the CCTT as well as the SDLI were captured electronically. The Statistical Consultation Services of the North-West University (Potchefstroom Campus) executed the statistical analysis. Descriptive statistics were done in order to determine, amongst others, the standard deviations and mean scores. Hierarchical linear models, taking into account the interrelationship of learners in a class, were used to determine the p-value and d-value in order to establish the statistical and practical significance of the mean scores of different groups (experimental groups and control group) and measuring instruments (pre-tests and post-tests) (Hancock & Mueller, 2010). Qualitative data were transcribed verbatim and by using ATLAS.ti (computer-based qualitative data analysis tool), codes, categories and themes were determined.

1.5.8. Ethical aspects

Cohen *et al*. (2007) describe several ethical aspects to be considered when conducting research. For this study, the following ethical aspects were considered.

All participants' parents were asked to give consent for learners to participate in the research. The informed consent form (Addendum F) stated that participation in the study was voluntary and that all data gathered would be kept confidential. Volunteers' information as well as the schools' information will remain confidential.

Apart from the participants' informed consent, permission was obtained from the Department of Basic Education as well as the principals of participating schools and IT teachers of IT classes involved in the research. Ethical clearance from the North-West University was obtained (Addendum C).

General aspects which were adhered to were the fact that the disrupting of teaching time was avoided as far as possible. Data will be stored for five years in a safe place, and lastly access to the data is limited to only the researcher, the promoter and Statistical Consultation Services of the North-West University.

1.6. CONTRIBUTION OF THE STUDY

On completion of the study, the researcher aimed at contributing not only to the research focus area of SDL, but also to the body of scholarship in the field of CT, CL and SDL. The contributions of this study are discussed in sections 1.6.1– 1.6.2.

1.6.1. Contribution to the subject area or discipline

The current study contributed to the body of scholarship in various ways.

In South Africa, the need to improve IT learners' CT and in effect IT education, has been expressed in previous sections, and after successful completion of this study, the role of CT in IT education in South Africa is better understood.

CTS is one of the four pillars of education and contributing to the development of these skills plays an important role in the contribution to education. The CTI developed in this study was tested in IT education, but could be expanded to other subject areas as well.

With the implementation of the CTI in a CL environment (in the form of PP), this study aimed at contributing to the successful implementation of PP in the IT class. PP had been proven to be successful in IT education; however, no study of this extent and size and incorporating CT could be found in the context of South Africa or internationally. SDL benefits not only the learner but also society as a whole as we are in need of citizens who are willing to be lifelong learners who take responsibility for their own learning. Determining the way in which CT can be fostered in the IT classroom and the effect thereof on SDL, this study contributed to the body of scholarship regarding IT education and education in general. The study also contributed to the body of scholarship in the fields of CT, CL and SDL by addressing the gap as described in the problem statement.

1.6.2. Contribution to the proposed research focus area

The North-West University (Potchefstroom Campus), Faculty of Education Sciences has a research focus area concentrating on SDL research. This study contributed to the SDL research focus area as a whole, as it contributed to SDL research but also to the sub-programme in the research focus area specialising in CL. No research regarding CT and its relation to SDL was conducted in the research focus area as yet; therefore, this study expanded the scope of the focus area.

1.7. STRUCTURE OF THE THESIS

The structure of the thesis is as follow:

Chapter 1: Introduction
Chapter 2: Critical thinking skills: A theoretical approach
Chapter 3: Teaching-learning strategies conducive to the development of critical thinking skills in the Information Technology classroom
Chapter 4: Self-Directed Learning: A necessity for Information Technology teaching and learning
Chapter 5: Research design and methodology
Chapter 6: Data analyses and research results
Chapter 7: Conclusions and recommendations

CHAPTER 2

CRITICAL THINKING SKILLS: A THEORETICAL APPROACH

2.1. INTRODUCTION

In Chapter 1, an introduction to the study was given where the main research question was stipulated alongside with the secondary research questions that directed the study. In this chapter, the following secondary research questions will be addressed:

- What do critical thinking skills (CTS) entail?
- What is the importance of critical thinking (CT) in education and specifically in the Information Technology (IT) classroom? and
- How can CTS be developed in the IT classroom?

In order to address these three research questions, an in-depth review of the body of scholarship on CT was conducted and is reported in this chapter.

2.2. ORIGIN OF CRITICAL THINKING

In an attempt to analyse and consider CT, a discussion regarding the origin of CT is needed as this will illustrate where CT comes from.

2.2.1. Three philosophers and critical thinking

Philosopher Socrates has been described as the forerunner of CT as he was the first to use questioning to lead his students to more in-depth thinking (Gutek, 2009:20). Gutek (2009:20) goes on to explain that Socrates used dialogue to assist his students in dealing with questions and definitions, criticising it and developing more appropriate definitions all of which used CTS.

Just as Socrates, Plato also did not specifically make mention of CTS but aimed to empower his students to have the ability to think for themselves and weigh up the different aspects to come to the best solution (Leigh, 2007). Daly (1998:324) explains that Plato viewed education as an act that does not only provide information to students but also teaches students to ask questions, examine and reflect on ideas and values, all of which confirm CTS. Plato moved on from Socrates' view of teaching and added that students should have the ability to distinguish whether certain claims are true or false, and that this ability needed to be taught, directly or indirectly (Leigh, 2007:315).

Aristotle (another disciple of Socrates) took Socrates' teaching further and was the first to set out rules for correct reasoning (Bailin *et al*., 1999:292). Reasoning skills are seen as some of the pivotal skills in CT (Halpern, 2003:14). According to Halx and Reybold (2005:312), Aristotle viewed effective thinking as the ability to 'entertain' different viewpoints without necessarily accepting it, which added to students' ability to be critical thinkers. Aristotle had however not named it CT explicitly.

To synthesise from the three Greek philosophers (Socrates, Plato and Aristotle), CT has its roots as early as 2500 years ago. Although it had not yet been named in those early years, it was clear that effective learning was already characterised by the ability to think systematically (Socrates), make use of reasoning (Aristotle) and ascertain whether a claim is true or false (Plato).

2.2.2. The term 'critical thinking' is born

As mentioned in 2.2.1, philosophers like Socrates, Plato and Aristotle are said to have initiated CT as a way of thinking without coining the term explicitly. The term 'critical thinking' was born in the twentieth century through the first works of John Dewey's reflective thinking (Buffington, 2007:17; Fisher, 2001:2). In the next section, John Dewey's theory of reflective thinking and its influence on the CT scholarship will be discussed.

2.2.2.1. John Dewey and critical thinking

In his ground-breaking work *How we think*, John Dewey coined the phrase 'reflective thinking' as an attempt to define thinking in a more deliberate way (Dewey, 1910:6). Reflective thinking, according to Dewey (1910:6), is an active consideration of any belief based on the grounds that support the belief and the conclusions to which it leads.

Considering the three philosophers mentioned in 2.2.1, a clear connection is evident between their view of effective learning (thinking) and Dewey's view of reflective thinking. Socrates made mention of the ability to go about thinking systematically, which Dewey also acknowledges by noting that reflective thinking can be attained through the systematic process of the science method (Dewey, 1910). Aristotle emphasised the use of reasoning, which is clearly stipulated by Dewey in his explanation of the mental aspects of the thought cycle, being inference and reasoning (Dewey, 1910:77). To bring Plato and Dewey in connection with each other, Plato focused on the determination of whether a claim is true/false, which was directly underpinned by Dewey (1910:6) as the outcome of reflective thinking.

The process of reflective thinking is defined by Dewey (1910:72) as a five-step process:

1. **Experience a challenge**
   The 'challenge' that Dewey describes can be seen as a problem with which an individual is faced albeit in a learning situation or everyday life situation. If the individual is not faced with a difficulty, reflective thinking will not occur as it will not be needed.

2. **Definition of the challenge**
   In order to move through the reflective process, the challenge/problem as described in the first step needs to be defined in terms of its characteristics so as to know what the individual has to face in the problem.

3. **Suggestion of possible solution**
   Once the characteristics of the challenge have been defined, suggestions of possible solutions need to be established in order to move closer to a final solution.

4. **Development by reasoning of the grounds of suggestions**
   Through reasoning between the various possible solutions as suggested, each solution is weighed up according to its grounds and whether it can be corroborated or not. During this step of reflective thinking, the best possible solution is chosen.

5. **Further observations and experiments leading to the acceptance or rejection of suggestion**
   Once a suggestion of a possible solution is determined, the individual makes use of further observations and experiments to test the solution. Based on the outcome of these observations and experiments, the solution is either accepted or rejected.

It is Dewey himself who states that the terms 'critical thinking' and 'reflective thinking' can be used interchangeably (Dewey, 1922:31) thus we can deduce that the five steps mentioned above are for Dewey as much true in CT as it is in reflective thinking, making him the first to call this method of thinking 'critical thinking'. In accordance with this, Buffington (2007:19) also ascribes the first notion of CT to the works of John Dewey; however, he notes that it was only in the second phase of the CT movement that the term 'critical thinking' was born.

2.2.2.2. Reflective thinking versus critical thinking

Buffington (2007:19) notes that it was the works of among others Glaser and Russell that led the second phase of the CT movement.

Edward Glaser defined CT as being drawn to consider problems that an individual experiences in a thoughtful way, having knowledge of logic and reasoning methods to address the problem and the skills to apply these methods in such a manner that the methods address the problem (Glaser, 1941:5). Glaser (1941:6) then mentions a long list of skills that are related to CT:

- recognising the problem;
- finding workable means for meeting those problems;
- gathering relevant information;
- using appropriate language skills in the CT process;
- interpreting data;
- analysing evidence and statements;
- recognising correlations between propositions;
- inferring conclusions;
- evaluating conclusions;
- changing one's beliefs after evaluation; and
- making judgements accordingly.

Although this list of skills is much more comprehensive than Dewey's five steps of reflective thinking, it is easy to note that Dewey's five steps and Glaser's eleven skills connect to one another as –

- both make mention of the awareness of a problem (Glaser) or difficulty (Dewey);
- both emphasise the process of logic and reasoning to work through the problem;
- both note that one should investigate the grounds of inferences; and
- both researchers explain that the thinking process ends with a judgement.

Russell (1943:746), as one of the major researchers in the second phase of the development of CT (Buffington, 2007:19), made mention of four aspects that constitute CT:

- knowledge of the field in which thinking is done;
- attitudes to question and make judgements;
- application of the scientific method; and
- taking action in accordance with the thinking being done.

Once again, it can be drawn that Russell's view of CT (Russell, 1943) is in some accordance with what Dewey mentioned in his reflective thinking (Dewey, 1910) as well as what Glaser mentioned in his definition of CT (Glaser, 1941) as all three highlight knowledge, questioning, the scientific method (logic or reasoning) and drawing conclusions that influence future thinking processes.

What Glaser and Russell however added to Dewey's reflective thinking was the more detailed definition of CT. Glaser (1941) made explicit mention of problem solving during CT whereas Russell (1943) focused his attention on the aspect of thinking in general; however it is clear that a relationship exists between reflective thinking and CT.

2.2.3. Critical thinking being refined

As Fisher (2001:4) as well as Buffington (2007:19) notes, Robert Ennis and his works on CT in the third phase of the development of scholarship on CT is one of the most cited contributors to the scholarship of CT. Ennis defined CT as the correct assessment of statements (Ennis, 1964:599) implying that his focus was on drawing the right conclusions rather than just drawing conclusions (Buffington, 2007:19). The focus of Ennis on the process of assessing statements as CT is evident in his description of an effective critical thinker, whom he describes as an individual who can:

- judge whether a statement is in accordance with a premise;
- identify assumptions;
- judge whether an observation is reliable;
- judge whether generalisation is possible;
- test hypotheses;
- test a theory;
- judge whether an argument is based on ambiguity;
- determine whether a statement is vague or too detailed; and
- judge whether an authority is reliable.

These nine characteristics elude the action of thinking deliberately and focus on the outcome of each thinking step. Thinking therefore becomes the process behind CT, as each of these characteristics requires a set of thoughts to be applied before the characteristic can be reached. Ennis' definition of CT differs somewhat from his predecessors as they (the philosophers, Dewey, Glaser and Russell) were all concerned with the process of thinking whereas Ennis is concerned with the assessment of statements and the making of judgements on each level of thinking.

As Buffington (2007:19) notes, and as mentioned in the previous section (see 2.2.2), the CT movement reaches a pivotal moment where its definition becomes increasingly complex and additional components are added. In more recent years, CT has been broadened to include various facets of thinking not previously included in the definitions of CT. One of the alternatives to CT is that of the cognitive theory as developed by Benjamin Bloom.

2.2.3.1. Bloom's taxonomy and critical thinking

In 1956, Benjamin Bloom and his colleagues formulated a taxonomy to illustrate the cognitive domain (Bloom *et al.*, 1956). This taxonomy closely relates to CT. In Bloom's taxonomy, he describes six categories of cognition as developed in his study. In Figure 2.1, the original taxonomy is illustrated followed by a discussion of each of the levels.

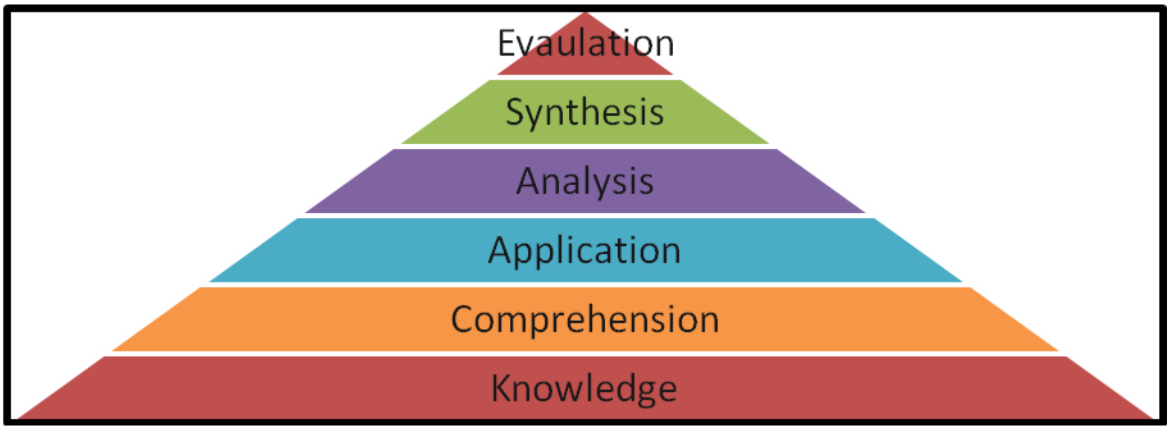


Figure 2.1 Bloom's taxonomy

The first level of Bloom's taxonomy is the knowledge level where he argues the individual uses basic knowledge like memorising facts and information (Bloom *et al*., 1956:62). At level two, comprehension occurs where the individual aims to understand the facts. In the application level (level three) of the taxonomy, the individual aims to apply the comprehended facts in such a manner that it is generalisable in various situations. Level four, which is the synthesis level, goes beyond application and requires the individual to make connections between different elements of the facts. The last level, evaluation, is aimed at critically evaluating whether the information obtained through the first five levels rings true (Bloom *et al*., 1956:89, 120, 185). According to Bloom *et al*. (1956:38), this taxonomy is used to set learning objectives for intellectual abilities and skills, which they continue to say is synonymous with CT, reflective thinking or problem solving.

In accordance to Bloom *et al.*'s (1956) notion that the taxonomy is appropriate for CT, researchers like Paul (1995:36) and Gokhale, (1995), argue that teachers need to ask appropriate questions that would lead learners to move to the levels of analysis, synthesis and evaluation if they are to acquire the necessary knowledge and skills for effective CT. In the revised taxonomy, Anderson *et al.* (2001) CT is also visible.

2.2.4. Critical thinking in the modern world

Facione (1990:4) found that the skills constituting CT closely relate to Bloom's taxonomy. More recently, Bissell and Lemons (2006:66) in their attempt to formulate a new method for assessing CT in the classroom also used Bloom's taxonomy as a vantage point. With Facione being a recognisable figure in the CT research community, his view of CT will subsequently be discussed.

2.2.4.1. Facione and critical thinking

In his Delphi study aimed at reaching consensus regarding CT, Facione (1990:7) found that experts in the field of CT view the following cognitive skills as relating to CT:

- **Interpretation**
  The individual categorises information, decodes the significance of the information and clarifies the meaning of information.
- **Analysis**
  The individual examines ideas, identifies arguments and analyses arguments.
- **Evaluation**
  Claims and arguments are assessed.
- **Inference**
  The individual queries the evidence presented, develops alternatives and draws conclusions.
- **Explanation**
  The individual states the results, justifies the procedures and presents his/her own argument.
- **Self-regulation**
  The individual examines him/herself as well as corrects him/herself.

Although Facione's list of cognitive skills differs somewhat from Bloom's taxonomy of cognitive domain, connections between the two can be made. Both Bloom and Facione note that basic knowledge is the first step in the thinking process although Bloom's taxonomy has two levels (knowledge and comprehension) whereas Facione's list combines the knowledge and comprehension of information into one cognitive skill. Analysis of information occurs in Bloom's and Facione's views of cognition. In Facione's list (1990), evaluation is the third cognitive skill that occurs in CT, whereas Bloom *et. al.* (1956) refers to evaluation as being the last level of cognition, leaving one to wonder whether CT moves beyond mere cognition. The last three cognitive skills that Facione (1990) describes are inference, explanation and self-regulation all of which move toward the metacognitive level of thinking explaining why these skills would not be visible in Bloom's taxonomy of the cognitive domain.

2.2.4.2. Comprehensive definition of critical thinking

CT has been transformed through the ages; however, it has not yet come to a standstill and is forever changing and evolving.

McAllister (2009:5) notes that Facione's definition of CT is the most comprehensive and cited definition of CT. CT is defined by Facione (1990:2) as "a purposeful, self-regulatory judgement that results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual consideration upon which that judgement is based".

In Facione's (1990) definition, bearing in mind the journey CT has taken, it is clear that the definition encompasses aspects from the early days of Socrates, Plato and Aristotle as it emphasises the systematic approach (as CT is purposeful), makes use of reasoning (in that CT uses interpretation, analysis, evaluation and inference) and aims to determine whether a claim is true or false (that is, determines whether a judgement is right). Furthermore, the works of scholars – like Dewey in his work on reflective thinking – are also visible in the definition as it aims to determine whether a judgement is true by testing the judgement as Dewey illustrated in his fifth step of reflective thinking (Facione, 1990). Later scholars like Glaser, Russell and Ennis also contributed to the definition so it encompasses all of which they set CT out to be although they defined it much more complex. Facione's (1990) definition will therefore be accepted as the definition for this study and where further mention is made of CT, it will be defined.

With CT discussed, the following section will describe the importance of CT in education specifically.

2.3. IMPORTANCE OF CRITICAL THINKING IN EDUCATION

CT is currently regarded by several researchers as one of the most important skills (Halpern, 2003:2; Tiwari *et al.*, 2006:547).

As Fahy (2005:13) expresses, CTS is cited as the primary objective of education in all fields. Paul and Elder (2005) also state that CT is not just subject to one core field of education, but necessary in all learning environments and at all levels of education. CTS are related to the success of learning environments and to an individual's learning process.

Lorenzo and Dziuban (2006) note that the effect of how much is learnt is linked to the individual's ability to make use of CTS. CT is seen as an indicator of students' success (Ennis, 2008). Apart from CT illustrating academic success, Fagin *et al.* (2006:1) also argue that CT abilities comprise a core characteristic trait of a 'well-educated person'. To emphasise the importance of CT further, Michael Scriven associates CTS with that of literacy skills in that both are vitally important in education (Fisher, 2001:10).

Not only do CTS contribute to the overall education of an individual it also contributes to a society. In a globalised era where access to information is at the tip of each individual's fingertips, focus on CTS to foster critical participation in the modern society is pivotal (Ten Dam & Volman, 2004:360). McAllister (2009:3) supports this notion and states that students are in need of CTS in order to become successful citizens in a democratic world.

One of the facets of being part of a global society is access to information through the internet. Browne *et al*. (2000) note that the emphasis given to CT in an age where individuals rely on the Internet to gain knowledge is mandatory. The Internet offers various truths and untruths and therefore, as Yang *et al*. (2005:25) state, CT is the desired process when individuals work with the Internet. Lorenzo and Dziuban (2006) also found in their study that the importance of CT development in an age where information that is untrustworthy (as often found on the internet) is at our fingertips cannot be underestimated.

With the above-mentioned discussion in mind, it is evident that CTSs are still relevant today even though it originates as far as 2500 years back (see 2.2). It is in this light that CT in education is emphasised worldwide, especially in countries like the United Kingdom, Australia and North America (Hughes & Davies, 2009; Pithers & Sodan, 2000).

In the United Kingdom, CT is already introduced in the third key stage of education which falls in the age category of 11–14 years of age (United Kingdom Department of Education, 2013). Table 2.1 summarises all aspects of the curriculum focused on CT as described by the United Kingdom Department of Education (2013).

Table 2.1 Critical thinking in the United Kingdom curriculum

Key stage	Subject content	Description of critical thinking implementation
3	Reading	Read critically and make critical comparisons across texts (United Kingdom Department of Education, 2013:81)
3	Mathematics	Reason mathematically by following a line of enquiry, conjecturing relationships and generalisations, and developing an argument, justification or prove using mathematical language (United Kingdom Department of Education, 2013:103)
3	Art and design	As pupils progress, they should be able to think critically (United Kingdom Department of Education, 2013:199)
3 and 4	Citizenship	Pupils should be equipped with the skills to think critically and debate political questions (United Kingdom Department of Education, 2013:201)
3	History	Teaching should equip pupils to ask perceptive questions, think critically, weigh evidence, sift arguments, and develop perspective and judgement (United Kingdom Department of Education, 2013:219)
3	Music	As pupils progress, they should develop a critical engagement with music (United Kingdom Department of Education, 2013:231)

In Australia, the Australian Curriculum, Assessment and Reporting Authority (Australian Curriculum, Assessment and Reporting Authority, 2011a:1) noted that CTS are considered a general capability that pupils (in Foundation phase to Grade 10) develop across the curriculum. Furthermore, CT is evident in all subject areas described by the Australian Curriculum, Assessment and Reporting Authority. Table 2.2 summarises how CT is emphasised in each core subject.

Table 2.2 Summary of critical thinking in Australian curriculum

Subject	Description of critical thinking implementation
The Arts	As emerging critical and creative thinkers, students will gain the confidence and the tools to understand and analyse and discuss the Arts in everyday life (Australian Curriculum Assessment and Reporting Authority, 2011b:3)
English	Australians need to interact in a global environment, know how to learn, adapt, create and communicate effectively, and interpret and use information more fluently and critically (Australian Curriculum Assessment and Reporting Authority, 2009a:4)
Health and Physical Education	A critical inquiry approach directs the Health and Physical Education curriculum (Australian Curriculum Assessment and Reporting Authority, 2012a:5)
Civics and Citizenship	The Civics and Citizenship skills are: questioning and research, analysis and synthesis, collaborative problem solving and decision-making, communication and interpretation, all to support students in becoming active, informed and critical citizens (Australian Curriculum Assessment and Reporting Authority, 2012b:9)
Economics and Business	The subject is underpinned by skills including adaptability, initiative, critical and creative thinking (Australian Curriculum Assessment and Reporting Authority, 2012c:11)
Geography	The Geography curriculum will develop students' ability to think logically, critically and creatively (Australian Curriculum Assessment and Reporting Authority, 2011b:8)
History	Students develop a critical perspective on versions of the past and learn to compare and appreciate conflicts and ambiguities (Australian Curriculum Assessment and Reporting Authority, 2009b:5)
Languages	Learning languages strengthens intellectual and analytical capabilities and enhances creative and CT (Australian Curriculum Assessment and Reporting Authority, 2011c:7)

Table 2.2 Summary of critical thinking in Australian curriculum (continued)

Subject	Description of critical thinking implementation
Mathematics	It is important that citizens can examine those issues critically by using and interpreting mathematical perspectives (Australian Curriculum Assessment and Reporting Authority, 2009c:5)
Science	Australians will need to interact in a global environment, know how to learn, adapt, create and communicate effectively, and interpret and use information more fluently and critically (Australian Curriculum Assessment and Reporting Authority, 2009d:4)
Technologies	Students need continuing opportunities and sustained engagement to build the capacity to think critically, creatively and innovatively when using and creating with technologies and technologies processes (Australian Curriculum Assessment and Reporting Authority, 2012d:12)

In his book: *Critical thinking: What every person needs to survive in a rapidly changing world*, Richard Paul describes the state of CT in North America as the cornerstone of the CT movement (Paul, 2012:33). Paul's notion that North America is leading the CT revolution had already been noted by Moon (2004:4). Leading researchers in the field of CT like Facione, Ennis, Paul, Elder, Halpern and Fisher all work in North America.

CT can therefore not be seen as an isolated educational movement bound to only a few countries, but as seen in this discussion, it is a worldwide movement gaining more interest every day. In South Africa, an emphasis on CT is also found as a national concern.

In the Strategic Plan for 2011 to 2014, the National Department of Basic Education states that South African learners need to be prepared by schools to read, write, think critically and solve numerical problems adequately (Department of Basic Education, 2011:11). To reach this goal of equipping South African learners with CTS, several South African researchers emphasise the importance of CT in South African education (Belluigi, 2009; Chabeli, 2006; Lombard & Grosser, 2008).

In their study on first-year tertiary education students, Lombard and Grosser (2008) investigated the students' CT abilities by using the Watson Glaser Critical Thinking Appraisal. They established that, although CTS are regarded as a necessity in South African education, very few students showed an adequate ability regarding CT (Lombard & Grosser, 2008:572). While

Lombard and Grosser focused on pre-service teachers, and illustrated that these teachers did not have adequate CTS, it comes as no surprise that in-service teachers, as in the case of Souls' study (Souls, 2009) were negative toward the teaching of CT possibly because they themselves did not possess CTS. Souls (2009) describes a model for changing teachers' attitudes toward CT in South African education, as his study revealed that teachers in South Africa do not value the teaching of CT although it is a national priority.

The South African National Curriculum Statement (NCS) Grades R–12 emphasises that it is based on, amongst others, a principle to encourage an active and critical approach to learning rather than an uncritical learning of given truths (Department of Basic Education, 2012:3). With this principle of critical and active learning in mind and noting that it is emphasised in the NCS of South African education, this raises concern as to why more is not being done to promote CTS explicitly in South African schools. This pertains especially to subjects that permit the development of CTS and prescribe CT as a part of the subject scope, for instance Information Technology (IT) in Grades 10 to 12.

2.4. IMPORTANCE OF CRITICAL THINKING SKILLS IN INFORMATION TECHNOLOGY AS SCHOOL SUBJECT IN SOUTH AFRICA

IT as school subject in South Africa focuses on several aspects of computers, which include data handling and computer programming or software development. In South Africa, IT is one of the many elective subjects Grade 10 learners may choose. The IT syllabus consists of five main topics (Solution development, Communication technologies, Systems technologies, Internet technologies, Data and information management and Social implications) of which software development make up 60% of the subject matter (Department of Basic Education, 2012). The Department of Basic Education (2012:8) define IT as: "The study of various interrelated physical and non-physical technologies used for the capturing of data, the processing of data into useful information and the management, presentation and dissemination of data". In this study, the abbreviation IT will be used to refer to the school subject as described above.

With the definition of IT in mind, the following sections provide a discussion on how CT plays an important role in contributing to the success of the subject.

2.4.1. Critical thinking supports problem identification

Fuller *et al*. (2007:163) argue that the essence of computer science is problem identification and finding the most effective and efficient way to solve it. This relates to CT as described by Sosu

(2013:107) in that CT focuses on the individual's ability to identify a problem and give a reasonable solution for the problem. The Department of Basic Education (2012:23) also emphasises the importance of problem identification and the role problem-solving play in the success of IT.

Apart from CT relating to problem identification and problem solving, CT also assists in the success of computer programming as described in 2.4.2.

2.4.2. Critical thinking supports computer programming

Computer programming has been noted as being difficult (Teague & Roe, 2008) whether at high school level or tertiary level. In order to foster successful programming skills, teachers need to shift the focus of their classes from requiring the mere memorisation of programming syntax to the facilitation of the development of skills that are conducive to successful programming. One of the skills proposed to contribute to the success of programming is CTS. Fagin *et al.*, (2006) state that when assisting learners with the development of CTS, computer programming skills increased significantly.

In her book *Studying programming,* Sally Fincher (2006:35–38) states that there are certain skills that are necessary when learning programming. Firstly, she describes similarities between learning a natural language and learning a programming language. Secondly, she notes that learning to program takes a lot of practice. Fincher continues to describe the connection between mathematics and computer programming as both are focused on problem-solving skills where the individual needs to identify the problem, break it down into smaller problems and then find the best solution. Lastly, Fincher points out that, in order to complete a programming task successfully, one would need to be able to plan the solution in cases where you cannot simply start right away but have to plan first. When referring to the definition of CT (Facione, 1990), we see that the skills needed for programming (language skills, willingness to persist, problem-solving skills and creative skills) are all encompassed in the definition.

2.4.3. Critical thinking supports general computer skills

McMahon (2009:280) describes that his study, which comprised 150 girls in an Australian school with a focus on their computer skills as well as CTS, found that there was a statistically significant correlation between computer skills (as tested with the Australian Schools Computer Skills Competition) and the girls' CTS (as assessed by means of the Ennis–Weir Critical Thinking Essay Test).

With the importance of CT in education in general and IT education in particular explained, the following section (2.5) will describe the development of CTS. CT has been demonstrated as an important component in successful computer programming (Fagin *et al.*, 2006) and computer programming plays an integral part of IT as school subject.

2.5. DEVELOPING CRITICAL THINKING

From the previous discussion on CT it is evident that CT can be valuable for learners. Fisher (2005:53) notes that an individual's development of CT should be fostered explicitly as the development thereof does not necessarily occur naturally. As Halpern (2003:11–13) claims, there is evidence that CT can be developed. There are several different foci on the theory of developing CT but it is commonly believed that CT can be developed although it is hard to do so (Dunn *et al.*, 2008:7). To infuse the elements of CT (logic, reasoning, questioning and self-reflection) a holistic practice for developing CTS as illustrated by Lau (2011:15) can be used. Lau (2011:15) notes that one should learn the theory of CT, practice CT and adopt the right attitude towards CT in order to develop CT effectively. Section 2.5.1 will describe the different factors that have an influence on the development of CT, the role of the facilitator during the development of CT and teaching strategies that are conducive to CT development.

2.5.1. Factors to consider during the development of critical thinking

Several factors have been identified as having an influence on the development of CT.

2.5.1.1 Cultural, intellectual and/or gender differences

One aspect to consider is whether there are any differences regarding biographical variables in individuals acquiring CTS. Manalo *et al.* (2013) conducted a study to determine whether culture-related factors have an influence on CT development. In their study comprising 363 undergraduate students from Japan and 87 from New Zealand who completed the Motivated Strategies for Learning Questionnaire (MSLQ), which includes aspects of CTS, Manalo *et al.* (2013) found that there were no differences between Western and Asian cultures in terms of the use of CT. It has also been reported that CTS are not influenced by intellect or gender (Myers & Dyer, 2004).

Another factor that plays an influence on the development of CT is whether CT is imbedded in the content of a subject or explicitly taught outside the realms of the subject matter.

2.5.1.2. Imbedded or explicit instruction

Halpern and Marin (2011:1) note that the imbedded approach to CT occurs when the development of CTS is woven into the subject matter. Explicit instruction occurs when the development of CTS is executed during separate lessons, which are specifically focused on CTS development (Halpern & Marin, 2011:1). Willingham (2007:18) argues that specific CT development programmes are not successful and that CT development should occur within the context of a specific subject. In accordance to Willingham, Paul and Elder (2005) also emphasise the importance of teaching CT in conjunction with subject content.

Some researchers (Facione, 1990; Halpern & Marin, 2011) also emphasise the benefits of explicit CTI. In his much quoted Delphi study, Facione (1990:17) found that CTI cannot be limited to subject content and needs to include authentic topics of global value such as normative, moral, ethical or political content. In a class of 45–50 minutes, teachers do not have sufficient time to delve deeply into the development of CTS (McAllister, 2009:17) and often omit to develop these skills at all. Halpern and Marin (2011) illustrated this notion with their study, where they focused on determining whether CT was better taught explicitly or imbedded. Of their participants, 28 completed an explicit CT web-based workshop and 18 participants completed an introductory psychology module, which imbedded CT for six sessions over three weeks. Halpern and Marin (2011) found that both of the groups' CTS improved; however, the explicit instruction group scored much higher than the imbedded group, implying that an intervention targeting specific CTS is a viable option.

From the two points discussed above, it is evident that the development of CT through explicit instruction is beneficial. In cases where explicit instruction is impossible, imbedded instruction could result in as much benefit if CT development is intentionally woven into the subject matter.

Although CT can be developed, regardless of culture, intellect or gender and can be developed either through explicit instruction or imbedded instruction, the role of the facilitator needs be to clearly defined as the facilitator also plays an important role in the success of CT development. Section 2,5,2 will subsequently focus on what the role of the facilitator is in the development of CT.

2.5.2. The role of the facilitator in the development of critical thinking

The first aspect that is emphasised is that the facilitator or the teacher should model CT in the classroom.

2.5.2.1. Modelling critical thinking in the classroom

Van Gelder (2001:17) and Snyder and Snyder (2008:94) are of the opinion that CT is most effectively developed when the facilitator of a course him/herself exhibits CTS. Dunn *et al.* (2008:56) note that teachers should model effective CTS in class and share experiences where they have implemented CT in everyday life. Coming back to our founding father of CT, Socrates, it is evident that he himself firstly modelled CT and in doing so inspired and led his students to do the same (Gutek, 2009:20).

Although these researchers all agree that instructors (whether teachers or facilitators of a class) should model the CTS they require from their students, this is not always evident in practice. Dunn *et al*. (2008:53) point out that many teachers do not possess CTS themselves and therefore do not know how to teach or model these skills. Souls (2009) conducted a study where he implemented a model for CTS and through questionnaires and interviews determined teachers' attitudes toward the implementation of CT in their classes. He found that the teachers in his study experienced the teaching of CT negatively, a result which he then realised necessitated that teachers be taught how to teach CT effectively (which would change their perceptions thereof). Developing teachers' ability to model CTS in their classes is as important as teaching those teachers CTS.

There are several strategies that can be used to model CT in the classroom. Brookfield (2012:62–68) describes the techniques he found plausible in modelling CT in the classroom.

- **Speaking in tongues**

This technique of modelling CT involves showing students how ideas and facts can be interpreted differently. In order to do so, Brookfield (2012:62) explains that teachers should post several signs around the classroom stating different perspectives for viewing a certain topic. After explaining the topic at hand, the teacher moves to the first sign, which states the first perspective and explains how a person might view the topic according to that perspective. Brookfield (2012:63) continues to note that this activity can be expanded by dividing the class into groups, and having each group represent one of the several perspectives posted on the classroom wall.

- **Compiling an ‘assumptions inventory’**

By making use of an assumption inventory, the teachers present an audit of the assumptions that informed the material he/she had just presented. The teacher’s assumption inventory can be focused on the reasoning behind the way a topic was presented, explaining how an activity was designed, describing how he or she discerned between several meanings, summarising causal chains regarding the topic, reviewing how the topic is applied in real life and justifying why certain theories are chosen over other theories (Brookfield, 2012:64).

- **Modelling point-counterpoint**

Brookfield (2012:65) describes the modelling point–counterpoint strategy as a team-based teaching activity where two or more teachers teach a topic together, illustrating different perspectives on the topic as well as the ways in which respectful disagreements are possible. Teachers co-teaching according to the point–counterpoint method can ask each other questions emphasising the need for evidence without becoming judgemental in their interactions but emphasising the search of truth regarding the topic (Brookfield, 2012:65).

- **Engaging in structured devil’s advocacy**

Structured devil’s advocacy is said to be the solo version of the point–counterpoint strategy as the teacher constantly presents arguments that counter his/her own assertions (Brookfield, 2012:66). By playing devil’s advocate, the teacher is able to present several perspectives and model critical analysis by illustrating that a point does not necessarily only have one correct perspective.

- **Using the critical incident questionnaire**

The critical incident questionnaire (CIQ) is an evaluation instrument which implements five items that ask students to review their own learning according to five specific questions:

  - At what moment were you most engaged in the learning process?
  - What moment were you most distanced in the learning process?
  - What action that anyone took in class did you find most helpful?
  - What action that anyone took in class did you find most confusing?
  - What surprised you the most about the class? (Brookfield, 2012:54).

Brookfield (2012:67) states that by using the CIQ, teachers have the opportunity to model CT by illustrating to students that they reflect on their own teaching practices as informed by the students’ responses on the CIQ.

- **Ending lectures and discussions with questions**

Good lecturers end the learning process by raising awareness as to questions that have emerged from the content or topic discussed in the lesson (Brookfield, 2012:68). To implement the questions strategy, Brookfield (2012:68) suggests that teachers spend about ten minutes at the end of the lesson asking students to write down all the questions that have been posed to them during the lesson followed by a method of sharing the questions in class, either in small group form or whole class form.

From the discussion regarding the modelling of CT in the classroom, it is evident that teachers need to be made aware of these strategies (modelling strategies) in order to foster effective CT in learners. Apart from focusing teachers' attention on the importance of modelling CT, teachers need to teach learners the theory of CT to create awareness of the value of CT and what CT entails (see 2.5.1 & 2.5.2) Section 2.5.2.2 focuses on what teaching the theory of CT entails.

2.5.2.2. Teach learners the theory of critical thinking

Lau (2011:4) describes the theoretical knowledge and refers to it as consisting of five areas:

- meaning analysis (where ideas are explained and clarified);
- logic (the analysis of arguments);
- scientific method (application of the scientific method as described in earlier CT scholarship);
- decisions and values (as decision-making and reflections of values); and
- fallacies and biases (identifying mistakes of reasoning).

Dick (1991:84) devised a taxonomy for CT where five levels are present (identifying arguments, analysis of arguments, considering external influences, scientifically analysing reasoning and reasoning and logic). Progressing through all five levels moves cognition from a lower level of CT to a deeper level of CT as illustrated in Figure 2.2. Identifying arguments will be the lowest level of CT in that it requires the individual merely to notice themes, conclusions, reasons and possibly organise these in structural ways. Analysing arguments moves slightly further into CT in that it requires the individual to analyse an argument by referring to certain assumptions that are made (which will weaken the argument), seek out vagueness in the argument, and be aware of omissions that have either been used to strengthen the argument unrealistically or to have caused a faulty argument. Once individuals have moved from the first two levels of Dick's taxonomy, they should be able to move beyond mere argument analysis and be able to consider which external influences have played a role in the argument. When people present a problem or an argument, they are often influenced by values placed over them by authority as well as the use of emotional language that might cause an argument to seem more believable. Being aware of these external influences assists learners in their quest for CT in that they move to a deeper understanding of which argument they are up against. The last two levels of the taxonomy refer to the reasoning that takes place once an individual has come to grips with the argument that is presented and the nature of such argument. Having learners probe into how the argument can be proved statistically or how the argument is presented gives them the opportunity to move toward the scientific analytic reasoning level where the argument is scientifically examined and judged. The last level of Dick's taxonomy is reasoning and logic, where the individual makes analogies, deductions and inductions based on the findings of the previous levels. It is only once the final level is reached that learners are truly engaged in CT and a true judgement of whether something is true or false can be made (Dick, 1999).

When considering what Lau (2011) refers to as 'teaching learners the theory of CT' is similar to what Astleitner (2002:54) refers to as the theoretical approach that learners have to know in order to be successful critical thinkers. Astleitner accepts that Dick's taxonomy of CT does just that in that it summarises the theoretical knowledge into a comprehensible taxonomy.

Identifying arguments (Themes, conclusions, reasons, organisation)	Low
Analysing arguments (Assumptions, vagueness, omissions)	
Considering external influences (Values, authority, emotional language)	
Scientific analytic reasoning (Causality, statistical reasoning, representativity)	High
Reasoning and logic (Analogy, deduction, induction)	

Figure 2.2 Empirical taxonomy of critical thinking by Dick (1991:84)

Explaining to learners the empirical taxonomy of CT as well as the five theoretical aspects of Lau (see 2.5) can give them an opportunity to gain theoretical insight into the nature of CT. CT consists of two aspects, CTS and a CTD (Facione, 1990). These two aspects will be described in the next section.

2.5.3. Critical thinking skills versus a critical thinking disposition

Several researchers have demonstrated different perspectives on the development of CTS (Bailin *et al*., 1999; Dunn *et al*., 2008; Halpern, 2003; Moon, 2008). In his Delphi report, Facione (1990) includes 46 CT experts who found that the development of CTS should be focused on two aspects: specific CTS and CTD. Fisher (2005:53) agrees that developing CT comprises not only the development of certain skills but also the development of certain attitudes or dispositions that contribute to CT. Paul and Elder (2005) also state that CT encompasses intellectual skills, abilities and dispositions. Subsequently, the next two sections will focus on describing both CTS as well as a CTD.

2.5.3.1. Critical thinking skills

Facione (1990) emphasises the focus on CTS development. A factor to focus on when developing CTS is structuring activities that allow students to practice their CTS.

2.5.3.1.1. Give students authentic problems

Authentic problems are real-world problems that hold relevance to the individual and engage the individual in the learning process as he/she can make a direct connection with what is required of him or her (Mims, 2003:2). Mims (2003) continues to note that authentic learning features several characteristics which include:

- tasks are learner-centred and focused on what the learner is interested in;
- learning is not bound to the experience of the classroom;
- students engage with others in social discourse regarding problems; and
- students make use of higher-order thinking such as analysing, synthesising, designing, manipulating information and evaluation information.

From Mims' explanation of authentic learning and the characteristics described, relevance between CT and authentic problems is noticeable. Lai (2011:2) notes that facilitators should give students open-ended, real-world or authentic problems when attempting to promote CT. These problems should have more than one solution devisable by using different perspectives. Dunn *et al*. (2008:56) suggest that CTS should be fostered in the classroom by providing students with a problem for all topics in the syllabi. Pierce (2005) also emphasises giving students assignments that require them to apply thinking skills and which are primarily focused by thinking abilities. Other aspects that can be focused on to assist in the development of students' CTS is to give students everyday life examples that require the use of CT (Dunn *et al.*,

2008) and to focus on why a specific suggestion to the problem is better suited than another as well as which persuasive techniques were needed (Halpern, 2003).

2.5.3.1.2. Give students oral and written assignments

Oral assignments are those assignments that require students to complete tasks orally. Joughin (2010) explains that oral assessment is conducted by assessing students' learning as executed by word of mouth in part or in whole. He continues to illustrate that there are many theories that emphasise making use of oral assignments where students articulate their ideas.

Written assignments refer to assignments that require students to write answers, arguments and solutions. This is the most commonly used form of assessment in traditional learning (Joughin, 2010:3).

Pierce (2005) notes that having students execute oral and written assignments can contribute to their development of CTS. This can be done by having students draw a diagram to organise information (Halpern, 2003:19).

2.5.3.1.3. Promote questioning in class

Students should acquire and practice effective questioning skills (Pierce, 2005). Lau (2011) describes his fourfold path to good thinking, which includes practicing questioning. To practice questioning, Lau, states that students should ask four questions when faced with a problem:

- What does it mean?
- How many supporting reasons and objections?
- Why is this important or relevant?
- Which are the other possibilities to consider?

By asking these questions, students can identify the most important concepts and why these concepts are important, categorise findings in meaningful ways and design two solutions to the problem (Halpern, 2003:19).

Brookfield (2012:203) lists the following as questions that sometimes intimidate students, but which hold great value in the learning process:

- What assumption are you making that you are least confident about?
- What assumption are you making that you are the most confident about?
- What is a good example of what you are talking about?
- What do you mean by that?
- Can you explain the term you just used?

- Why is your conclusion accurate?
- What data is your claim based on?
- Can you put that in another way?
- Why do you think that's true?
- Can you give a different illustration of your point?
- What do you think you are leaving out?
- What do you think you might have missed?
- Whose point of views might you have missed?

2.5.3.1.4. Do not under-emphasise metacognition

Beth Black (2012:108), as several others, describes metacognition as thinking about one's own thinking. She continues to note that being able to think critically requires metacognitive skills in that such thinking involves improving one's own thinking, spotting weaknesses and finding flaws in reasoning. Metacognition can be described as either a core CT skill or a subconscious sub-skill or disposition.

Halpern (2003:19) emphasises the importance of metacognitive processes by stating that students should present two reasons as support to conclusions made and two reasons as opposed to the conclusions that they have made. Halpern continues to say that students should also present two actions they would do differently to improve their solution or conclusion. These steps described by Halpern correspond with Pierce's (2005) notion that students' metacognitive abilities should be improved to assist in the development of their CTS.

From the above-noted discussion, several conclusions regarding the development of CTS can be made. In Table 2.3 a summary of these findings is illustrated.

Table 2.3 Summary regarding the development of critical thinking skills

Aspect to develop critical thinking skills	Steps to implement
Authentic problems	• Provide students with a problem for all topics in the class (Dunn *et al.*, 2008:56) • Give everyday life examples that require CT (Dunn *et al.*, 2008:56) • Give students tasks that require them to think as a primary goal (Pierce, 2005)
Written and oral assignments	• Have students execute oral and written language frequently (Pierce, 2005) • Draw diagrams to organise information (Halpern, 2003:19)
Questioning	• Use effective questioning strategies (Pierce, 2005) • Fourfold path to good thinking (Lau, 2011)
Metacognition	• Improve students' metacognitive abilities (Pierce, 2005) • Present two reasons as support to conclusions and two reasons as opposed to conclusions (Halpern, 2003:19) • Explain why a specific suggestion was selected (Halpern, 2003:19) • Present two actions you will do differently to improve (Halpern, 2003:19)

Apart from developing CTS, a disposition that is conducive to CT needs to be fostered. Section 2.5.3.2 provides a description of a CTD.

2.5.3.2. Critical thinking disposition

The disposition of CT is described as the attitudes that promote the pursuit of truth (Ennis, 2008). Fisher (2005) continues to say that these attitudes are "a desire to learn, willingness to challenge and a passion for truth".

Studies like the one by Lampert (2007) tested whether the CTD of undergraduate students – from non-arts freshmen, arts freshmen to mixed non-arts (freshmen and seniors) – and senior arts majors differed in order to establish whether their arts programme had an effect on students' CTD. By using the California Critical Thinking Disposition Inventory (CCTDI), Lampert found that the arts students' CTD increased after four years in the arts programme implying that the arts programme had a positive effect on the students' CTD (Lampert, 2007).

Stupnisky *et al*. (2008:515) conducted a study to determine whether college students' CTD predicts their academic control, or whether their academic control predicts their CTD, and which influence these two factors (CTD and academic control) had on the participating students' academic performance. The sample was selected from the Motivation and Academic Achievement dataset developed by a Canadian University, and consisted of 211 students from 1997, 515 students from 1998 and 470 students from 2000. By using the MSLQ, Stupnisky *et al.* (2009:518–519) could measure students' willingness to use CTS. The perceived academic control was measured by using the Perceived Academic control scale developed by Perry *et al*. (2001). High school academic performance was determined by calculating the M value of each student, and the Grade Point Average was determined by calculating the average for each student's first-year subjects. Stupnisky *et al.* (2008:524) found that students with a higher CTD scored higher, than those with lower CTDs, in their perceived academic control test. Furthermore, participating students' perceived academic control could predict their use of CTS throughout the year. Lastly, the researchers found that students' perceived academic control had a greater effect on students' academic performance than students' CTD had.

The reason given as to why the CTD does not reflect as having an influence on students' academic achievement is that assignments and tests that are given often do not require students to use CTS. Che (2002:90) found that the most important aspect of a CT development project is focusing on the development of students' attitudes/disposition toward CT. CTDs will subsequently be discussed.

2.5.3.2.1. Truth seeking

Students who are successful in CT tend to value truth as well as value reason greatly (Bailin *et al.*, 1999). Fisher (2005) also acknowledges the passion for truth as a positive disposition towards CT.

2.5.3.2.2. Respecting

Apart from seeking truth, respect plays a role in the success of CT implementation. Bailin *et al*. (1999) note that students should be able to respect other during discussions. Furthermore, Halpern (2003) emphasises that, although CT sometimes requires consensus seeking, it should be done respectfully.

2.5.3.2.3. Metacognitive use

Metacognition is viewed as both a skill of CT as well as a favourable disposition towards CT. Facione (1990) suggests that self-awareness (a metacognitive state) of biases, prejudices, stereotypes, egocentrism as well as socio-centrism contributes to CT. The willingness to plan, which is also underpinned by metacognition, is emphasised by Halpern (2003) whereas Facione (1990) and Lau (2011) emphasise that reflection is an important disposition.

2.5.3.2.4. Inquisitive

Successful critical thinkers tend to be inquisitive. Inquisitiveness includes being attracted to a wide range of topics as well as being interested and well-informed regarding subject matter (Facione, 1990).

2.5.3.2.5. Flexible

Although critical thinkers seek the truth and make the best judgements, being flexible is having a disposition which is favourable towards CT in that successful critical thinkers will need to be flexible to change their opinions or stances if new and better evidence is presented (Facione, 1990; Halpern, 2003).

2.5.3.2.6. Uses critical thinking

Successful critical thinkers know when and why to use CT, therefore having the disposition to use CTS assists in CT (Facione, 1990). Bailin *et al*. (1999) also note that the willingness to use CT principles is a disposition that is conducive to CT.

2.5.3.2.7. Open-minded

CT requires individuals to be open to new ideas, new evidence, new arguments and new judgements; therefore, being open-minded is an important disposition (Facione, 1990). Lau (2011) notes that students who are open-minded, level-headed and able to be impartial are likely to be better critical thinkers than those who are narrow-minded.

2.5.3.2.8. Persistent

Both Facione (1990) and Halpern (2003) emphasise how important it is for individuals to have a disposition of persistence in order to be successful critical thinkers. Persistence allows individuals to have that ‘never-give-up’ spirit, which in turn contributes to their passion for seeking truth continuously (see 2.5.3.2.1).

From the eight dispositions described above, Table 2.4 illustrates several dispositions that are conducive to CT. These dispositions are based on work by Facione (1990), Bailin *et al.* (1999), Halpern (2003), Fisher (2005) and Lau (2011).

Table 2.4 Dispositions that are conducive to critical thinking

Disposition category	Dispositions described by researchers
Truth seeking	• Values reason and truth (Bailin *et al.*, 1999) • Passion for truth (Fisher, 2005)
Respect	• Respects others during discussions (Bailin *et al.*, 1999) • Respectful consensus seeking (Halpern, 2003)
Metacognition	• Level-headedness and impartiality (Lau, 2011) • Self-awareness of biases, prejudices, stereotypes, egocentric or socio-centric tendencies (Facione, 1990) • Willingness to plan (Halpern, 2003) • An analytical and reflective attitude (Lau, 2011) • Willingness to reconsider views where reflection warrants change (Facione, 1990)
Inquisitive	• Being inquisitive regarding a wide range of issues (Facione, 1990) • Focused on being well-informed (Facione, 1990)
Flexible	• Willingness to change opinions when better evidence is presented (Facione, 1990; Halpern, 2003)
Using CT	• Mindful to use CT (Facione, 1990) • Uses principles of CT (Bailin *et al.*, 1999)
Open-minded	• Open to new ideas, evidence and arguments (Facione, 1990) • Impartial (Lau, 2011)
Persistent	• Never give-up spirit (Halpern, 2003) • Persistence in seeking information (Facione, 1990)

2.5.4. Teaching–learning strategies conducive to the development of critical thinking

In an attempt to develop CT, several teaching–learning strategies have been suggested. This section describes some of these teaching–learning strategies.

In a study to determine which strategies would be effective in teaching CT, Snyder and Snyder (2008) emphasised the importance of actively engaging students in the learning process. Moon

(2008) mentions that oral presentation, written presentation and graphic depictions (all of which are activities that engage students in the learning process) are all activities that can be incorporated in a classroom to contribute to the development of CT. Examples of active learning include problem-based learning, computer-based learning, the Socratic Method and CL. These four teaching–learning strategies will therefore be discussed.

2.5.4.1. Problem-based learning

Problem-based learning implements cases which pose a problem leading students to make use of problem solving and in doing so, to acquire new knowledge and skills (Massaro *et al.*, 2006:2256).

Tiwari *et al.* (2006) compared a problem-based learning class with a lecture-based class at a Hong Kong University. The study included 79 nursing students who completed the CCTDI. Problem-based learning classes outperformed the lecture-based classes in terms of development of their disposition towards CT. Lampert (2007) conducted a study in Arts education with 141 undergraduate students to determine the development of their CTD. Lampert made use of four different groups consisting of freshmen non-arts majors, freshmen arts majors, mixed non-arts majors and senior arts majors. By comparing their Critical Thinking Disposition Inventory scores, Lampert (2007) discovered that all students' disposition towards CT increased over the four years, illustrating a natural growth curve.

2.5.4.2. Computer-based learning

Aleven *et al.* (2003) describe computer-based learning also known as 'computer-assisted instruction' as a learning method that uses computers to assist learners in problem solving. Using computers allow students to receive real-time feedback although the feedback to answers given by students is not individualised but universal.

One study conducted by McMahon (2009) investigated the influence of a technology-rich environment on students' CT. For the study, McMahon asked 150 girls at an Australian secondary school to complete three questionnaires: the Level of Technology Implementation Questionnaire (LTIQ), the Australian Schools Computer Skills Competition (ASCSC) and the Ennis–Weir Critical Thinking Essay Test. It was found that there was no correlation between the students' CT development and their exposure to the technology-rich environment. There was however a statistically significant correlation between students' CTS and their computer skills measured by the ASCSC.

In a study to determine the effectiveness of an online resource to assist in the development of CT, Carmichael and Farell (2012) developed a Blackboard site consisting of interactive learning modules, multimedia segments, assignments and reflective journals. Of the 448 students participating in the research, 73% noted that they found the Blackboard site useful in their development of CTS.

One method for giving learners the opportunity to practice their CTS is that of Van Gelder (2001). In his study, he focused on the logical side of CT and its improvement by using computer software. The four questions of Lau (2011) (see 2.5.3.1.3) are especially evident in the building mode of the software package where learners have the opportunity to build arguments in order to articulate their reasoning, a process they could go through by using Lau's fourfold path to good thinking (see 2.5.3.1.3). Van Gelder (2001) tested his undergraduate students using a pre-test–post-test design with the California Critical Thinking Skills Test (CCTST). The pre-test was following a 12-week course where students made use of the Reason! program (computer-simulated teaching tool) developed by Van Gelder and his colleagues (Van Gelder, 2001), which was then ended with a post-test. Van Gelder found that the Reason! program set within the context of his study, improved the students' CTS; therefore, teaching logic or reasoning improves CTS.

Another study which made use of electronic computer-related CTI, where the four questions of Lau (2011) could be evident, is that of Greenlaw and DeLoach (2003). They made use of electronic discussion boards to assist their undergraduate economic students to engage in discussions and improve their CTS. Although they do not offer any empirical data to illustrate whether their students' CTS increased during the two-week electronic discussion course, they indicate that theoretically it can be deduced that the students' CT scores would increase.

2.5.4.3. The Socratic Method

One strategy that has been proved effective in the development of CT is that of the Socratic Method. Schiller (2008:41) describes the Socratic Method as a pedagogical method that pursues the truth by means of analytical discussion. Carvalho-Grevious (2013) conducted a study to determine whether the Socratic Method could enhance CT. In the study, 27 Social Work bachelor students enrolled in a 14-week course had to complete reflection paper assignments where they had to analyse and discuss an article. Students in the course were also given a writing and CT grading rubric and they had the opportunity during class time to engage in dialogue with fellow students. She (Carvalho-Grevious) found that by using the

Socratic Method, students' CT was enhanced. Furthermore, Carvalho-Grevious (2013) found that students enjoyed the opportunity of being engaged in the CTI and the assessment thereof.

Relating to the discussion approach to CT, Boghassian (2006) also promotes the use of discussion in his study on the effects of the Socratic Method on inmates' CTS. Boghassian (2006:44) describes the Socratic Method as having five steps: wonder, hypothesis, cross-examination, acceptance/rejection of hypothesis and action according to judgement. Through conversations with inmates in the form of the Socratic Method, he found that from the 10 inmates participating in his study where conversations occurred for four days (Monday to Thursday) and where he engaged in conversations for two hours per day, the participants' CTS increased significantly (Boghassian, 2006:60). Another instructional method that advances the use of discussion is CL.

2.5.4.4. Cooperative learning

Johnson *et al.* (2008:1:5) define CL as a learning environment that divides students into small groups so as to have the students work together to maximise the learning of the group as well as each individual's learning.

Researchers like Moss (2004) found that through discussion, middle school learners' CT are fostered. To deepen the notion of discussion as a catalyst for the development of CT, Chabeli (2006) describes CT as being underpinned by the social constructivist theory, related closely to the SCT (see 1.2).

The first conclusion therefore is that the development of CTS should include discussions in some form or another, which can either be facilitated by means of technology or take place as one-on-one facilitator–learner or learner–learner conversations. The discussion should however include questions that raise awareness of CT.

Although the aforementioned sections all focus on the nature of CT and CTS as well as how to develop these skills, it is still unclear how these skills should be assessed. The following section will therefore focus on the assessment of CTS.

2.6. ASSESSING CRITICAL THINKING SKILLS

Facione (1990:16) emphasises the importance of developing (and implementing) a valid and reliable CT assessment strategy which can be used to make reliable inferences regarding learners' CTS.

Dunn *et al.* (2008:72–75) list the most prevalent measuring instruments that are used in the assessment of CT. These include:

- Academic Profile test;
- Assessment of Reasoning and Communication Test;
- California Critical Thinking Skills Test (CCTST) – college level;
- California Critical Thinking Disposition Inventory Test (CCTDI);
- Cornell Critical Thinking Test (CCTT) – Level X;
- Cornell Critical Thinking Test (CCTT) – Level Z;
- Cambridge Thinking Skills Assessment Test;
- Ennis–Weir Critical Thinking Essay Test;
- International Centre for the Assessment of Thinking (ICAT) Critical Thinking Essay Test;
- Test of Everyday Reasoning (TER); and
- Watson–Glaser Critical Thinking Appraisal (W–G CTA**)**.

Each of the aforementioned measuring instruments is discussed in the sections below.

2.6.1. Academic Profile test

Marr (2008) describes the Academic Profile test as a test designed by the Education Testing Service of America to assess the outcomes of undergraduate general education programmes. The test assesses academic skills like reading, writing and CTS. Pierce (2005) notes that in 2004, 8 675 American students completed the Academic Profile test and it was found that 86 per cent of the students scored inadequately in their CT proficiency.

To determine the validity of the Academic Profile test, Marr (2008) conducted a study with 5 092 graduate students completing the questionnaire. For each subsection tested, Marr found that the questionnaire was valid.

2.6.2. Assessment of Reasoning and Communication Test

The Assessment of Reasoning and Communication Test is aimed at testing social reasoning, scientific reasoning and artistic reasoning (Dunn *et al.*, 2008). It is, according to Goodwin and Sommervold (2012:71), an accepted CT measurement instrument**.** This test requires students (mostly just finished with college) to write three short essays and three short speeches. The main aim of the test is to grade participants' reasoning skills through their writing (Ennis, 2009:online).

2.6.3. The California Critical Thinking Skills Test – college level

The CCTST was designed by Facione (1990) after an extensive Delphi study had been conducted. The test measures CTS required to succeed in educational or workplace settings, and therefore it is suitable for use in graduate classes in all fields of study (Insight Assessment, 2013a:online). The test consists of 35 piloted multiple-choice items focused on the cognitive skills identified in Facione's Delphi study: interpretation, analysis, evaluation and inference (Facione, 1990:6).

Facione determined the validity of the CCTST by administering it to over 945 college students in 1989 and 1990. The reliability coefficient was determined as .69 for the pre-tests and .68 for the post-tests, indicating that the tests both proved reliable (Singh, 2007). Although the test is used worldwide and has been translated into several languages, it is focused on undergraduate, graduate and adult students (Insight Assessment, 2013b:online) and therefore not appropriate for secondary school learners.

2.6.4. The California Critical Thinking Disposition Inventory Test

In order to test the CTD, the CCTDI was developed in combination with the CCTST. The CCTDI measures an individual's willingness and attitudes toward CT and is suitable for undergraduates, technical and professional school students and graduate students (Insight Assessment, 2013c:online). This test comprises two sections: demographic information and 47 CT questions. The CT questions are focused on the seven CT subscales: description, analyticity, open-mindedness, truth seeking, systematicity, self-confidence, inquisitiveness and maturity (Alwi *et al.*, 2012:139).

Alwi *et al*. (2012) conducted a study to determine the validity of the CCTDI by administering the test to 433 undergraduate students (193 in their first year and 240 in their fourth year). The researchers found that all constructs (sub-scales) proved reliable according to Cronbach's alpha coefficient (reliable at 0.7 and above):

- analyticity: 0.973
- open-mindedness: .888
- truth seeking: .976
- systematicity: .921
- self-confidence: .973
- inquisitiveness: .985
- maturity: .961

Although it is clear that the test proved valid, this study was focused on undergraduate students and therefore the test might not necessarily be valid for secondary school learners.

2.6.5. Cornell Critical Thinking Test – Level X

According to the Critical Thinking Company, the CCTT is the most widely used CT test and suitable for Grades 5 to 12 (Critical Thinking Company, 2013a:online). The test measures four CTS: induction, deduction, credibility and identification of assumptions.

French *et al*. (2012) describe the study they conducted with a sample of 907 students to determine the validity of the CCTT – Level X. The CCTT – Level X is calculated to have an internal consistency score of between 0.67 and 0.9 (French *et al*., 2012:203). The test is also noted by French *et al*. (2012) as the most widely used CT test.

According to the CCTT – Level X Administration Manual, the questionnaire includes several CT aspects making it a viable questionnaire in the assessment of CT. Furthermore, the validity of this questionnaire has been illustrated by Ennis *et al*. (2005:32).

2.6.6. Cornell Critical Thinking Test – Level Z

Just like the CCTT – Level X, this test is widely renowned for use in Grade 11 and onward as it includes three more difficult skills to be assessed: semantics, definition and prediction in planning experiments (Critical Thinking Company, 2013b:online).

Several studies illustrated in the Administration Manual for the CCTT – Level Z show that the test is valid (Ennis *et al.,* 2005:14). In South Africa, specifically, Lombard and Grosser (2008) has used the CCTT-Level X previously but noted that the W–G CTA (United Kingdom version) proved to be more reliable in their research context.

2.6.7. Cambridge Thinking Skills Assessment Test

The test was developed by the University of Cambridge Local Examination Syndicate as an attempt to assess thinking skills. The test consists of 50 questions of which 25 are problem-solving questions and 25 are CT questions (Admission Testing Service, 2013:online).

The Cambridge Thinking Skills Assessment Test is a college entry level test used as part of the University of Cambridge's admission process (Admission Testing Service, 2013:online) and thus not used as frequently as other CT tests. In a study to determine the validity of the test, Willmott (2005) found the test to score 0.85 in reliability and thus that the test is a reliable method for use as an admissions test. It is however not appropriate for use at high school level.

2.6.8. Ennis–Weir Critical Thinking Essay Test

The Ennis–Weir Critical Thinking Essay Test is an essay-based test that requires college students to write a letter to an editor of a newspaper stating their case through arguments (Ennis & Weir, 1985). Ennis and Weir claim that the test includes several CT competencies like reasoning, arguing and determining relevance. Although the test has been used at high school and college level, Ennis and Weir (1985) found it more suitable for younger learners.

Regarding the validity and reliability of the test, Ennis and Weir (1985) describe the test to have content validity but also a reliability score of .86 and .82 from two different studies.

2.6.9. International Centre for the Assessment of Thinking Critical Thinking Essay Test

The ICAT CT Essay Test was designed by Richard Paul and Linda Elder to assess the fundamentals of CT. The test is divided into two parts: analysis of a writing report and assessment of a writing report. Ennis (2009) describes the ICAT CT Essay Test as consisting of an editorial selected for test takers on which the test takers respond by summarising it, identifying its focus as well as commenting on its strengths and weaknesses.

When referring to the validity of the ICAT CT Essay Test, the test is said to have a high 'face validity' as it tests students' ability to determine intellectual structures and complete this exercise in writing. Furthermore, reasoning is rated highly in the test too.

2.6.10. The Test of Everyday Reasoning

The TER is designed to test college students, high school students as well as adults' reasoning (Insight Assessment, 2013c:online). It is divided into 35 multiple-choice questions focused on analysis, interpretation, evaluation, explanation, induction, deduction and reasoning skills as well as numeracy skills (Insight Assessment, 2013c:online). The construct validity of the test of everyday reasoning is said to be 0.766.

2.6.11. Watson–Glaser Critical Thinking Appraisal

One of the oldest CT assessment measurements, developed in 1925, is the W–G CTA. The test is focused on assessing CT ability as well as decision-making through a 40-item multiple-choice questionnaire. The W–G CTA is often used by managers to evaluate future employees; however, only trained test administrators may administer the W–G CTA.

Grosser and Lombard (2008) made use of the W–G CTA questionnaire in the South African context. The sample used in the Grosser–Lombard study comprised 114 pre-service teachers enrolled for a BEd degree at a South African university. They found the W–G CTA to be valid with a Cronbach alpha coefficient of 0.81.

Table 2.5 presents a summary of the measuring instruments investigated, focusing on the target group and whether the instrument was found valid or not.

Table 2.5 Summary of measuring instruments

Measuring instrument	Target group	Validity proven Yes (Y)/No (N) or Not available (N.A.)
Academic Profile Test	Graduate students	Y
Assessment of Reasoning and Communication Test	Students just finished with college	N.A.
The CCTST-college level	College students	Y
The CCTDI	Undergraduate students	Y
CCTT – Level X	Grades 5–12	Y
CCTT – Level Z	Grade 11 and older	Y
Cambridge Thinking Skills Assessment Test	Students enrolled	Y
Ennis–Weir Critical Thinking Essay Test	College students	Y
ICAT Critical Thinking Essay Test	Not specified	N.A.
TER	College students	Y
W–G CTA	Anyone past high school	Y

2.7. CONCLUSION

CT is seen as a beneficial and necessary skill. In school curricula across the world, the emphasis is on the development of these skills as information is growing at such a pace that learners are in need of the necessary skills to cope with these changes. As IT is one of the subjects in the South African curriculum that requires learners to possess CTS, the development of these skills cannot be ignored.

To define CT is a complex task. Definitions emanate from as early as 2500 years ago when philosophers like Socrates, Plato and Aristotle viewed learning similarly to what we see CT to be. Educational researchers like John Dewey and Benjamin Bloom coined the phrase 'critical thinking' after much extensive research had been conducted. From all the works of these forerunners, a concise definition of CT was developed. The most widely used definition of these definitions is that of Facione (1990:2), as discussed in his Delphi study. The definition states that CT is a purposeful, self-regulatory judgement that results in interpretation, analysis, evaluation and inference, as well as explanation of the evidential, conceptual, methodological, criteriological or contextual consideration upon which such judgement is based. From the study of the body of scholarship on CT, it was also established that CT consists of certain skills and certain attitudes (also referred to as *disposition*) that are conducive to CT.

The CTS identified include identifying arguments, analysing arguments, considering external influences, scientific analytic reasoning, reasoning and logic. Dispositions toward CT that have been identified as conducive to CT are willingness to plan, flexibility, persistence, willingness to self-correct, being mindful and consensus seeking.

Although it has been established that CTS can be developed, the methodology of developing these skills is not cast in stone, and still requires further empirical research. What has been concluded, though, is that CTS can be taught deliberately as a non-imbedded course and that participants in the course should have the opportunity to practice CT as much as possible infused in their curricula. Another factor that has come to the foreground is the fact that several studies emphasise the importance of several teaching–learning strategies that are conducive to the development of CT.

Once CT has been developed by whichever method, assessment of the participants' CT development is needed in order to establish whether the course was successful. Various CT assessment tests are available and have been proved valid; however, only two have been used in the South African context (up to this point): the W–G CTA and the CCTT – Level Z. Both these tests were used with a sample of university students and therefore they are not necessarily appropriate for Grade 10 IT learners.

With the development of CT in the IT classroom in mind, Chapter 3 will be focused on teaching-learning strategies conducive to the development of CTSs in the IT class.

CHAPTER 3

TEACHING–LEARNING STRATEGIES CONDUCIVE TO THE DEVELOPMENT OF CRITICAL THINKING SKILLS IN THE INFORMATION TECHNOLOGY CLASSROOM

3.1. INTRODUCTION

In Chapter 1, a general introduction to the study was provided where it was established that critical thinking (CT) is a necessity especially in the 21st century. In Chapter 2, an in-depth discussion on CT was provided. From this discussion, it was established that, amongst others, cooperative learning (CL) and the Socratic Method are two strategies that are conducive to CT development. In Chapter 3, these two teaching–learning strategies will be discussed in more depth. This discussion will include a focus on the scholarly work regarding the two teaching–learning strategies as well as ways in which these strategies can be implemented in the Information Technology (IT) classroom.

3.2. COOPERATIVE LEARNING

As mentioned in Chapter 2 (see 2.5.4.4), CL as teaching–learning strategy has been noted as one of the successful strategies for developing CT. In this section, this notion will be explored further by discussing the scholarly work on CL in more depth. The discussion will include the history of CL, the definition of CL and the implementation of CL in the IT classroom.

3.2.1. Cooperative learning defined

According to Johnson *et al.* (2008:A:3) CL has been around for centuries, dating as far back as the first century. In a timeline of CL illustrated in their book Johnson *et al.* (2008:A:3), it shows that there was a peak in CL research between 1970 and 1990 when several books were published on the topic and conferences gave more attention to the topic. Although the timeline stops at 1996, research on CL has all but stopped, and it continues to be a popular teaching–learning strategy in all sectors of education.

Throughout the history of CL, it has been defined differently by researchers. Two of the leading authors in CL, David and Frank Johnson, define CL as the instructional use of small groups where individuals work together to maximise each other’s learning (Johnson & Johnson, 2013:449). Felder and Brent (2007:34) define CL as learning where students work together in teams to reach a common goal. Joliffe (2007:3) describes CL as learning that consists of key elements, positive interdependence and individual accountability. These elements are derived from Johnson and Johnson's (2013:102–109) five basic elements of cooperation. These elements are discussed in sections 3.2.1.1–3.2.1.5.

3.2.1.1. Positive interdependence

Positive interdependence requires all students to work together in such a manner that neither one can succeed unless the other one succeeds (Johnson & Johnson, 2013:102). When positive interdependence is achieved, all students work in such a way that the group members need the others in order to complete the task as all group members contribute to the learning process (Joliffe, 2007:3). Johnson and Johnson (2008) in Gillies *et al.* 2008) divide positive interdependence into three categories: outcome interdependence, means interdependence and boundary interdependence.

- **Outcome interdependence**

Outcome interdependence is found where individuals in the group realise the shared goal or reward which they hope to achieve. Outcome interdependence includes three types of interdependence: goal, reward and fantasy (Johnson & Johnson, 2008:6:22).

- **Means interdependence**

Means interdependence focuses on the means or processes the group undertakes to reach the set outcome. The means interdependence category include role, resource and task interdependence (Johnson & Johnson, 2008:6:22).

- **Boundary interdependence**

Boundary interdependence describes which individuals in the group are most interdependent on one another, which influences the effectiveness of the group. Johnson and Johnson (2008:6:22) note that the three types of interdependence included in this category are environmental, identity and outside enemy.

Scorzoni (2007:2) suggests that teachers are responsible for creating conditions that support students' positive interdependence. This positive interdependence can be created by giving students complex authentic problems that require them to work together actively and to draw on each other's strengths (Scorzoni, 2007:2).

3.2.1.2. Individual accountability

Johnson and Johnson (2013:105) describe individual accountability as the element in CL that exists when each individual's performance is evaluated and reported back to the whole group and the group holds the individual accountable for their efforts in the group's success. Johnson *et al.* (2008:G:3) define individual accountability as the measure of whether an individual in the group successfully contributed to the result of the group. In short, Beck *et al.* (2005:471) summarises individual accountability as all members contributing to the group while at the same time also acquiring knowledge themselves.

Conklin (2012:131) emphasises that only through assessing each student's understanding of concepts addressed in the learning process will the teacher be able to evaluate whether the CL experience was beneficial for all students. All students need to be held accountable during the CL experience for it to be successful. To achieve the goal of individual accountability, each student can be asked to complete an assessment stating what his or her contribution to the group task was (Conklin, 2012:132). Another strategy that is viable to encourage individual accountability is to have the group discuss ways in which individual accountability can be established (Race, 2000:45). Mentz *et al.* (2008:3) note that each individual can be required to complete an individual assessment to ensure that members of the group know that, although they work together, they should still be able to achieve as individuals as well.

3.2.1.3. Promotive (face-to-face) interaction

Promotive (face-to-face) interaction occurs when the members of the group encourage each other by providing assistance and support, sharing resources and reason with each other in order to achieve the group's goals (Johnson & Johnson, 2013:106). Johnson and Johnson continue to state that promotive (face-to-face) interaction ensures that members in the group feel they can trust one another as the interaction reduces the anxiety and stress sometimes felt during group activities. Felder and Brent (2007:39) note the positive effects face-to-face interactions have on students' academic performance.

Joliffe (2007:43) notes that there are two aspects that are conducive to face-to-face interaction, namely the physical layout of the classroom and the interaction that stems from the group activity. Joliffe suggests that a classroom should be organised in such a manner that the members of the group can comfortably face each other and implement learning structures (like having students summarising partners' thoughts) that assist in face-to-face interaction.

3.2.1.4. Social skills

A number of studies illustrate the benefits that social interactions have on students' learning (Gillies & Ashman, 2003:9). Battistich and Watson (2003:20) explain that CL holds advantages for teachers to develop students' social and emotional skills. Joliffe (2007:40) however states that students do not always possess the necessary social skills to participate effectively in group activities. As Johnson and Johnson (2013:106) point out, putting individuals who lack social skills into a group together will cause CL to fail. It is the responsibility of teachers to facilitate the development of these skills, which include decision-making skills, conflict management, communication, leadership skills as well as trust-building skills (Joliffe, 2007:40). Setting the social context for learning is therefore a key aspect in productive CL (Gillies & Ashman, 2003:9).

Gillies (2003:36) and Johnson and Johnson (2013:107) found that when students have the appropriate social skills, academic achievement increases and students are more prone to building positive relationships among each other. Johnson *et al.* (2008:7:22) make use of a report form to evaluate students' social skills. This report form gives the facilitator an opportunity to state whether the student needs improvement in a specific area, is making progress, is satisfactory or is excellent in a specific social skill. The social skills that are presented are divided into four categories (Johnson & Johnson, 2008:7:22):

- **Forming skills**
  A cooperative attitude (comprising forming skills) is visible when the student moves into the group quietly, stays with the group, takes turns, is positive about working with others, and shows courtesy toward others.

- **Functioning skills**
  Leadership (functioning) skills are visible when the student clarifies goals, encourages others' participation, supports others, contributes ideas as well as relieves tension in the group.

- **Formulating skills**
  Facilitating understanding (formulating) skills can be identified when students seek accuracy, relate new learning to old, check for understanding and make covert reasoning overt.

- **Fermenting skills**

  Intellectual challenge (fermenting) skills are seen when the student criticises ideas and not people, integrates members' ideas, extends others' reasoning and probes complex questions.

3.2.1.5. Group processing

During CL, the effectiveness of the group is influenced by the group's ability to reflect (Johnson & Johnson, 2013:107; Macpherson, 2007:35). Johnson and Johnson (2013) continue by stating that group processing includes reflection on two aspects of the group, namely describing which actions of the group members were helpful or not as well as making decisions about the actions to take or change. Students need to be given an opportunity and time to process and analyse how well their group efforts are and also to see whether they used the appropriate skills needed (Joliffe, 2007:40). Group processing assists students in the development of their metacognitive abilities (Johnson & Johnson, 2013:108).

Joliffe (2007:42) makes four suggestions regarding how group processing can be fostered during CL. Firstly, she suggests that a particular processing skill should be made the 'skill of the week' and that this be put up in class where students are constantly reminded of the importance of such skill at the end of the CL lesson. Members of the groups should comment and evaluate whether they had developed the 'skill of the week' and if so, how they did it. Secondly, Joliffe suggests that students should be given the opportunity to set goals for themselves as well as their group, which can then be evaluated at the end of the session. Thirdly, time for reflection and group processing at the end of the session as well as during pivotal moments during the group session is of the utmost importance. Joliffe lastly notes that it would be helpful, if time allows, to ask groups to present their evaluations (Joliffe, 2007:42).

Macpherson (2007:35) explains that group processing can also be done by having the instructor pose questions to learners during the last 10 minutes of the lesson. Such questions should encourage reflection. Learners could also be asked to identify how the group interacted and what could be improved on.

From the above discussion, CL can be described as a structured teaching–learning strategy that can only be effective when implementing the five basic elements of CL (see 3.2.1.1–3.2.1.5). The next section focuses on discussing CL as it relates to CT.

3.2.2. Cooperative learning and critical thinking

Many studies have illustrated the advantages CL hold in the development of CT (Zipp, 2007:62). Ten Dam and Volman (2004) also note that many scholars view CL as the instructional method that can effectively promote CT. In a study by Schamber and Mahoney (2006), which investigated the development of CT in general education by means of CL in first-year general education students, it was found that CT is improved through group work.

Spencer and Gillis (2008:95) in Dunn (2008) note that CL activities provide a platform for developing CT as such activities allow students to model CT, gain from others' ideas, and provide and receive feedback. In this section, the relationship between CT and CL will be discussed by focusing on the elements of CL, which contribute to the development of CT.

One of the elements of CL is its ability to open dialogue. The finding of studies such as that of the Hong Kong Institute of Education (Li & Lam, 2005:10–33) where it was noted that CL hold many advantages of which the development of CT is one advantage. Li and Lam (2005:11) go on to describe that CL stimulates CT development in that it allows individuals to converse at a higher level when in smaller groups than when the whole class and the teacher converse together. CL also allows individuals to argue and negotiate different perspectives leading to a heightened conceptual learning through this dialogical process. In 2014, the concept of CT being developed through dialogue, was still prevalent through dialogical instruction as illustrated in Paul and Elder (2014). Paul and Elder (2014:372) define dialogical instruction as instruction that allow discussions and debates of ideas from several perspectives, which proves essential in the development of CT. Regarding the definition of CL by Johnson and Johnson (2013:449) and the definition of dialogical instruction by Paul and Elder (2014:372), it is possible to note that the two instructional strategies (CL and dialogical instruction) intertwine with each other in that CL can be used as a form of dialogical instruction to maximise the development of CT.

Another advantage that CL holds is the fact that individuals in the group receive immediate feedback from other group members, which in turn allows them to develop CTS (Richardson *et al.*, 2007). Brookfield (2012:146) explains that a beneficial strategy – which he has experienced in his classes – is that of peer learning where students have the opportunity to give each other feedback before individuals submit their final papers. He continues to note that a peer critique protocol should be given to the students so that their feedback is structured and advantageous to both their partners and themselves. By allowing students to give immediate feedback through questioning, students are led to critical learning. Brookfield's peer learning for feedback can easily be achieved continuously during the CL process and especially during group processing.

Ten Dam and Volman (2004:366) emphasise the value placed in the literature on CL to increase CT.

CL also increases higher-order skills as well as higher-reasoning strategies (Ten Dam & Volman, 2004:366). In a study by Schamber and Mahoney (2006), they determined the effect of instructional strategies on the improvement of CTS. The participants involved in the study were approximately 770 college students enrolled in a first-year course entitled “Mentor Seminar II: Today’s decisions” in which students were required to think critically about social issues and to work with other students to reach consensus in reaching a common goal by means of CL. They made use of two strategies: revision in writing and a CT rubric. As the researchers note, CL research often tends to focus on higher-order learning, but seldom regards the outcome it has on the group’s CT (Schamber & Mahoney, 2006:119). By allowing groups to rewrite their assignments, Schamber and Mahoney (2006) illustrate that individuals show an increase in CTS. With the use of the holistic CT scoring rubric, their research group also showed a greater improvement in CT (Schamber & Mahoney, 2006). The researchers (Schamber & Mahoney) concluded that CL increases CT if the teaching strategy implemented is designed and implemented correctly.

The following section will subsequently focus on the implementation of CL in the IT classroom.

3.2.3. Cooperative learning in the Information Technology classroom

With software development forming 60% of the IT syllabus, a strategy, which is conducive to the successful teaching and learning of programming, is necessary. Mentz and Goosen (2013:131) note that CL is a viable teaching–learning strategy for the IT classroom. Mentz and Goosen (2013) further note that, over the past ten years, programming in the IT industry has shifted from an individual activity to a group activity as groups outperform individuals in programming tasks. One CL strategy that has proved successful in the IT class is that of PP (Mentz *et al.*, 2008).

3.2.3.1. Pair programming as a cooperative learning strategy

Traditionally, PP has been viewed as a collaborative teaching strategy (Williams & Kessler, 2003), but has also been implemented as a cooperative teaching–learning strategy (Mentz *et al.*, 2008).

3.2.3.1.1. Defining pair programming

Although the term 'pair programming' only originated in the nineties (Salleh, 2008:2), the practice of working together in pairs had already found its way into the programming industry as early as 1950 (Williams & Kessler, 2003:5). PP form part of 12 'extreme programming' strategies that were developed by Beck, Jeffries and Cunningham (cited in Sadasivan, 2005:3). Waite and Leonardi (2004:2) explain that a need for PP to be implemented in students' training was expressed as a result of the programming industry noting that students were not adequately equipped to work in groups once graduated. In a study focused on students in introductory computer programming classes conducted by Werner *et al*. (2004:3) in California, they found that students who were taught by means of PP expressed that they experienced less frustration during programming and felt more confident in their programming skills. The students in Werner *et al.'s* (200) study preferred PP over individual programming. This notion that students prefer PP over individual programming can also be found in studies like that of Nagappan *et al.* (2003:362) who found that 59.9% of students experienced PP positively. Williams and Kessler (2001:8) note that students in their study experienced PP extremely positive, while Cliburn (2003:28) report that students in their study felt that PP increased their academic performance, their interpersonal skills as well as the quality of their programmes. PP thus holds many advantages (Slaten *et al.*, 2005:327, Williams & Layman, 2007:76).

Wiebe *et al.* (2003:5) found that pair programmers are self-directed seeing as they are actively involved in the teaching–learning process and therefore responsible for their own success. To realise this outcome of individuals maximising their learning success, PP has to be implemented correctly.

PP is a programming strategy where two individuals work together on one programming task by developing, coding and testing their solution simultaneously on one computer (Vanhanen & Korpi, 2007, Williams *et al.*, 2000:20). The members of the pair each fulfil a specific role, one being the 'driver' and the other the 'navigator'. These roles are discussed in 3.2.3.1.2.

3.2.3.1.2. Individual roles during pair programming

The driver is responsible for controlling the pencil, mouse and/or keyboard to write on paper or to code on the computer. The navigator, on the other hand, is responsible for guiding the driver's actions by continuously consulting resources, focusing on what the driver is doing and watching to ensure that the driver does not make any mistakes (Williams *et al*., 2000:20). Wiebe *et al.* (2003:1) as well as Cliburn (2003:22) emphasises that the driver should continuously ask the navigator for advice regarding what should be done in the task and, in return, the navigator should continuously give feedback on error identification, give support and ask the driver to explain what he/she is doing. An important aspect to adhere to in order to have PP implemented correctly is to remind the pairs that individuals should switch roles continuously (Cicirello, 2009:45).

3.2.3.1.3. Advantages and disadvantages of pair programming

When the roles of the individuals in the pair are fulfilled correctly, PP holds several advantages (Williams & Layman, 2007:73).

In a study by Williams *et al.* (2002:3–4), which focused on determining the effect of PP on first-year computer science students' academic achievement, they found that those students who were exposed to PP significantly improved their academic results compared to those who had not been exposed to PP. Another advantage of PP is that it improves cognitive processes, as described by Bryant *et al.* (2008:522). Bryant *et al.* (2008:521) continue to explain that PP allows students to understand concepts better as pairs are continuously communicating and, in doing so, strengthening each other's understanding of concepts.

PP also has been proved to increase enjoyment of programming by individuals (Cliburn, 2003:28). Cockburn and Williams (2000:240) found that 90% of their students enjoyed the programming module as a result of implementing PP.

A great advantage illustrated by Williams and Upchurch (2001:327) as well Palmieri (2002:14) is the fact that PP decreases errors in programming**.** In their study, Williams and Upchurch found that students were 15% less likely to make mistakes when programming in pairs than individually. One possible reason for the decrease in errors and mistakes could be the continuous communication during PP (Lee, 2003:6).

Although PP holds many advantages, certain disadvantages have also been noted in the body of scholarship.

Williams and Kessler (2003) describe several disadvantages that may occur during PP. One individual might become dependent on the other during PP and therefore LeJeune (2003:282) advises that individual assessment should still form the basis of assessment during PP. Another disadvantage mentioned by Williams and Kessler (2003) is that pairs with different programming adequacy may experience it challenging to work with one another. Urness (2009:88) suggests that pairs should be randomly selected and Lee (2003:16) notes that pairs should be switched frequently so as to limit frustrations that could occur in the pair due to differences in programming adequacy. Researchers like Katira *et al.* (2004:10) however found that differences in programming skills do not play a role in the success of PP.

Disadvantages found in the body of scholarship can mostly be ascribed to PP not being implemented correctly (Liebenberg, 2010:44) which confirms Mentz's (2012) notion that PP should be implemented with the five basic elements of CL (Johnson & Johnson, 2009) being infused in it (see 3.2.1.1–3.2.1.5). Although numerous studies show the benefits of CL, a number of teachers complain about difficulties experienced when implementing CL in their classrooms (Gillies, 2003:37). With PP placed in CL, it is influenced by two key factors: the role of the teacher and the role of the learner.

3.2.3.1.4. The role of the teacher when implementing pair programming

Liebenberg (2010:43) notes that teachers play a vital role in ensuring the success of PP. To ensure this success, teachers need to adhere to certain guidelines, which include assessment of PP as well as how to select the pairs (Urness, 2009:87–88).

An important aspect of CL when implementing PP as a CL strategy, is to prepare students for the CL process. Race (2000:28–29) lists suggestions when introducing students to CL:

- provide students with an opportunity to realise the advantages CL holds for them;
- form groups carefully and let students know they will be changing groups often;
- form groups of different sizes for different tasks;
- train students in group processes;
- provide students with an opportunity to realise what could go wrong during CL;
- provide students with support and encouragement when things go wrong during CL;
- ensure students are comfortable during the CL experiences;
- ensure students know that all cooperative work and individual work in the group will be assessed; and
- give students the opportunity to take part in the assessment of the group's effectiveness.

When selecting pairs, researchers differ in opinion regarding how individuals should be paired up. Bevan *et al.* (2002:104) suggest that teachers should pair learners according to their skills and confidence in programming, whereas Williams *et al.* (2006:414–416) state that pairs can be selected according to personality types, learning styles, skills levels, programming confidence, work ethic as well as time management skills. It is important to note that Williams *et al.* (2006) focus on tertiary students who do not only use PP in a formal setting, but also outside of the classroom.

Mentz *et al.* (2008:259) as well as Liebenberg (2010:43–48) illustrates that teachers' infusion of CL elements into PP is the most important role of the teacher to implement PP successfully. The implementation of the basic CL elements in PP is discussed below.

- **Positive interdependence (see 3.2.1.1)**

As mentioned in section 3.2.1.1, it is important for all individuals participating in any CL setting to realise that they cannot achieve success unless the whole group and each individual achieve success, therefore they sink or swim together as a group (Johnson & Johnson, 2009:109). Mentz *et al.* (2008:249) suggest that teachers award bonus marks and/or other motivational strategies to encourage both individuals in the pair to succeed instead of only one individual in the pair reaching success. Preston (2006:89) notes that certain suggestions can be followed to support positive interdependence:

- allow pairs only one screen, one pencil and one textbook, which encourages them to share;
- allow the driver to refer to the textbook/resources only if he/she is asking the navigator a question; and
- encourage the navigator to take full responsibility for controlling the resources such as the textbook.

Apart from working together as a pair to ensure interdependence, each individual in the pair should also take individual accountability.

- **Individual accountability (see 3.2.1.2.)**

Liebenberg (2010:44) notes that, in PP, certain guidelines should be implemented to ensure that each learner contributes to the learning process. Preston (2006:90) as well as Mentz *et al.* (2008:249) suggests that individual tests be given and that these individual tests should carry the greater weight in the individual's assessment mark. Mentz *et al.* (2008:249) emphasise that pairs should be aware that they will not only be assessed as a pair but also as individuals, which contributes to each individual taking responsibility for his/her own learning as well. These individual scores should also be communicated with the group as a whole in order for the group to determine their effectiveness to contribute to everybody's learning.

- **Promotive face-to-face interaction (see 3.2.1.3)**

Promotive face-to-face interaction in PP is achieved when individuals in the pair support each other by sharing resources and challenging each other's suggestions and ideas about how to solve the programming problem (Mentz *et al.*, 2008:250).

- **Social skills (see 3.2.1.4)**

Johnson and Johnson (2009:111) emphasise that individuals need to acquire interpersonal skills for successful cooperation. Liebenberg (2010:44) notes that in her study, learners in the IT classroom enjoyed programming more and felt more motivated as a result of their social skills improving. Social skills are easily developed through PP (Ally *et al.*, 2005:84) as PP includes continuous communication (Begel & Nagappan, 2008:125). Social skills therefore need to be taught for successful cooperation, but can also further be developed in a CL setting.

- **Group processing (see 3.2.1.5)**

Members of the group need to evaluate their thoughts and actions consistently (Johnson & Johnson, 2009:112). Metacognition forms an important part of PP and therefore pairs need to be granted the opportunity to evaluate and examine how they performed.

Although the teacher/facilitator plays an important role in ensuring the success of any CL process, including PP, the learners also play a part in the process. The role of the learner when implementing PP as a CL strategy is discussed below.

3.2.3.1.4. The role of the learner when implementing pair programming

Although learners need to be confident in the PP process, it is important for each individual learner to realise that he/she has a responsibility to ensure success. As learners work together conflict is bound to rise; it is therefore important to allow learners to work toward a compromise but each individual should still feel confident to stand up for his/her belief (Williams & Kessler, 2003:203–208).

Another important aspect regarding the role of the learners in PP is described by Mentz and Goosen (2013:149). They note that each learner should know what his/her role in the pair is. Furthermore, learners should listen carefully to one another, share resources and be prepared when attending classes.

With the teacher/facilitator and individuals in pairs fulfilling their roles successfully, PP in the class will be successful as a CL strategy. PP has also been implemented in the South African IT school subject context (Liebenberg, 2010; Mentz *et al.*, 2008). As CL assists in the development of CT, and PP has been successfully set in CL, PP might be a way in which CTS can be developed. No evidence could however be found from the body of scholarship to confirm this notion.

Another strategy that not only promotes CT but also learning during CL is the Socratic Method.

3.3. THE SOCRATIC METHOD

Yang *et al.* (2005) note that the Socratic Method or Socratic questioning is the most popular teaching approach used to foster CT. This notion is reiterated by Ryan *et al*. (2013:410) who state that the Socratic Method provides educators with the tools for developing students' CT, reasoned analysis, oral presentation, performance under pressure as well as disciplined multi-factor analysis. With its apparent use in CT development, the following section will discuss the Socratic Method.

3.3.1. The Socratic Method defined

The Socratic Method has its origin almost 2500 years ago with the Greek philosopher Socrates who made use of this way of teaching with his students, like Plato. By the nineteenth century, the Socratic Method was seen as a popular method in the K-12 education (schooling grades) fields in the United States (Schneider, 2013:621). The modern world came to know about Socrates' method of teaching through Plato's writings about Socrates in his Platonic Dialogues (Boghassian, 2006:44). Schneider (2013:613) adds that the Socratic Method is accepted by several education stakeholders as a legitimate teaching–learning approach.

The Socratic Method is divided into six conversational stages (Boghassian (2006:44). Firstly, it involves *wonder* about a topic, then one forms a *hypothesis* regarding a judgement. To ensure the hypothesis is correct, Socrates used a step called *Elunchus,* which is a form of cross-examination to weigh up strengths and weaknesses of the hypothesis made. The last two stages of the Socratic Method according to Boghassian are *accepting or rejecting the hypothesis* according to the Elunchus and then only *acting according* to the accepted or rejected hypothesis. Paul and Elder (2014:429) describe Socratic questioning as the method derived from Socrates, which entails questioning the meaning, justification, logical strengths and weaknesses of a judgement or claim and/or logical line of reasoning. In another work by Paul and Elder (2006:91–92) on the tools used to transform into a good thinker, they list the fundamentals of Socratic questioning:

- investigate the foundations of statements or beliefs;
- acknowledge that all thoughts are interlinked;
- focus on clarifying all thoughts; and
- recognise that all questions follow on previous questions and thinking follow on prior thinking.

Lam (2011:2) describes the Socratic Method as a constructivist learning approach with four key steps:

- **Determining/eliciting preconceptions**
  As learners bring preconceptions to the learning process, it is important to ask them specific questions to elicit these preconceptions.

- **Clarifying preconceptions**
  During the first step of the Socratic Method, according to Lam, learners will become aware of their preconceptions, which should then be clarified, according to the second step of the Socratic Method.

- **Testing the hypothesis**
  Once preconceptions are evident, learners will make hypotheses based on these preconceptions, which need to be tested to determine their strengths and weaknesses.

- **Accepting or rejecting the hypothesis**
  Based on the evaluation of the hypothesis, learners can go on to act according to their evaluation. Should the hypothesis prove to be viable, it can be accepted; should it be rejected, the process will have to start again.

Richard Paul (1995) described six types of Socratic questions that can be used during the implementation of the Socratic Method:

1. Questions for clarification

Why do you say that?
How does this relate to our discussion?

2. Questions that probe assumptions

What could we assume instead?
How can you verify or disapprove that assumption?

3. Questions that probe reason and evidence

What would be an example?
What is A analogous to?
What do you think causes B to happen? Why?

4. Questions about viewpoints and perspectives

What would be an alternative?

What is another way to look at it?

Would you explain why it is necessary or beneficial, and who benefits?

Why is C the best?

What are the strengths and weaknesses of D?

How are E and F similar?

5. Questions that probe implications and consequences

Which generalisation can you make?

What are the consequences of that assumption?

What are you implying?

How does G affect H?

How does I tie in with what we have learned before?

6. Questions about the questions

What was the point to this question?

Why do you think I asked this question?

What does J mean?

How does K apply to everyday life?

By asking these questions, which are the foundation of the Socratic Method (Whiteley, 2006:68), learners can systematically move through topics and gradually improve their CTS. The following section focuses on the Socratic Method and CT.

3.3.2. The Socratic Method and critical thinking

Walker (2003) investigated effective teaching–learning strategies that can be employed to develop CT. Walker concluded that questioning, classroom discussions and debates as well as written assignments all are active learning strategies that promote CT. The Socratic Method is used as a questioning strategy for developing CT. Paul and Elder (2006:i) concur that critical thinkers are required to question deeply, and in an attempt to develop these questioning skills, a study of Socrates' method of questioning is needed. Having students ask structured questions induces students' higher-level cognition including reflection, revision and social negotiation as well as allowing paradigm shifts regarding misconceptions. These skills, developed through questioning, are all necessary for the development of CT (Yang *et al*., 2005:164). Paul and Elder (2006:2–3) explain that, in order to deepen CT, Socratic questioning should be employed in teaching as this type of questioning frames questions that are necessary in the pursuit of meaning and truth.

In a study by Yang *et al.* (2005), they investigated the effect of Socratic questioning on 16 undergraduate distance learning veterinary students. In the first event of the study, the lecturer implemented Socratic questioning during the second semester of the 32-week (two semesters) course. In the second instance of the study, the lecturer implemented Socratic questioning in the first semester and asked students to continue this practice in the second semester. Making use of the California Critical Thinking Skills Test (CCTST), as a pre-test as well as post-test, both groups showed improvements in their CTS; however, the second group's CTS improved more than those of the group where Socratic questioning was only introduced in the second semester. Another advantage reported in this study was the fact that the group who was introduced to Socratic questioning in the first semester continued interactions at a higher level evident in their online discussions (Yang *et al.*, 2005:178). Boghassian (2006) supports this finding in his study on inmates where he determined that their CT also improved through the use of the Socratic Method.

Ryan *et al.* (2013) conducted a multicultural study involving law students from both America and China to determine the effects of the Socratic Method on students' creativity and CT. Through student surveys, they established that 47% of the students noted that they enjoyed the learning model, 100% noted that they did indeed learn something in the course and most importantly, students reported that they found this teaching model valuable in the development of their creativity and CT.

Based on the list of CTS described by Facione (1990:7), it is possible to deduce that the Socratic Method proves advantageous for the development of these skills. Figure 3.1 illustrates the skills with the accompanied Socratic Method steps.

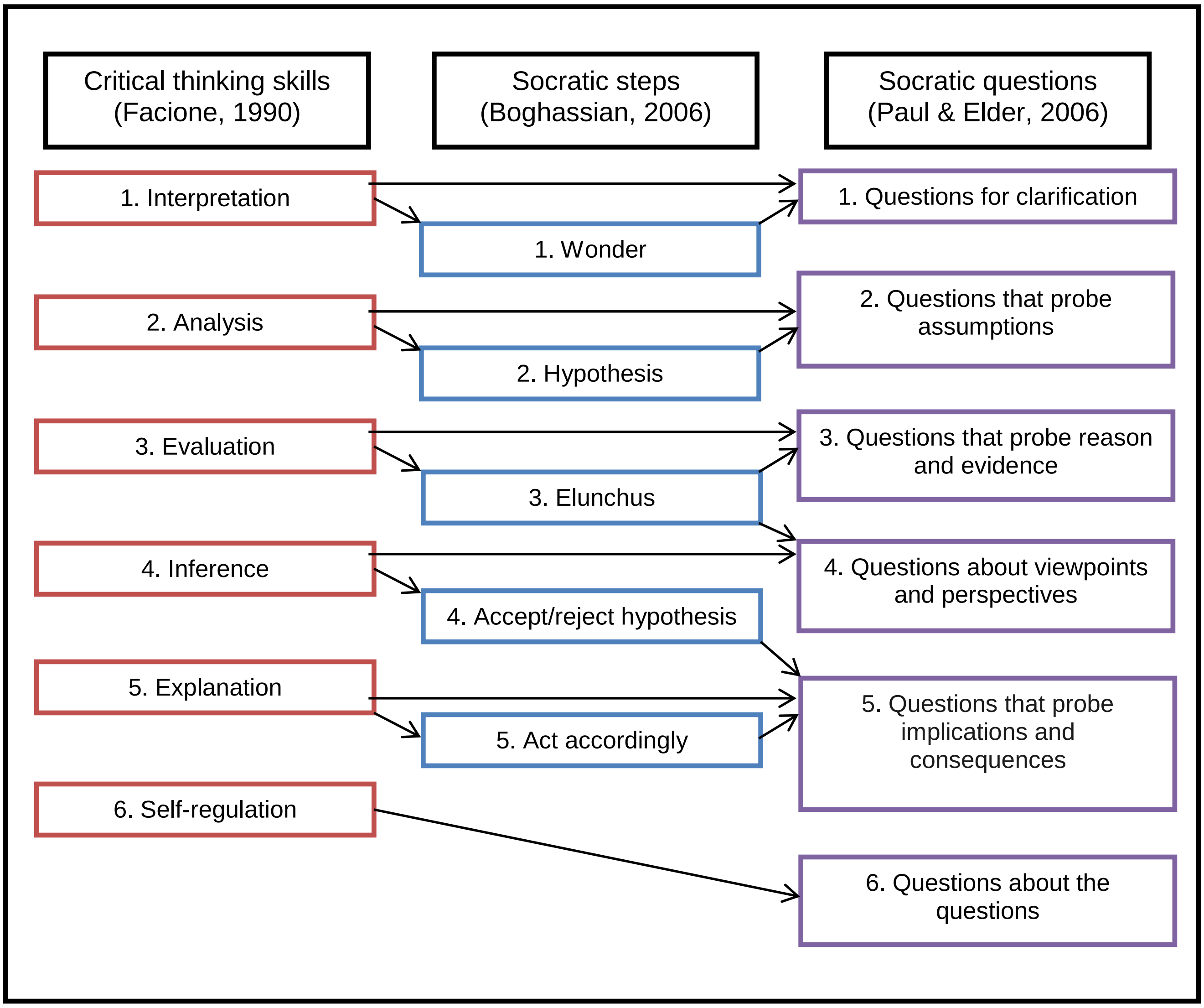


Figure 3.1 Critical thinking skills connected to the Socratic Method

The first step of the Socratic Method is to wonder, where the skill of interpretation is needed as the individual will look at the topic at hand and have to interpret what is given. During interpretation, questions for clarification can be used to assist with the interpretation as it includes questions like: Why do you say that? and How does this relate to our discussion? To elicit the skill of analysis, the second step of the Socratic Method is hypothesis, where an individual needs to take the wonder and clarification from the previous step and develop a hypothesis through analysis. When hypotheses are developed, it is important to elicit assumptions that will play a role in the hypotheses. Socrates often made use of what was called the Elunchus or cross-examination, which assists in the development of evaluation skills as Socratic questions that probe reason and evidence as well as viewpoints and perspectives can be asked as cross-examination strategies. Making use of step 4 of the Socratic Method, which requires that an individual either accepts or rejects the hypothesis made. The skill of inference can be elicited as it is only through inference that one can derive whether you should accept or reject a hypothesis. Once a decision whether to accept or reject a hypothesis has to be made, a critical thinker needs the skills to explain why the decision was made, which is made easier through the Socratic questions that probe implications and consequences as the Socratic Method asks questions like:

- What are the consequences of that assumption?
- What are you implying?
- How does A affect B? and
- How does C tie in with what we have learned before?

Lastly, the skill of self-regulation is required from critical thinkers, which can be developed by using Socratic questioning about questions like:

- What was the point to this question?
- Why do you think I asked this question?
- What does D mean? and
- How does E apply to everyday life?

Schick and Vaughn (2005:178) state that CT can be achieved by making use of the scientific method. What becomes clear is that the scientific method described by Schick and Vaughn (2005) closely resembles the Socratic Method steps discussed by Boghassian (2006). Figure 3.2 illustrates these two methods as linked to each other, showing that the Socratic Method holds value in CT.

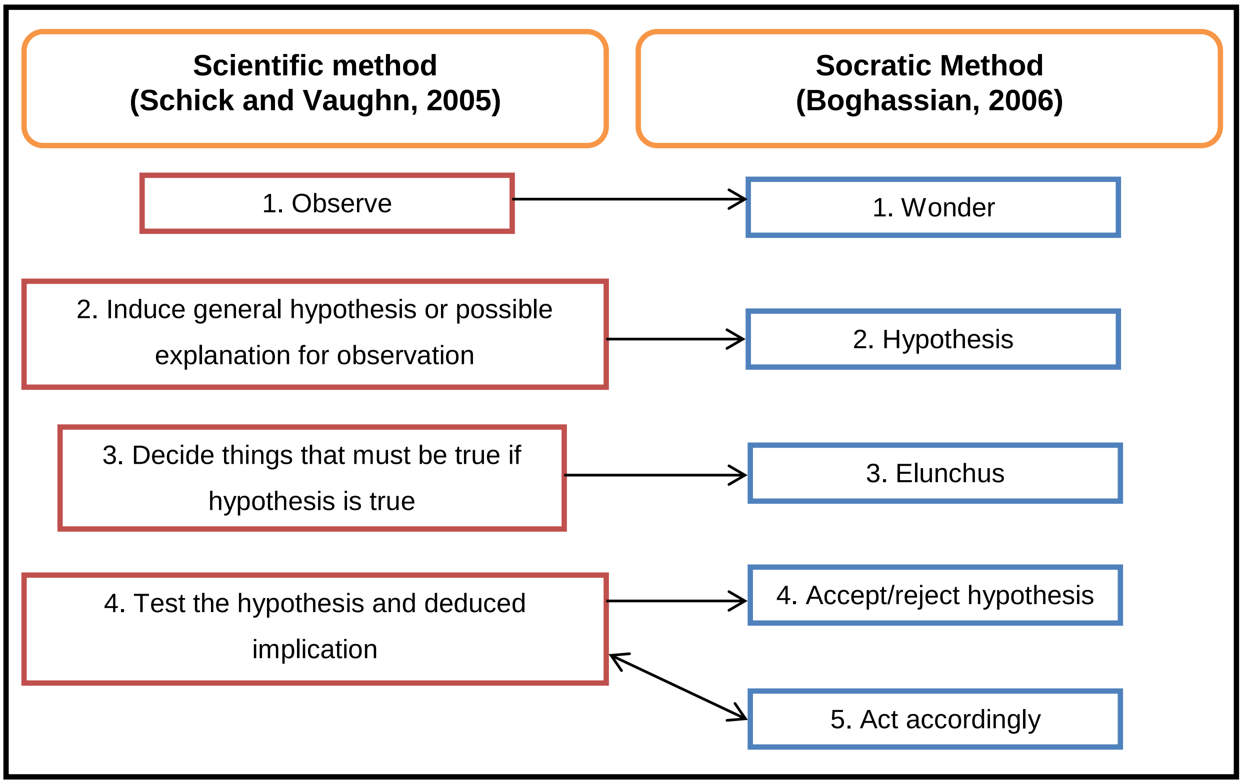


Figure 3.2 The scientific method connected to the Socratic Method to elicit critical thinking

The Socratic Method includes a step which calls for action, whereas Schick and Vaughn's scientific method ends with the testing of the hypothesis, but implies action.

Although both CL and the Socratic Method hold advantages and disadvantages for the IT classroom, some other strategies have also been noted as viable for the development of CT (see 2.5.2.1)

3.4. A FRAMEWORK FOR DEVELOPING CRITICAL THINKING SKILLS IN THE INFORMATION TECHNOLOGY CLASSROOM

3.4.1. Supporting Information Technology teachers: Teach the teachers

IT learners' CT can only be developed if their teachers model CT, which implies that teachers need to be supported in CT development (see 2.4). One way of supporting teachers in their acquisition of CTS as well as the ability to develop their learners' CTS is through professional development.

Professional development gives teachers an opportunity to continue their own learning process and in turn have an effect on their students' learning (Murtaza, 2010:213). As Blazer (2005) notes, effective professional development of teachers is characterised by a change in teachers' instructional practice. By creating an opportunity for them to engage in an individual face-to-face professional development programme, teachers feel more engaged and confident as they have all the attention of the facilitator (Bailey, 2013:28). With this in mind and the strategies noted that can be used to develop IT learners' CT, a professional development manual can accompany the face-to-face professional development session to allow teachers to refer back to after the once-off professional development session has been conducted. The proposed manual is included as Addendum A. In this manual, teachers are introduced to CT, given several strategies that can promote the development of CT, as well as some examples on how to implement these strategies in the IT classroom.

3.4.2. Supporting Information Technology learners: Conquer the challenges

IT learners need to be developed in the skills of CT (see 2.5); however, as few classes devote attention to developing these skills, learners face challenges with the new way of thinking.

Introducing learners to the theory of CT is suggested (see 2.5.2.2). This can be done by using informative videos, class discussions, flash cards and/or posters. It is also important to give learners clear instructions when using the strategies decided on to develop their CT.

3. 5. CONCLUSION

CTS can be developed by using CL strategies as well as the Socratic Method.

When implementing CL in the IT classroom, one can make use of PP, given that it incorporates the five elements of CL (see 3.2.3.1.3). In South Africa, success of implementing PP in IT at school level has been reported. With the success of CL in the development of CT, and the effectiveness of PP as a CL strategy, one can deduce that PP can possibly be used to develop CT; however no reports of the success of PP to develop CT could be found in IT classrooms in SA schools.

Another strategy that has been illustrated as successful in the development of CT is the Socratic Method (see 3.3). This strategy can be used individually or infused in PP; however, no reports of this method being implemented in South African schools in the IT classroom have been found.

In the next chapter, the implementation and examination of these strategies in IT classrooms in South Africa are discussed.

CHAPTER 4

SELF-DIRECTED LEARNING: A NECESSITY FOR INFORMATION TECHNOLOGY TEACHING AND LEARNING

4.1. INTRODUCTION

In Chapter 2 and Chapter 3, critical thinking (CT) and cooperative learning (CL) were discussed. By implementing strategies like speaking in tongues, assumptions inventory, devil's advocacy, questioning and the Socratic Method, Information Technology (IT) learners' CTS may be developed.

In this chapter, Self-Directed Learning (SDL) as an educational outcome during the teaching and learning of IT learners will be discussed.

4.2. RATIONALE FOR SELF-DIRECTED LEARNING

SDL as an educational goal is not a new endeavour (Bolhuis, 2003:327) and holds many advantages in several fields of study. This section will be focused on illustrating the necessity of SDL in education.

Bolhuis and Voeten (2001) explain that SDL is an important educational goal. This notion is emphasised by Birenbaum (2002:119) in what she deems the self-directed active learning pole of education that needs to be promoted as opposed to the external regulation pole, which is more frequently found in educational settings. Guglielmino (2008:2) notes that SDL is a necessity as a result of our human nature (inquisitiveness to learn) and the environment (ever-changing world) within which we find ourselves. Guglielmino (2008) illustrates how a baby would be inquisitive and through this intrigue, explores all aspects of that which is before him/her, therefore illustrating a natural sense of self-direction. Apart from our natural tendency to continuously learn and explore for the sake of gaining knowledge, the ever-changing environment within which we find ourselves requires of us to keep up with these changes through constant learning endeavours (Guglielmino, 2008:4).

In another study by Guglielmino (2013:7), she states that it is through SDL approaches that our basic needs for optimal motivation and well-being are met. Although SDL has been emphasised as important in education, researchers like Silén and Uhlin (2008:461) state that the development of SDL has been neglected in educational settings. Brockett (2006:27) notes that the technological advances in recent years brought with it opportunities that have not been possible 20 years ago. With these advances, the importance of making good decisions is emphasised. Brockett (2006:33) explains that SDL is concerned with freedom, autonomy and choice, all of which are aspects that assist in coping with the ever-changing world within which we find ourselves today.

SDL is an important goal in order to survive in this generation filled with knowledge and change. Before delving into how SDL can be developed, it is necessary to define SDL clearly. The following section therefore focuses on explaining SDL.

4.3. THINKING ABOUT SELF-DIRECTED LEARNING

SDL, although researched comprehensively, is a complicated concept. SDL has been defined as early as the 1900 yet varied definitions can still be found in the body of scholarship regarding SDL (Long & Associates, 2000). In this section, SDL as an educational outcome is discussed in depth.

When defining any concept, it is worthwhile firstly to break the concept into its basic elements and defining each element separately. SDL comprises the elements 'self', 'directed' and 'learning'. The Oxford Dictionary (2015a:online) defines self as: "A person's essential being that distinguishes them from others, especially considered as the object or reflexive action". Referring to the element 'directed' in the concept of SDL, the Oxford Dictionary (2015b:online) defines it as: "To control the operations or manage or govern". 'Learning' is defined more broadly and brings with it a set of underpinning theories; however, the Oxford Dictionary (2015c:online) defines 'learning' as: "The acquisition of knowledge or skills through study, experience, or being taught". From the definitions provided, SDL can be narrowly defined as the acquisition of knowledge or skills directed by oneself through reflexive action.

SDL has been used synonymously with independent learning (Brookfield, 1982). Independent learning is defined as a process where a learner acquires knowledge by his/her own efforts, and develops the ability for enquiry and critical evaluation (Candy, 1991). SDL in this sense, as a synonym for independent learning, therefore describes a learner who takes initiative for his/her own learning. However, SDL (as used synonymously with independent learning) does not note how the learning process takes place, only its outcome and starting point are mentioned. Malcolm Knowles (1975) was the first to state that SDL (which he grounds in andragogy, i.e. adult education) should be implemented in primary education. Knowles defines SDL in a broader sense, expanding from the fact that it is when the learner conducts learning independently.

According to Knowles (1975), SDL is a process where the learner takes initiative for learning, diagnoses his/her learning needs, formulates learning goals, identifies resources for learning, chooses appropriate learning strategies and evaluates learning outcomes. In accordance to Knowles' definition, Wood (1975) lists eight skills that are needed for SDL to be successful. The learner needs to be able to:

- operate independently;
- seek answers without assistance;
- manage class time;
- plan;
- use study skills;
- conduct learning on his/her own;
- adapt activities to suit own needs; and
- work at a pace correlated with his/her ability.

Knowles (1975) and Wood (1975) both emphasise that the SDL process should be guided by the learner him/herself; however, Knowles adds that learning can occur with or without the assistance of others. Wood (1975) defines SDL in the light of competencies of the learner and not necessarily in the light of the learning process, as is the case with Knowles.

Regardless of efforts by researchers like Knowles and Wood to define SDL as much more than self-study, Long and Ashford (1976) note that terms like 'Self-Directed Learning', 'self-directed inquiry', 'independent study' and 'self-study' are used interchangeably. They add that this interchangeable use of terms makes it difficult to trace the heritage of SDL. Long and Ashford (1976) make use of the term 'self-directed inquiry', which they define as an educational activity where the learner voluntarily engages in learning through his/her own planning and motivation. They add that the purpose of this activity is either for practical self-activity or curiosity or even both. The greatest emphasis placed by Long and Ashford is on the fact that self-directed inquiry moves from educational activities structured by the educator (which directs the learner's participation) to the learner directing his/her own participation. In theory, it is easy to note that education should move from teacher-directed educational activities to student-directed education, but in practice this poses some challenges.

In realising these challenges, Gibbons and Phillips (1978) define SDL similarly to all the aforementioned pioneer researchers (Knowles, Wood, Long and Ashford) but emphasise that students who are expected to move from a teacher-directed educational activity to a self-directed educational activity should be guided through several critical stages in the transition from teacher-directed education to self-directed education.

Gibbons and Phillips (1978) thus position SDL as a transitional process where the student moves from being less ready to engage in SDL to being actively involved in SDL. During this transition, students initially experience ecstasy where they are highly optimistic about being in a class where there is less teacher-directedness and more responsibility and freedom placed on them (stage one). However, when students are expected to diagnose their learning needs or implement goal setting they often fail at choosing appropriate activities. Wood (1975) notes that self-direction occurs when the student chooses activities in line with his/her abilities. Furthermore, in the second stage (shock of recognition) students become aware of the responsibility that is upon them, the effect of their decisions, and what the implications of SDL are. It is during this stage that students often plead to go back to a more teacher-directed class (Gibbons & Phillips, 1978). The next stage (crisis stage) is found when students move from shock to procrastination. Some students internalise this feeling of crisis, and start believing they are not able to complete the task, whereas others may externalise it by blaming the educator for not giving enough guidance. If educators can get students to sustain through the stage of crisis, students may reach a stage of realism where they accept failure and learn from it. In this stage, students often realise the actuality of being self-directed and what SDL expects from them. Once students have reached the point where they are realistic about SDL, they get to the stage of commitment (Gibbons & Phillips, 1978). It is only during this stage that behaviours and attitudes necessary for SDL become visible. In becoming more self-directed, students enter the phase of achievement where they eventually obtain greater achievements and experience great satisfaction in learning. Although it would be easy to surmise that the stage of achievement is the outcome of educational activities, Gibbons and Phillips (1978) note that two more stages are visible in SDL. After the achievement stage, students enter a plateau stage where complacency is possible. Students can stagnate in their achievement and forget to move beyond it. The final stage is that of mobilisation where students become productive and ready to be self-directed in various activities. As Gibbons and Phillips (1978), Grow (1991) also defines SDL in stages. Grow (1991) developed a four-stage model, noting that SDL consists of four stages. In stage one, learners are not self-directed and rely heavily on the educator to lecture subject content. In stage two, a learner sees the educator as a motivator and inspiring performer, but is still guided by the educator throughout the learning process. Stage three sees the learner moving from being educator-led to being educator-facilitated. The learner will take some responsibility by participating in group projects for instance. In the final stage of self-direction, the learner takes on all responsibility for the learning process (Grow, 1991).

One of the leaders in the field of SDL, Lucy Guglielmino, further developed the definition of SDL by noting that all individuals are self-directed to some extent, but readiness to engage in SDL differs. Guglielmino (1978:34) defines SDL as comprising three elements: context, activation and universality. Self- directed learning can occur in a variety of situations/contexts, guided by workplace or personal needs executed independently or collaboratively. In order to activate SDL, the learner's attitudes, abilities and values play the most important role: the self-directed learner takes responsibility for his/her own learning. Regarding the universality of SDL, Guglielmino (1978:34) states that all learners are self-directed to some extent. To conclude, Guglielmino (1978) refines the definition of SDL as learning that occurs in any setting which is directed by the learner him/herself, influenced by his/her disposition to learning and readiness to engage in self-direction. Guglielmino (1978) and Gibbons and Phillips (1978) all emphasise the fact that there exists a level of self-direction in all learners.

The aforementioned researchers positioned SDL as a learning process (Knowles, Wood, Long & Ashford) or a disposition (Guglielmino, Gibbons & Phillips); however, a paradigm shift occurred in the definition of SDL when researchers like Krabbe (1983) defined SDL as a learning opportunity where the learner has the option to choose what to learn, how to learn, when to learn and how to evaluate the learning, therefore placing the emphasis on the teacher to facilitate the opportunity for self-direction. This view of SDL is also supported by Garrison (1997) who defined SDL as an approach where learners are motivated to take responsibility for their own learning by controlling cognitive and contextual processes in constructing meaningful learning outcomes. SDL therefore becomes a way of setting up the teaching–learning process instead of just looking to the learner to individualise his/her own learning and going through a self-directed process him/herself.

In the year 2000, Huey Long organised SDL research in a meaningful way, structuring the progress it has made over the years. He categorises the definitions of SDL into four conceptualisations: sociological, technique, methodological and psychological (Long, 2000). The sociological conceptualisation emphasises the learner as an individual and solitary learner who makes use of educators or other experts only for their skill or content. This definition of SDL is visible in work by researchers like Candy (1991), who defines SDL similarly to independent learning. In the technique conceptualisation, SDL is defined as a group activity. Knowles (1975), who emphasises the fact that SDL can occur with or without the help of others, supports this notion of group work. Krabbe (1983) states that the educator carries the responsibility for facilitating and setting the stage for SDL. Long (2000) describes his third conceptualisation as the methodological conceptualisation. Here, ideas are based on distance education processes where the learner may experience SDL in solitude (as with the sociological conceptualisation) or with the help of others (technique conceptualisation). The most recent conceptualisation of SDL is that of psychological nature (Long, 2000). The psychological conceptualisation focuses on the internal influences of SDL as described in Long (1987). Long (1987) notes that self-direction would likely not be possible if focus is only placed on the first three conceptualisations, which focus on the external influences. The psychological conceptualisation can further be broken into primary dimensions: metacognition, motivation and self-regulation (Long, 2000). Metacognition describes our thinking about thinking, and in SDL we require awareness of our cognition during learning (Long, 2000). Motivation can be either intrinsic, extrinsic or absent (Long, 2000). In the psychological conceptualisation, Long (2000) explains that four secondary dimensions occur: choice, competence, control and confidence.

Although it is the responsibility of the educator to set the stage for SDL (Krabbe, 1983), Long (2000) notes that if the learner does not illustrate intrinsic motivation, self-direction will be less likely to occur. Self-regulation or self-regulated learning, according to Zimmerman and Pons (1986), seeks to understand learners' ability to learn on their own as well as their motivation to do so. Zimmerman and Pons (1986) continue that several categories are found in self-regulated learning: goal-setting, environmental structuring, self-consequences and self-evaluating. Long (2000) states that the quality of SDL lie in the application of self-regulated processes. Gibbons and Phillips' (1978) critical transition stages as well as Grow's (1991) four stages of SDL can also be classified under the psychological conceptualisation as they describe the internal manifestation of the learner when presented with a SDL context.

Considering Guglielmino's (1978) description that SDL occurs in three elements: context, activation and universality, and Long's (2000) view that SDL can be conceptualised from a sociological, technique, methodological and/or psychological viewpoint, it is clear that SDL is a complex concept. From the discussion, SDL is defined as a teaching–learning process that is influenced by various factors (teacher, educator, teaching–learning strategies, etc.) which promote a learner's self-directedness.

4.4. SELF-DIRECTED LEARNING IN INFORMATION TECHNOLOGY EDUCATION

According to Zander *et al.* (2012:111), it is universally accepted that technical fields that possess constant change require professionals to keep learning throughout their careers. Zander *et al.* (2012) conducted a qualitative study where computing professionals in the industry were asked to comment on what they expected from fellow and future colleagues. The general notion of the computing professionals was that the industry requires employees who can use numerous resources and strategies as well as being able to work well with others (Zander *et al.*, 2012:111).

SDL in computer programming was studied by Boyer *et al.* (2008), who focused on the relationship between self-direction and programming skills as the programming industry requires graduates who are self-directed. Boyer *et al.*'s study involved 15 junior-level computer programming students, of which eight were enrolled in the introductory course and seven were enrolled in the intermediate course (Boyer *et al.*, 2008:91). By using the Personal Responsibility Orientation to Self-Direction in Learning Scale (PRO-SDLS) instrument, the students' level of personal responsibility for the learning process was determined. The students had the opportunity to make use of peer learning, forums and 'live coding hands-on exercises'. Boyer *et al.* (2008) found that by making use of these teaching activities (peer learning, forums and 'live coding hands-on exercises'), students' self-direction improved.

Goede and Taylor (2011) note that students' SDL needs to be developed in order to prepare students for lifelong learning. This was especially true for the students in Goede and Taylor's research group as these were fourth-year Information Systems students who were required to solve problems (Goede & Taylor, 2011:141).

Regarding IT in the South African school context, which was the setting of the present study, SDL also plays an important role. In the Curriculum and Assessment Policy Statement (CAPS) for IT, it is illustrated that software development weighs most, at 60% of the subject content to be mastered (Department of Basic Education, 2012:9). Advances in software development occur daily, programming languages change often and learners are confronted with new problems to solve in examinations. Without the ability to be self-directed, learners will experience difficulty keeping up with these changes occurring in the subject.

4.5. DEVELOPING SELF-DIRECTED LEARNING

Several strategies have been suggested for developing SDL; however, certain conditions that are conducive to the development of SDL are also important to consider. The following section will focus on firstly discussing the conditions that are conducive to promoting SDL and secondly, the possible strategies that can be used to develop SDL.

4.5.1. Conditions conducive to the promotion of Self-Directed Learning

Douglas and Morris (2014) conducted a study to determine which elements assist in the promotion of SDL in students as well as what institutions can do to facilitate the development of SDL. To reach this aim, Douglas and Morris conducted focus group interviews with 80 undergraduate Business, Health and Human Sciences students at the Midwestern University, Arizona. The study revealed three themes that illustrate factors influencing students' development of SDL: student-controlled elements, faculty-controlled elements and administration-controlled elements (Douglas & Morris, 2014:16). Both Straka (2000) and Ahmad and Majid (2010) emphasise factors that occur outside of the classroom, such as cultural influences and socio-historical influences. These factors call for a fourth category to be added to Douglas and Morris' elements that influence SDL development, which can be termed 'inexplicitly controlled elements'. The following sections will discuss these four factors that relate to conditions that are conducive to the promotion of SDL.

4.5.1.1. Student-controlled elements

Student-controlled elements are facilitators and barriers regarding students' development of SDL over which students have control (Douglas & Morris, 2014:16–17). Students noted that they control whether they proactively take part in the lesson during class time. Another factor that the students mentioned was the fact that good study habits and metacognitive control assist in the development of SDL. Students explained that when they attended classes, networked with other students and experts in their field, managed their time properly, and identified and understood their own learning styles, their self-directedness improved (Douglas & Morris, 2014:16–17). Cazan and Schiopca (2014) conducted a similar qualitative study with 121 undergraduate students from a Romanian university, making use of the Self-Rating Scale of Self-Directed Learning (SRSSDL) of Williamson (see 4.6.2) as well as International Personality Item Pool (IPIP-50) personality measuring instrument. Cazan and Schiopca (2014) aimed at determining the relationship between academic performance and self-directedness as they hypothesised that students with higher self-directedness would have higher academic achievements. Cazan and Schiopca's study revealed that SDL and students' academic achievement correlate although it is important to note that it is a greater factor at third-year academic level than at first-year academic level.

Although it may be easy to categorise personality traits, culture, gender and other factors relating to students under student-controlled elements, it is debatable whether students have control over these factors; therefore, these factors will be categorised under inexplicitly controlled elements.

4.5.1.2. Faculty-controlled elements

The faculty-controlled elements describe the facilitators and barriers over which lecturers/educators have control and which would influence SDL (Douglas & Morris, 2014:18). Guglielmino (2013:11) states that it is important to create a climate that would support SDL when aiming to develop students' SDL.

In order to facilitate SDL in the classroom, faculty members should create awareness of the importance of SDL (Guglielmino, 2013). Douglas and Morris (2014) also emphasise the importance of creating a good class structure as it will play a role in the success of the students' SDL development. Both Guglielmino (2013) and Douglas and Morris (2014) note that professionalism and attitudes of the faculty members play a role in students' SDL development. Faculty members should encourage a two-way respect relationship with students (Guglielmino, 2013). Guglielmino adds that teaching staff should encourage questioning in their classes, which can be implemented through specific curriculum design (Douglas & Morris, 2014). Kek and Huijser (2011) explain that lecturers who employ student-centred strategies in their classes have students who are more likely to implement SDL.

Students explained that if lecturers had a good attendance policy where students were held accountable for attendance, had detailed grading systems, gave internship opportunities and used real-world experiences when presenting courses students' self-directedness would improve (Douglas & Morris, 2014:18–19).

4.5.1.3. Administration-controlled elements

Douglas and Morris (2014:20) lastly conclude that students felt that certain elements controlled by administration would assist in the development of SDL. These elements included those factors that the university would be responsible for such as infrastructure and resources and incentives for students (such as bursaries or scholarships). The scheduling of class times and class sizes are all done by administration. Furthermore, the technology that is made available to students as well as the rewards given to achieving students all play a role in students' self-directedness (Douglas & Morris, 2014:20).

It is important to note though that, although some students may feel that lecturers and administration are responsible for providing resources and facilitating learning, students still need to be reminded that they are responsible for their own learning. Apart from the three elements noted by Douglas and Morris, a fourth inexplicitly controlled element can be added.

4.5.1.4. Inexplicitly controlled elements

Inexplicitly controlled elements are those elements that do not fall into one of the three categories set out by Douglas and Morris (2014). Straka (2000) investigated conditions that would assist the promotion of SDL in sales administration companies in Germany. He surveyed 295 employees from different sales companies to determine the effect of certain conditions on the employees. Straka (2000:245) notes that socio-historical conditions play an important role. In accordance with Straka, Ahmad and Majid (2010) investigated cultural factors and SDL. Ahmad and Majid (2010) focused specifically on the effect the Malay culture had on students' self-directedness by distributing the SDLRS amongst 20 adult distance learning students in Malaysia in order to determine the students' self-directedness. From the results of the survey, students were categorised in two categories: high self-directedness and low self-directedness. Three of the students (two from the high self-directedness group and one from the low self-directedness group) were asked to keep a journal, they were observed during class time and they also participated in an interview at the end of the study (Ahmad & Majid, 2010:258). In conclusion, Ahmad and Majid (2010:261–262) note that cultural elements could play a role in the development of students' SDL as culture often determines whether students are obedient, challenges everything, the way students communicate and whether students are submissive or not.

Kek and Huijser (2011) found that learners whose parents were more involved in their children's learning were more likely to be self-directed. By doing a regression analysis, Cazan and Schiopca concluded that students' self-directedness positively correlated with their personality traits: students who are more conscientious, extraverted and agreeable have a likelihood to be self-directed (Cazan & Schiopca, 2014:642).

Table 4.1 illustrates a summary of the four elements discussed above, which play a role in the development of SDL.

Table 4.1 Four elements that influence Self-Directed Learning development (adapted from Douglas and Morris, 2014)

Student-controlled	Faculty-controlled	Administration-controlled	Inexplicitly controlled
Proactivity	Classroom climate	Infrastructure	Socio-historical
Metacognition	Curriculum design	Scheduling	Culture
Academic achievement	Professionalism	Class sizes	Parent involvement
Self-regulated learning	Teaching–learning strategies		Personality
Motivation			

4.5.2. Teaching–learning strategies for developing Self-Directed Learning

Hmelo and Coté (1996:421) and Guglielmino (2013:12) note that problem-based learning is one possible teaching–learning strategy for developing SDL. In accordance with Hmelo and Coté, Silén and Uhlin (2008) also note that SDL is a core feature in problem-based learning. Choi *et al.* (2014) conducted a study to determine the effect of problem-based learning on 90 first-year nursing students' CT, problem solving and SDL. The students studied in two different cities in South Korea. Students in one city received traditional lectures while the other group received lectures in the form of problem-based learning. The instruments used were the CT ability scale for college students, the problem-solving scale for college students and the Self-Directed Learning scale for college students (Choi *et al.*, 2014:53–54). Although Choi *et al.* concluded that all learning outcomes (CT, problem solving and SDL) correlated it was not statistically significant. An interesting finding, though, was that the traditional lecture group's problem solving and SDL decreased after the 16 weeks (Choi *et al*., 2014:55).

Kim (2013) investigated the use of reflective journals in promoting SDL. The study focused on the 40–50 postgraduate students enrolled in a master's degree in a management programme at the University of South Australia (Kim, 2013:256). As intervention, the students were asked to write a reflective journal after each topic had been covered over a ten-week period. By emphasising cognitive dimensions and critical reflections on subject matter, students' reflective journals can provide a helpful tool for promoting students' SDL (Kim, 2013:258).

Another possible strategy for promoting students' SDL is that of e-learning environments. By designing and implementing an e-Student-Oriented Learning Management System (e-SOLMS), Idros *et al.* (2010) emphasise the importance of incorporating students' awareness of the role they play in the learning process. Idros *et al.* (2010) tested 239 students by making use of the Self-Directed Learning Readiness Scale (SDLRS) and found that the e-SOLMS tool positively affected students' self-directedness. Amandu *et al.* (2013) explain how they implemented Moodle, an e-learning environment that allows educators to create online courses, and facilitates online collaboration, in their second-year nursing classes. By making use of all three the educators' observations in the classrooms as well their findings in the body of scholarship, Amandu *et al.* (2013:682) conclude that if the Moodle e-learning platform is utilised effectively, students' self-directedness increases as it enhances students' pre-class preparation, post-class participation as well as their motivation for learning.

Silén and Uhlin (2008:472) argue that active teaching strategies, like group work, promote students' ownership in their learning process, which forms an important aspect of SDL. Promoting awareness of self by letting students work in groups to share their learning experiences, promotes SDL (Guglielmino, 2013:11).

Another strategy proposed by Guglielmino (2013:11–12) is the use of transition structures, which can be done by gradually increasing the responsibility students have for the learning process, making use of different methods to demonstrate success and using learning contracts.

Guglielmino's notion of gradual development of SDL coincides with that of Gibbons and Phillips (1978) as well as Grow's (1991) four-stage model for SDL development.

Table 4.2 presents a summary of the suggested teaching–learning strategies that can be implemented to develop SDL.

Table 4.2 Teaching–learning strategies for developing Self-Directed Learning

Teaching–learning strategy	**Conclusion**
Problem-based learning	**ACTIVE LEARNING**
E-learning	
CL	

From the discussion and the summary, as illustrated in Table 4.2, it is evident that SDL is developed by making use of active teaching–learning strategies. When considering the four elements that contribute to conditions to promote SDL, active learning caters especially for the student-controlled and faculty-controlled elements as active learning allows students to be actively involved in their learning, thus being able to be proactive. Teaching staff who implement active learning strategies will be able to facilitate the elements that are prescribed in section 4.5.1.2.

4.6. ASSESSING SELF-DIRECTED LEARNING

In her guidelines for incorporating SDL into the curriculum, Guglielmino (2013:11) encourages making use of self-assessment strategies like learning style assessments and/or SDL readiness assessment. From the aforementioned studies quoted in the previous sections regarding SDL, it became evident that several instruments and strategies can be used to determine an individual's self-directedness. In this section, possible methods for assessing SDL will be discussed in order to determine which methods are available and which can possibly be used for measuring SDL.

4.6.1. Self-Directed Learning Readiness Scale

The most frequently used method for assessing SDL is the Self-Directed Learning Readiness Scale (SDLRS) formulated by Guglielmino (Merriam *et al.*, 2007). Guglielmino first developed this instrument by making use of a three-round Delphi survey that required 13 renowned SDL researchers to comment on which characteristics a self-directed learner should possess (Guglielmino *et al.*, 2004:6). Guglielmino and Guglielmino (2014) describe the SDLRS for adults as a 58-item self-reporting instrument to determine individuals' readiness to engage in SDL influenced by their attitudes, abilities and characteristics. The SDLRS is also available for adults with lower reading ability (SDLRS-ABE) and elementary school learners (SDLRS-E). The instrument, which is also known as the Learning Preference Assessment (LPA), has been used by more than 500 organisations, has been translated into 22 languages and has been completed by more than 120 000 adults and more than 5 000 children (Guglielmino & Guglielmino, 2014:online).

In their study validating the SDLRS, Long and Agyekum (1983:77) describe the instrument as an instrument that can identify SDL behaviour. Long and Agyekum (1983:78) conclude that the instrument does not take cultural differences into account or what the relationship between educators' perception of SDL and students' SDLRS scores are (Long and Agyekum, 1983:78). The SDLRS has also been used in a number of studies in the South African context (Goede & Taylor, 2011; Tredoux, 2012:124); however, it has not been validated at secondary school level in South Africa.

4.6.2. Self-Rating Scale of Self-Directed Learning

Another instrument found in the body of scholarship regarding the measurement of SDL is the Self-Rating Scale of Self-Directed Learning (SRSSDL) by Williamson (2007). This instrument was developed by conducting an intensive literature review, which elicited 75 behaviours commonly found in self-directed learners. Once the list of behaviours was set, Williamson (2007) conducted a Delphi study using 15 panel members who were required to rate each behaviour according to a five-point Likert-type scale (one being strongly disagree and five being strongly agree). Williamson (2007:70–71) describes the SRSSDL as a 60-item instrument developed to measure the level of an individual's self-directedness during the learning process. The instrument focuses on five sub-categories: awareness, learning strategies, learning activities, evaluation and interpersonal skills.

To test the construct validity and reliability of the SRSSDL, Williamson (2007:71–72) describes that he purposefully sampled 15 first-year and 15 final-year undergraduate nursing students. During analysis, she made use of the Cronbach's alpha coefficient to determine the internal consistency, which illustrated that all five categories fulfilled the requirements for internal consistency (Williamson, 2007:74).

Cadorin *et al.* (2013) conducted a study to determine the validity of the Italian version of the SRSSDL by means of factor analysis. The Italian version of the SRSSDL consisted of 60 items, according to the original SRSSDL; however, it was translated into Italian (Cadorin *et al.*, 2013:1512). The study included a total of 844 participants, comprising registered nurses, nursing students, radiology technicians as well as radiology technician students. One interesting factor emerging was the fact that through factor analysis, Cadorin *et al.* (2007:1515) determined that eight factors instead of only five (as on the original version) emerged with an average Cronbach's alpha of 0.929. Further elicitation also showed that the Italian version of the SRSSDL more appropriately consisted of 40 items, which reduced the time needed to complete the instrument.

In the South African context, Conradie and Van der Gryp (2013:322) conducted a study with fourth-year chemical and minerals engineering students where the researchers distributed both the SDLRS as well as the SRSSDL questionnaires, resulting in a correlation between the two instruments. The SRSSDL, however, has not been implemented in the secondary school context of South Africa.

4.6.3. Self-Directed Learning with Technology Scale

Teaching and learning can occur within a technologically rich learning environment such as online learning and e-learning. Teo *et al.* (2010) identified a gap in the body of scholarship regarding SDL assessment. In their search, they could not find any SDL assessment strategies that were focused on younger learners and/or any that incorporated technology as an element in SDL development. To address this gap, Teo *et al.* (2010:1766) developed a scale consisting of 21 items that could be categorised into three groups: goal setting, implementation of the learning plan, and self-evaluation of the learning process. By conducting various interviews with younger learners as well as focus groups, the 21-item scale was stripped to only seven items, as certain items were considered ambiguous. The validity of the instrument was determined by making use of 545 learners (average age 10.18 years) from six primary schools in Asia (Teo *et al.*, 2010:1767). Fahnoe and Mishra (2013) note that most of the SDL scales focus on adult learners as opposed to middle school learners. In their study they focused on over 900 middle school (Chicago, Illinois) learners' development of SDL within a technological environment. They also made use of the Self-Directed Learning with Technology Scale by Teo *et al.* (2010). Although Fahnoe and Mishra (2013:3136) state that the sixth question on the scale proved unreliable, questions one to five all proved statistically significant.

The three studies mentioned above all agree that the Self-Directed Learning with Technology Scale proved viable for use in younger learners; however, no studies using this scale in the South African context could be found.

4.6.4. Self-Directed Learning Instrument

The Self-Directed Learning Instrument (SDLI) was originally developed by Cheng *et al.* (2010) to serve as an appropriate SDL measurement for nursing students. By dividing the development process into four phases, Cheng *et al.* (2010) finalised the instrument as a 20-item scale focused on four domains: learning motivation, planning and implementing, self-monitoring, and interpersonal communication. Cheng *et al.* (2010:1155) describe that the internal consistency as calculated by using 1 072 nursing students was 0.916, proving that the instrument is reliable for use in nursing education.

Other SDL instruments have also been found in the body of scholarship, but not as widely quoted, for instance the Self-Directed Learning Competencies Self-Appraisal Form (Caffarella & Caffarella, 1986). Table 4.3 provides a summary of the four above-mentioned SDL measurement instruments.

Table 4.3 Self-Directed Learning assessment

Instrument	Developer(s)	Domains measured by instrument	Number of items
SDLRS-A (adults)	Guglielmino (1978)	Attitudes, abilities, characteristics that comprise readiness to engage in SDL	58 items
SRSSDL	Williamson (2007)	Awareness, learning strategies, learning activities, evaluation, interpersonal skills,	60 items
SDLTS	Teo *et al.* (2010)	Self-management; intentional learning	6 items
SDLI	Cheng *et al.* (2010)	Learning motivation, planning and implementing, self-monitoring, interpersonal communication	20 items

Although not explicitly noted, the length of a questionnaire is important, especially when the questionnaire is combined with another questionnaire, as was the case with the present study.

4.7. CONCLUSION

In this chapter, SDL was investigated. With the ever-changing knowledge-filled world we live in today, learners need to be equipped with the necessary attitudes and skills to cope with these changes. By being self-directed, learners develop the ability to learn with or without the help of others but, most importantly, to guide their own learning as needed.

To understand SDL better, a comprehensive definition was developed, which incorporated various ground-breaking definitions into one (see 4.3). It was construed that SDL is a complex concept entailing various elements, such as influences on learning, learning contexts as well as learning processes. The self-directed learner takes responsibility for his/her learning although being influenced by external factors. Finally, this chapter focused on the development of SDL as well as the assessment of SDL.

Much research has been done on the development of SDL, four major influencing elements were identified: student-controlled, faculty-controlled, administration-controlled and inexplicitly controlled elements. With the learning process being influenced by these elements, it is still important to note that the student/learner should take responsibility for his/her own learning and overcome these influences if they prove to be negative.

Regarding the assessment of SDL, several instruments were discussed including the SDLRS by Guglielmino, SRSSDL of Williamson, the SDLTS of Teo *et al.* and the SDLI by Cheng *et al.* It was established that the SDLRS is the most widely used and cited SDL assessment instrument (see Table 4.3). These four instruments were discussed by focusing on their validity as well as on the number of items in the instrument and the domains measured by the instruments. It was determined that the SDLI would be viable to use in a context where a time constraint is present as it consists only of 20 items, whereas the SDLRS consists of 58 items and the SRSSDL of 60 items. The SDLT instrument, although shorter than the SDLI, is only applicable in technology-rich educational settings.

SDL is placed in this study as the educational outcome where learners take responsibility for their own learning; CT forms part of this process and can lead to learners becoming more self-directed. With these two concepts established and the fact that CL can be implemented to enhance both CT and SDL, the socio-cognitive theory (as an approach to learning) informed this study (see 1.2.3). The next chapter will describe the research process followed to determine which implications the development of CT would have on Grade 10 IT learners' self-directedness.

CHAPTER 5
RESEARCH DESIGN AND METHODOLOGY

5.1. INTRODUCTION

In Chapters 2 and 3, an in-depth view of critical thinking (CT) and how CT can be developed was given. Chapter 4 focused on discussing and explaining Self-Directed Learning (SDL) as an educational outcome. In this chapter, the research methodology and design of the study are addressed to show how the research was conducted and which aspects influenced the research process.

5.2. RESEARCH PARADIGM AND DESIGN

In this section, the research paradigm and research design that guided this present study is discussed.

5.2.1. Research paradigm

At the onset of the study, the research paradigm was firstly determined as it plays a part in informing the selection of the research design. The research paradigm is determined by assumptions towards ontology, epistemology and methodology (Trafford & Leshem, 2008:97).

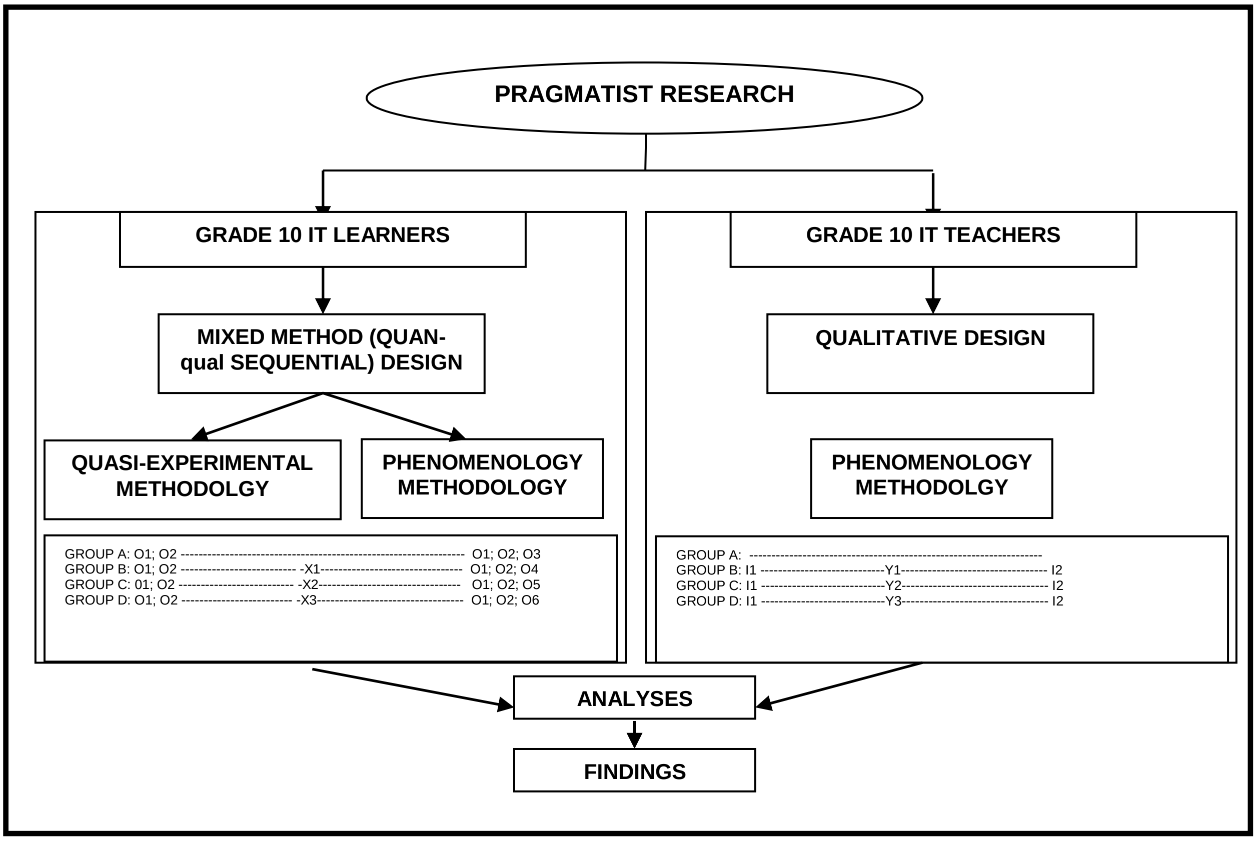
In layman's terms, ontology can be described as how one views reality, whereas the epistemology describes how one would acquire knowledge in this reality (Mack, 2010). Mack (2010) as well as Maree and Van der Westhuizen (2009) notes that ontology leads to epistemology, which in turn leads to the methodology of a study.

The present study was focused on Grade 10 IT learners and how their CTS can be developed. Furthermore, the study also focused on determining the implications that CT development had on the participants' SDL. In hypothesising that CTS and SDL can and should be developed, it is viable to state that the ontological assumptions of the study were that a reality can be reached and that this reality was reached as a result of an intervention. The epistemology of this study was that knowledge is gained objectively. This was possible as the researcher in this study was not involved in the participants' classes and was seen as an objective investigator. As described in Chapter 1, the methodological assumptions in this study were that participating schools had to be selected randomly within a convenient sample of provinces. As participants in the study could not be randomly selected (all students in a class received the intervention or no intervention), a quasi-experimental methodology was appropriate. Creswell (2009) describes pragmatism as a paradigm concerned with establishing what works, therefore making the focus of a pragmatist researcher the research problem rather than the research process. Creswell continues by noting that pragmatism is not committed to any specific research methods (accommodating the mixed methods research), it gives researchers the freedom to choose what they feel would work as the truth is seen as 'what works at the time'. Considering the complexity of this study, which focused on effectively two samples (Grade 10 IT learners and Grade 10 IT teachers) situated in a real-life context (the school and IT class), several methods were necessary to answer the research problem stated; therefore, qualifying why a pragmatist research paradigm is sufficient.

5.2.2. Research design

The purpose, as described in Chapter 1 (see 1.5) was to determine how Grade 10 IT learners' CTS could be developed. Furthermore, the study aimed to determine what the implication of the CT development was on the learners' SDL. To reach this purpose, a mixed method research design was implemented. The mixed method research design consisted of a QUAN-qual (sequential quantitative first) study, as the quantitative study was the primary method of investigation to answer the research questions (see 5.3). The quantitative investigation made use of a causal study design as an intervention was implemented with an attempt to verify the effect of the intervention on the set variables. The qualitative investigation made use of interpretivist study design as it set out to understand the participants' views (see 5.3).

To strengthen and further explain the quantitative findings of the study involving the Grade 10 IT learners, the study also qualitatively investigated the teachers responsible for implementing the intervention strategies, making use of an interpretivist design as the researcher aimed at understanding the teachers' experience of the intervention. Figure 5.1 illustrates the research process used in this study, which will be explained in greater depth in this chapter.



KEY

Group A: Control group

Group B: Critical thinking instruction experimental group

Group C: Critical thinking infused in pair programming experimental group

Group D: Pair programming experimental group

O1: Cornell critical thinking test (CCTT) – X
O2: Self-Directed Learning Instrument
O3: Narrative questions on critical thinking development
O4: Narrative questions on critical thinking development and experience of critical thinking strategies
O5: Narrative questions on critical thinking development and experience of critical thinking infused in pair programming strategies
O6: Narrative questions on critical thinking development and experience of pair programming strategy

X1: Critical thinking intervention
X2: Critical thinking infused in pair programming intervention
X3: Pair programming intervention

I1: Initial interview with teacher
I2: Follow-up interview with teacher

Y1: Critical thinking professional development
Y2: Critical thinking infused in pair programming professional development
Y3: Pair programming professional development

Figure 5.1 Research process

5.3. RESEARCH METHODOLOGY

The research methodology used in this study, informed by the two research designs implemented is discussed by focusing on several aspects:

- the investigation – QUAN-qual mixed method (for Grade 10 IT learners) and qualitative investigation (for Grade 10 IT teachers);
- the population and sampling;
- variables;
- data collection procedures;
- measuring instruments; and
- data analysis.

Where relevant, these aspects will be explained under the respective designs.

5.3.1. QUAN-qual mixed method investigation of Grade 10 Information Technology learners

With the main purpose of this study being to determine whether the CTS of Grade 10 IT learners increased with specific interventions, a QUAN-qual mixed method investigation was used.

As noted, a causal study during the quantitative investigation of the mixed method investigation was used as an intervention to determine the effect of the intervention on learners' CT and SDL. In the causal study, the researcher made use of a quasi-experimental study. This quasi-experimental study implied that the study made use of one control group. After the quantitative post-test, the qualitative investigation was executed within an interpretivist design as the researcher was interested in investigating the Grade 10 IT learners' experience of the intervention.

The following sections will focus on discussing all aspects relating to the mixed method investigation of the participants.

5.3.1.1. Population and sample

The population of the study comprised Grade 10 IT learners in South Africa; however, it would not have been possible to reach each Grade 10 IT learner in South Africa, thus the need to draw a sample.

For this study, a convenient sample was firstly implemented by selecting three of the nine provinces in South Africa. This was established by determining which provinces made use of the programming language Delphi to ensure that the programming language was not a factor as a variable. Another factor related to the selection of the purposive sample was the distance of travel to the provinces selected. With these factors in mind, the three provinces selected for the study were North West, Free State and Eastern Cape. An advantage of these three provinces was the fact that all three had a number of schools hosting IT as a subject for Grade 10 learners. Table 5.1 illustrates the number of schools said to host IT to Grade 10 learners, the number selected for study and the number of schools who agreed to participate in the study for each province.

Table 5.1 Number of schools hosting Information Technology for Grade 10 and sample drawn

Province	Number given by Department of Education	Number randomly selected	Number of schools who agreed to participate	Number of schools completing pre- and post-rounds
North West	22	20	15	13
Free State	20	20	3	3
Eastern Cape	20	20	7	7
Total	**62**	**60**	**25**	**23**

Although the Department of Basic Education indicated (per e-mail communication) schools that host IT for Grade 10 learners, some schools reported that they did not host IT for Grade 10s. Another reason provided as to why a school would not participate in the research was the fact that the IT teacher either opted not to participate or the principal regarded the school exhausted for research studies on account of previous research endeavours. Two schools in North-West withdrew from the study before the second (post-) round could be completed.

As a study of this nature could not omit any individuals by taking a random sample of learners, all learners in each IT class, who's parents gave consent, participated in the study, if they felt comfortable to do so. Table 5.2 shows the number of IT learners forecasted for each province and the actual number of learners participating in each province.

Table 5.2 Number of Grade 10 Information Technology learners forecasted and number of actual participants

Province	Number of learners expected to participate	Actual number of responses received
North-West	200	194
Free State	200	40
Eastern Cape	200	83
Total	**600**	**317**

Not all learners elected to complete the questionnaires and thus the actual number of learners who participated in the pre-tests and post-tests were smaller than the number of learners taking the subject.

5.3.1.2. Variables in quantitative investigation

One of the main items in a quantitative research design is the variables in the study (Creswell, 2009). The variables pertaining to this current study are discussed briefly below.

- **Independent variables**

Those variables that probably play a role in the outcome of the study (Creswell, 2009). In this study, the independent variables addressed in this study were the three different interventions applied to the three experimental groups.

- **Dependent variables**

Variables that are believed to be influenced by the intervention, that might also depend on the independent variables and which are normally the result or outcome of the study (Creswell, 2009). For this study, the dependent variables were the two aspects being measured, namely IT learners' CTS and IT learners' self-directedness.

- **Intervening (confounding) variables**

Stand between the independent variables and dependent variables (Creswell, 2009) and for this study, the intervening variable was the natural progress of the IT learners with regard to CTS and self-directedness. The presence of a control group where no interaction took place, took this into account.

With the variables determined, the following section is dedicated to explaining the data collection procedures that were followed.

5.3.1.3. Measuring instruments

In the quantitative investigation, two questionnaires were used to measure the Grade 10 IT learners' CTS as well as their self-directedness respectively.

5.3.1.3.1. Cornell Critical Thinking Test – Level X

The original Cornell Critical Thinking Test (CCTT) was developed by Robert Ennis, William Gardiner, Richard Morrow, Dieter Paulus and Lucille Ringel in 1964 (Ennis, 1964). In the latest version of the test, revised in 2005 by Ennis, Millman and Tomko, the test focuses on testing CT abilities, and this version can be used to determine students' CT by making use of four sub-sections: induction, deduction, credibility and identification of assumptions. By making use of 71 multiple-choice questions, the CCTT – Level X test is based on the definition of CT as reflective and reasonable thinking focused on determining what to believe in and/or what action to be taken (Ennis *et al.*, 2005:1). Ennis *et al.* (2005) continue to explain that the test can be taken either as a timed 50-minute timed test, or as a normal untimed test.

According to Fisher and Scriven, the CCTT provides the best model for testing CT (critical thinking.com:online). Carlson (2011) notes that the CCTT uses one approach of CT assessment focused on results (CTS) whereas other CT tests could be process-oriented (focusing on student perceptions). By focusing on 69 studies conducted using the CCTT – Level X, Ennis *et al.* (2005:25–27) determined that this CT test contributes to the understanding of the relationship between CT and IQ/aptitude, gender, academic accomplishments, age, socio-economic status, personality, and teaching experience of teachers. Furthermore, Ennis *et al.* note that these 69 studies confirm the construct validity of the CCTT – Level X.

5.3.1.3.2. Self-Directed Learning Instrument

The Self-Directed Learning Instrument (SDLI) created by Cheng *et al.* (2010) was originally developed with the aim to measure the SDL abilities of nursing students. By making use of four phases, the developers performed a literature review, two Delphi studies, a test with 1 072 nursing students (between ages of 15 and 22) and a test to determine the internal consistency and reliability.

The final version of the SDLI consists of 20 items covering four topics: learning motivation, planning and implementing, self-monitoring and interpersonal communication (Cheng *et al.*, 2010). The instrument gives learners the opportunity to state whether they agree or disagree with a statement on a scale of 1 to 5, 1 being strongly disagree and 5 being strongly agree.

5.3.1.3.3. Qualitative questions for Grade 10 Information Technology learners

As part of the qualitative investigation, learners were asked to answer either one or two questions, determined by the group within which they were categorised. All learners answered a general question on whether they felt that their CT had improved in the IT class. Learners in the control group only answered this one general question, whereas learners in the experimental group receiving only CTI were asked to answer a second question on how they experienced the CTI. The experimental group that received only PP as the intervention answered the general question as well as a question on how they experienced the PP. Lastly, the experimental group that received PP infused with CTI was asked to answer the general question on CT development as well as a question on how they experienced the PP infused with CT.

5.3.1.4. The pilot study

In order to determine the reliability of the questionnaires and whether the time given to Grade 10 IT learners to complete the two questionnaires would be sufficient, a pilot study was conducted. In the pilot study Grade 10 IT learners from one school completed the two questionnaires after which the researcher asked the learners to describe their experience of the two questionnaires completed. Learners in the pilot group noted that sufficient time was given to complete the questionnaires, that the language used in both questionnaires was understandable. Although some of the learners in the pilot study completed the questionnaires in less than an hour's time, the average completion time was approximately 40 – 60 minutes.

5.3.1.5. Data collection procedures

A pre-test was conducted, which was focused on testing the Grade 10 IT learners' CTS as well as a pre-test testing the learners' self-directedness. Learners had an hour to complete the two questionnaires.

After approximately six weeks since the completion of the pre-tests, post-tests were given to the learners. During the post-test, the same questionnaires were given to the learners (as in the pre-test) in order to determine whether any significant increase could be noted. Additionally, a qualitative section was added to the post-tests to explain any changes in the learners' CT and SDL skills further (see 5.3.1.3 for details regarding the questions posed to learners).

The researcher administered the questionnaires herself to ensure that a level playing field was established where learners were not receiving any additional assistance in completing the questionnaires and the questionnaires were completed in a controlled environment.

5.3.1.6. Data analysis

The two questionnaires were analysed by the Statistical Consultation Services of North-West University, Potchefstroom Campus. This section discusses the statistical elements in the analysis of the data from the quantitative investigation followed by a discussion on the data analysis of the narrative questions learners were asked to complete after the quantitative post-test.

5.3.1.6.1. Constructs on questionnaires

The CCTT – Level X and the SDLI questionnaires have been divided into specific constructs by the developers of the questionnaires as illustrated in Figure 5.2.

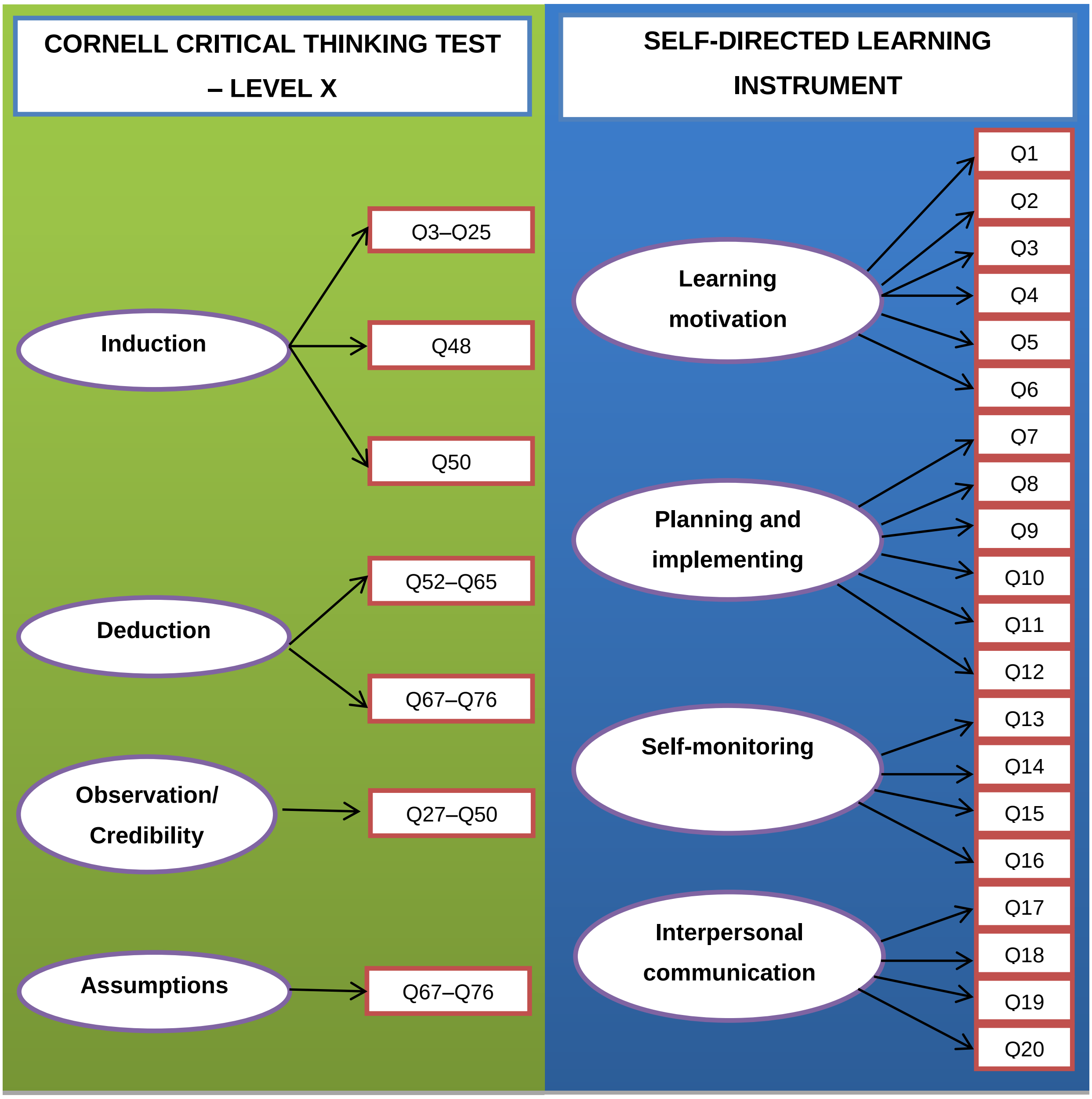


Figure 5.2 Division of constructs for the Cornell Critical Thinking Test – Level X (Ennis *et al.*, 2005) and the Self-Directed Learning Instrument (Cheng *et al.*, 2010)

From Figure 5.2, it is clear that each of the two questionnaires specifically focuses on constructs relating to the topic it tests. The CCTT – Level X provide some exemplary questions to assist participants in the completion of the questionnaire. In the present research, these questions were omitted from the construct division as it is not marked nor measured during analysis. The SDLI of Cheng *et al.* (2010) divided the questions into constructs. In order to ensure that the suggested constructs were valid for the present specific study, the split-half reliability method was used. One of the possible techniques to use during the split-half reliability is the calculation of Cronbach's alpha. Cronbach's alpha is calculated to test internal reliability by calculating the average of all split-half reliability coefficients and computed alpha coefficient. For an accepted level of reliability, a Cronbach alpha of at least 0.75 should be obtained (Singh, 2007:78). A factor analysis was also performed (see Chapter 6 for scores calculated) (Table 6.2 for CCTT and Table 6.9 for SDLI).

Babbie *et al.* (2008) define factor analysis as an analysis used to associate variations in values of several variables. Two types of factor analyses were conducted: exploratory factor analysis and confirmatory factor analysis. Exploratory factor analysis identifies the underlying factor structure whereas confirmatory factor analysis is a statistical technique to verify the factors identified in the exploratory factor analysis (Suhr, 2014).

Once suggested constructs had been established as being reliable, further statistical analysis was done. The quantitative investigation included several participants (Grade 10 IT learners) from various schools, backgrounds and teachers (indicating several effects that informed the study). For this reason, a mixed models (hierarchical linear model) (Garson, 2012) approach was used to analyse results. According to Seltman (2014), by using a mixed model approach for analysis, uneven spacing of repeated measurements can be handled and missing data is allowed on the grounds of the missing-at-random definition. Independent paired t-tests were conducted to determine the differences between a participant's pre-test and post-test scores.

5.3.1.6.2. Information Technology learners' qualitative narratives

The qualitative data gathered from IT learners were transcribed verbatim. Once transcripts had been double-checked, the researcher analysed it by making use of emerging codes, which in turn, were put into categories that formed themes. Coding was done by making use of ATLAS.ti, which is a computer program developed especially for qualitative data analyses.

With the QUAN-qual investigation of Grade 10 IT learners discussed, the following section is devoted to describing the qualitative investigation conducted with IT teachers in this study.

5.3.2. Qualitative investigation

Although the main purpose of this study was to determine the effect of an intervention on Grade 10 IT learners' CT and self-directedness, which required a quantitative investigation, a qualitative investigation with Grade 10 IT teachers was also conducted. This investigation was conducted as the researcher accepted the fact that IT teachers influence the outcome of IT learners' CT and SDL. Furthermore, the researcher aimed at eliciting the IT teachers' experience of the suggested strategies and how it was implemented as this played an important role in understanding the context within which the IT learners were.

5.3.2.1. Population and sample

For the qualitative investigation, all teachers that taught the Grade 10 learners used in the three experimental groups were included. In total, 25 IT teachers agreed to participate in the study. Of these 25, six teachers were in the control group, seven teachers were in the experimental group that received only CTI (CTI group), six teachers were in the experimental group that received only PP (PP group) and five teachers were in the experimental group that infused CT in PP (CTI+PP group) (see Table 5.3). As with the investigation with IT learners that showed some learners opting not to participate in the post-test, two IT teachers (two in CTI+PP group) did not participate in the post-test of the qualitative investigation (one teacher mentioned time as an issue and the other went on maternity leave and was unavailable).

Table 5.3 Number of teachers involved in study

Control	CTI	PP	CTI+PP
7	7	6	5 (2 discontinued)

5.3.2.2. Measuring instruments

IT teachers in the experimental groups participated in two semi-structured interviews: one before the intervention and one after the intervention. A semi-structured interview schedule was used to guide the interviews at the onset of the research as well as after the interventions had been implemented.

5.3.2.2.1. Initial interview with three experimental groups

IT teachers in the CTI experimental group were interviewed using the following semi-structured questions:

- What is your understanding of CT?
- Have you encountered any CT training before? If so, please describe.
- How important would you say CT is in the IT classroom?
- Do you implement any specific strategies in your IT classroom to develop the learners' CTS? If so, please describe.

IT teachers in the CTI+PP experimental group were interviewed using the following semi-structured questions:

- What is your understanding of CT?
- Have you encountered any CT training before? If so, please describe.
- How important would you say CT is in the IT classroom?
- Do you implement any specific strategies in your IT classroom to develop the learners' CTS? If so, please describe.
- What is your understanding of PP?
- Have you encountered any PP training before? If so, please describe.
- Do you implement PP in your IT classroom? If so, please describe.

IT teachers in the PP experimental group were interviewed using the following semi-structured questions:

- What is your understanding of PP?
- Have you encountered any PP training before? If so, please describe.
- Do you implement PP in your IT classroom? If so, please describe.

5.3.2.3. Data collection procedures

Grade 10 IT teachers were asked to participate in a semi-structured interview before the training regarding the teaching strategy suggested was done. Another semi-structured interview was conducted after the completion of the intervention (about six weeks later).

5.3.2.4. Data analysis

The qualitative data gathered from teachers were transcribed verbatim. Once transcripts had been double-checked, the researcher analysed it by making use of emerging codes, which in turn, were put into categories that formed themes. Coding was done by making use of ATLAS.ti, which is a computer program developed especially for qualitative data analyses.

5.3.3. Objectivity of the study

The study implemented both a QUAN-qual mixed methods approach (for Grade 10 IT learners) and a qualitative approach (for Grade 10 IT teachers). Objectivity in research describes the likelihood that results obtained are valid (Babbie *et al.*, 2008:645). The greater the likelihood of objectivity, the more reliable a study is. Table 5.4 illustrates the notions of objectivity for quantitative as well as qualitative data as described in Babbie *et al.* (2008:276).

Table 5.4 Notions of objectivity (Babbie *et al.*, 2008:276)

Quantitative investigation	Qualitative investigation
Internal validity	Credibility
External validity	Transferability
Reliability	Dependability
Objectivity	Confirmability

Each of these notions as well as how they were addressed in this study will be discussed in 5.3.3.1.

5.3.3.1. Quantitative investigation

To ensure the crystallisation of the quantitative investigation four aspects are considered:

5.3.3.1.1. Internal validity

In the quantitative investigation of the QUAN-qual mixed method approach, the researcher focused on identifying the possible threats to internal validity. Gorard (2004), Babbie *et al.* (2008) and Creswell (2009) describe aspects that can threaten internal validity and which should be taken into consideration. During the quantitative investigation, several steps were taken to promote internal validity. As no historical events took place during the tenure of the investigation, the *history threat* was not present. An advantage of the design used in this study (having a control group and three experimental groups) accounted for *natural maturation and statistical regression* occurring. The participants completed the pre-test and after approximately six weeks had passed, completed the post-test, therefore accounting for the *testing threat* where participants are influenced by the fact that they have completed the pre-test previously. Groups were randomly assigned to either control or experimental groups. Furthermore, all participants were Grade 10 IT learners who were completing the same curriculum and they all had to achieve the same outcomes at the end of the year– all accounting for *selection biases* *threat.* A large sample was drawn (600 learners) to account for the *experimental mortality threat*. Regarding the *causal time-order threat*, all teachers (in experimental groups) were asked to implement the intervention for at least six weeks. In no school more than one intervention was implemented, implying that the control groups and experimental groups did not influence one another, combating the *diffusion of treatment threat*. The control groups were not disadvantaged as they were not aware of any interventions taking place in other schools and teachers continued their IT classes as normal, accommodating the *compensation, compensatory rivalry and demoralisation threats to validity.*

5.3.3.1.2. External validity

Singh (2007) explains that external validity signifies the extent to which the specific research investigation can be duplicated to other situations

5.3.3.1.3. Reliability

Reliability entails the potential of a measuring instrument in a study to measure what is intended each time it is used. To determine the reliability in this investigation, the researcher calculated Cronbach's alpha (see 5.3.1.5). Reliability of the study further concentrated on the stability of the research by focusing on the measurement of the sample, on internal reliability to assess the indicators, and on inter-observer consistency by focusing on the different observers in the study (Singh, 2007). In this study, a pilot test was done on Grade 10 IT learners to determine whether the two questionnaires were appropriate for this sample.

5.3.3.1.4. Objectivity

In the quantitative investigation, the researcher needs to remain as objective as possible. Within the pragmatist paradigm, pure objectivity in a study is unlikely; however, the researcher ensured that she attempted to combat bias as far as possible by not influencing learners in any way to answer questionnaires in a specific manner. The same instructions were given to all the learners and teachers in the study in an attempt to level the playing field as far as possible.

5.3.3.2. Qualitative investigation(s)

Babbie *et al* (2008) emphasise the importance of ensuring the credibility, transferability, dependability and confirmability of a qualitative investigation: all contributing to the trustworthiness of the study. Creswell (2009) suggests that researchers implement several strategies to promote the trustworthiness of the study. In the present study, transcripts were double-checked to ensure correctness. Coding of transcripts was done by making use of the ATLAS.ti software to keep track of how codes were defined. Clear descriptions of findings were given by making use of concise descriptive discussion. A peer-debriefer was appointed to see to it that codes generated were in line with what participating teachers had said. The researcher presented both positive and negative findings from the transcripts as well as which biases may have influenced the findings.

5.4. THE INTERVENTION

In this section the intervention implemented in this study is discussed.

5.4.1. Critical thinking instruction intervention

For the CTI intervention a professional development session was designed which was guided by theory emerging from the body of scholarship on CT (see Chapter 2).

From the body of scholarship it became evident that CT can be developed; however that teachers themselves need to be developed in CT before they could implement it in their own classes. It also became clear that Brookfield's (2012) strategies for modelling CT (one of the most important factors in developing CT) and the Socratic method are both strategies that can contribute greatly to the development of CT in the IT classroom. It was therefore decided to focus on these two strategies as part of the CTI intervention.

To address the two strategies stated above; a manual outlining a brief background of theory to these strategies as well as possible techniques for implementing these strategies in the IT classroom specifically was compiled (see Addendum A1). Apart from the manual (as part of the professional development program), resources to assist IT teachers in implementing the intervention were also created. These resources consisted of an animated video (giving a brief background of CT), a key-ring (outlining the Socratic questions noted from the body of scholarship) and a bookmark (outlining general CTSs and CTDs). Learners were expected to use the key-ring and bookmark to constantly remind themselves of what the Socratic questions are and what CT entails. The aim was to have learners use the resources often enough for it to eventually become a natural part of their learning process. All of these resources were given to IT teachers to assist their learners in the implementation of the intervention (see Addendum B).

The manual and the learner resources were given to IT teachers during a face-to-face one-on-one professional development session where the researcher herself discussed the intervention with IT teachers in order to ensure all teachers understood what was expected of them.

Apart from CTI intervention, a PP intervention was also used in this study – this intervention will be discussed next.

5.4.2. Pair programming intervention

In Chapter 3 of this study, it was discussed that CL (in the form of PP) could be beneficial for the development of CT. In order to establish the influence CL would have on CT development as well as SDL, a PP intervention was included.

To implement the PP intervention, IT teachers in the PP group were also involved in a face-to-face one-on-one professional development session. The PP professional development session was based on professional development that was conducted with success in other schools by researchers involved in a South Africa-Netherlands project on alternative development (SANPAD). The researcher of this current study was also involved in the SANPAD project (as a junior researcher) and therefore had first-hand experience of the success the PP intervention held for teachers involved in the project. The PP professional development session consisted of a manual (see Addendum A2), a video (see Addendum B) and visual ques to illustrate PP principles to IT learners (see Addendum B). Learners were expected to use the PP key-ring to constantly remind themselves of aspects to remember during PP. The aim was to have learners use the resources often enough for it to eventually become a natural part of their learning process. Apart from the resources, special permission was granted from the project leader of the SANPAD project to use the manual for this current study.

Apart from CTI intervention, and PP intervention, an intervention conjoining CTI and PP was also used in this study – this intervention will be discussed next.

5.4.3. Critical thinking instruction infused into pair programming intervention

Some schools in this study were asked to participate in an intervention where deliberate CTI was infused into PP in the IT class. For the implementation of this CTI+PP intervention, IT teachers received a face-to-face one-on-one professional development session (also conducted by the researcher herself). The IT teachers received both the CTI manual as well as the PP manual; however the action plan, where teachers are guided on how the strategies should be implemented in the IT class, was formulated in such a manner that the CTI and PP interventions became one and teachers were given clear guidelines on how these two strategies could work together to form one strategy (see Addendum A1 and Addendum A2). Along with the manual, all resources included in the CTI professional development session as well as the PP professional development session were included in the CTI+PP professional development session (see Addendum B). Learners were expected to use the key-rings (CT and PP key-rings) and bookmark (CT bookmark) to constantly remind themselves of what the Socratic questions are, what aspects to remember during PP and what CT entails. The aim was to have learners use the resources often enough for it to eventually become a natural part of their learning process.

5.5. ADMINISTRATIVE PROCEDURES

In this investigation, several administrative procedures were followed to ensure that no participants were penalised or disadvantaged in any way. The administrative procedures included the ethical procedures for obtaining ethical approval from all stakeholders, as well as data handling procedures to ensure data were handled appropriately. The following subsections will discuss these two procedures in greater detail.

5.5.1. Ethical procedures

At the onset of this study, ethical approval was obtained from several stakeholders. Firstly, ethical approval was obtained from the North-West University's ethical committee. This process involved completing an application form, submitting the questionnaires to be used in the study for approval, submitting the interview schedule to be used during the semi-structured interviews as well as submitting the narrative questions presented to the Grade 10 IT learners to the ethical committee. Furthermore, the committee required a proposal describing the study, focusing specifically on the robustness of the study. Ethical approval was granted (see Addendum C).

Apart from the ethical committee of the North-West University, approval from the Department of Basic Education was obtained (Addendum D). This process entailed applying to the three provincial departments of education to obtain permission to conduct research in the three respective provinces (North-West, Free State and Eastern Cape).

In the third stage of the ethical procedures, permission from the school principals of schools involved in the study was requested. Alongside the request to conduct research in the school completed by the principal, IT teachers were also asked to grant permission for participating in the study. Addendum E shows the letter sent to the schools to obtain permission.

Once principals and IT teachers had agreed to participate in the research, Grade 10 IT learners in the specific schools were given a letter of informed consent (see Addendum F) to be signed by their parents/guardians giving permission that the learners (who were minors) were allowed to participate in the research study.

The provincial departments, principals, IT teachers as well as IT learners were all informed about the confidentiality of information making sure that no school or learner would be disadvantaged in any way should they choose to participate in the research. Furthermore, they (principals, IT teachers and IT learners) were informed that they would be able to withdraw from the research at any given time as participation occurred on a voluntary basis.

5.5.2. Logistical procedures

To conduct a research endeavour of this standard, several logistical arrangements needed to be done. The researcher set out to accommodate all participants as far as possible; therefore, IT teachers were granted the opportunity to schedule the professional development sessions at a time that suited them. This was also the case for the Grade 10 IT learners as teachers selected a time that suited learners best to conduct the pre- and post-tests. During the professional development sessions, IT teachers were explicitly told that they could contact the researcher at any time should they experience any challenges regarding the intervention or in the subject in general. After the initial professional development sessions (which occurred on the same day as the pre-tests), IT teachers were asked to implement the suggested strategies (CTI, PP or PP infused with CTI) for six weeks. IT teachers were once again visited by the researcher to conduct the post-tests and follow-up interviews with teachers in the experimental groups. Apart from the set appointments with teachers, the researcher also encouraged teachers to contact her with any questions they might have had so they had continuous support throughout the study.

5.5.3. Data handling procedures

During this study, the researcher was responsible for collecting all relevant data and safekeeping of the data. The researcher conducted all interviews and administered all questionnaires herself. Once all data had been gathered, the researcher was responsible for capturing the data. All data are kept in a safe environment and will be stored for at least five years before discarding it responsibly.

5.6. CONCLUSION

In this chapter, a discussion on the research design and methodology of this study was given. Several important aspects regarding the design and methodology were highlighted. Furthermore, the administrative procedures – consisting of the ethical procedures and data-handling procedures – were discussed.

This study was focused on determining Grade 10 IT learners' CT development and its implications on their SDL. To investigate this, participants (conveniently sampled) were divided into four groups: a control group receiving no intervention at all, an experimental group receiving CTI as intervention, an experimental group receiving CTI infused in PP as intervention and an experimental group that only did PP. Although the study was focused on Grade 10 IT learners, IT teachers of these learners were required to implement the suggested intervention, therefore necessitating an investigation into both IT learners and IT teachers in the study.

For the investigation regarding Grade 10 IT learners, a QUAN-qual sequential mixed method research design was implemented whereas the investigation regarding Grade 10 IT teachers implemented an interpretivist qualitative research design. Both investigations were informed by the pragmatist research paradigm.

The quantitative research investigation of Grade 10 IT learners made use of two measuring instruments. In the analysis of the data, several statistical tests were used, firstly, to establish reliability and also to assist in an analysis of obtained data. The qualitative investigation of the Grade 10 IT learners and teachers was analysed by identifying codes, grouping these codes into categories and grouping categories into themes.

Chapter 6 will be focused on investigating research questions four, five and six followed by Chapter 7 that will synthesise all research questions.

CHAPTER 6
DATA ANALYSES AND RESEARCH RESULTS

6.1 INTRODUCTION

The previous chapter reported on the research design and methodology implemented in this study. This chapter is focused on reporting the data analyses of the mixed method investigation of the Grade 10 IT learners as well as the qualitative investigation of the Grade 10 IT teachers in order to investigate research questions four, five and six. Detailed answers to these three research questions will be given in Chapter 7.

6.2 DATA ANALYSES

The data gathered in this study have been divided into two groups: Quantitative data analyses and qualitative data analyses, all to elicit answers to research question 4: What is the influence of a CL environment on the development of CT, research question 5: What is the influence of the intentional development of CT in the IT classroom on IT learners' CTS? and research question 6: To what extent, if any, do CTS foster SDL?

6.2.1 Quantitative data analyses

Grade 10 IT learners were asked to complete two questionnaires: the CCTT – Level X as well as the SDLI (see 5.3.1.3 for a discussion of the measuring instruments). Table 6.1 presents a summary of the biographical information obtained from the participants' pre-tests. Although there were 458 participants who completed the pre-tests and 372 participants who completed the post-tests, statistical measures were only applied to the data of participants who completed both the pre- and post-tests (n=317).

Table 6.1 Biographical information of learners

Biographical item	Options	Response	
		F	%
Age	15 years	141	44.5%
	16 years	133	42.0%
	17 years	24	7.6%
	18 years	6	1.9%
	Other	6	1.9%
	Total	310	97.8%
	Missing	7	2.2%
	Grand total	317	100.0%
Gender	Male	205	64.7%
	Female	105	33.1%
	Total	310	97.8%
	Missing	7	2.2%
	Grand total	317	100.0%
Home language	Afrikaans	82	25.9%
	English	80	25.2%
	isiNdebele	0	0.0%
	isiXhosa	12	3.8%
	isiZulu	4	1.3%
	Sesotho sa Leboa	1	0.3%
	Sesotho	11	3.5%
	Setswana	109	34.4%
	siSwati	0	0.0%
	Tshivenda	1	0.3%
	Xitsonga	0	0.0%
	Other	3	0.9%
	Total	303	95.6%
	Missing	14	4.4%
	Grand total	317	100.0%

Table 6.1 Biographical information of learners (continued)

Rural/Urban	Rural	122	38.5%
	Urban	195	61.5%
	Total	317	100.0%
Province	North-West	194	61.2%
	Free State	40	12.6%
	Eastern Cape	83	26.2%
	Total	317	100.0%
	Missing	0	0.0%
	Grand total	317	100.0%

Participants had the opportunity to indicate their age, home language and gender, whereas the researcher indicated the province and whether the school was in a rural or urban area. From Table 6.1 it is clear that participants were generally male (64.7%) and in the age category of 15 to 16 years (86.5%). The home languages most prevalent from the responses were Afrikaans, English and Setswana (85.5%). Only 38.5% of participants were from rural areas of South Africa and the majority of participants came from North-West (61.2%). The following sections will focus on disseminating the statistical results of each of the two questionnaires used. Each section will be divided into presenting the pre-test and the post-test results.

6.2.1.1 Cornell Critical Thinking Test – Level X

In order to assess Grade 10 IT learners' CTS, the CCTT – Level X was used. Table 6.2 illustrates the reliability calculated for the CCTT – Level X. The reliability was executed once the pre-tests had been conducted, making the number of participants used 466, although the inferential statistical tests were only implemented on the 317 participants who completed the pre- and post-test. The following two sections will describe the results of the pre- and post-test of the CCTT – Level X.

Table 6.2 Reliability of the Cornell Critical Thinking Test – Level X

Construct	Question numbers	Cronbach's alpha
Induction	3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25	0.769
Credibility	27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50	0.649
Deduction	52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65	0.729
Identification of assumptions	67, 68, 69, 70, 71, 72, 73, 74, 75, 76	0.472

In Table 6.2, the Cronbach's alpha coefficient for each construct as informed by the standardised CCTT – Level X is indicated (where the consistency estimates of the standardised test ranges from 0.67–0.90). Singh (2007) notes that Cronbach's alpha coefficient values should be 0.7 or higher for the questions to be reliably ranked; however, a score above 0.6 can still be used but with caution. As illustrated in Table 6.2, the induction and deduction constructs scored high enough and the credibility construct should be handled with caution; however, the identification of assumptions constructs scored too low to be considered reliable. Looking at the questionnaire in its totality, one can deduce that it has proven to possess sufficient reliability but the researcher did not conduct further analysis on the constructs where the reliability are considered too low and consistently reported the unreliability where reporting these constructs.

6.2.1.1.1. Test 1 (Pre-test)

This section will be focused on reporting the results of the CCTT – Level X pre-test as completed by the Grade 10 IT learners.

- **Descriptive statistics**

Table 6.3 reflects the descriptive statistics in terms of the construct, the school code, the number of participants per school, the mean score and the standard deviation. The questionnaire was marked (in accordance with the guidelines of the test) by taking all the right answers given (out of a total of 71) and deducting one half of the number of wrong answers. The mean scores were calculated for each construct of each school. The induction construct had a minimum score of 0 and a maximum score of 23. The credibility construct had a minimum score of 0 and a maximum score of 24. The deduction construct had a minimum score of 0 and a maximum score of 14.The minimum score for the total of the questionnaire was 0 whereas the maximum was 71.

Table 6.3 Descriptive statistics of the Cornell Critical Thinking Test – Level X pre-test

Construct	School code	N	Mean	Standard deviation
Induction	01	19	16.05	3.57
	02	8	16.13	3.98
	03	11	13.36	2.91
	04	19	9.74	3.28
	05	5	16.60	2.19
	06	44	10.16	3.19
	07	16	12.69	2.70
	08	4	13.25	5.91
	09	17	10.06	2.70
	10	10	10.20	3.43
	11	19	13.11	3.60
	12	8	15.88	3.23
	13	10	16.70	3.09
	14	9	16.44	2.19
	15	8	15.25	2.92
	16	19	15.68	2.81
	17	16	16.63	2.16
	18	13	8.77	2.39
	19	5	12.00	2.45
	20	19	18.05	2.01
	21	6	18.33	2.58
	23	11	19.09	1.58
	25	21	16.76	2.74
Credibility	01	19	12.00	3.30
	02	8	10.63	2.92
	03	11	10.45	2.07
	04	19	7.89	2.69
	05	5	12.00	2.55
	06	44	8.77	2.51
	07	16	9.94	3.09
	08	4	11.00	1.83
	09	17	7.12	2.06
	10	10	10.40	3.41
	11	19	11.16	2.63
	12	8	13.75	4.03
	13	10	12.90	3.00
	14	9	11.67	2.74
	15	8	10.50	2.14
	16	19	12.79	2.80
	17	16	11.56	3.29
	18	13	9.77	2.09
	19	5	10.40	2.19
	20	19	15.05	2.99
	21	6	13.83	2.64
	23	11	12.91	1.87
	25	21	13.48	3.37

Table 6.3 Descriptive statistics of the Cornell Critical Thinking Test – Level X pre-test (continued)

Construct	School code	N	Mean	Standard deviation
Deduction	01	19	7.63	3.18
	02	8	7.00	3.34
	03	11	7.18	2.75
	04	19	4.95	2.30
	05	5	8.00	1.58
	06	44	4.86	1.77
	07	16	5.00	2.10
	08	4	7.00	2.94
	09	17	4.59	1.97
	10	10	5.20	1.99
	11	19	6.32	2.71
	12	8	9.25	2.43
	13	10	10.20	2.35
	14	9	8.44	2.51
	15	8	6.63	2.56
	16	19	9.63	2.91
	17	16	8.56	2.56
	18	13	5.38	2.10
	19	5	5.20	3.49
	20	19	10.68	2.83
	21	6	9.50	1.38
	23	11	10.27	2.69
	25	21	9.76	2.61
CT total	01	19	24.50	12.09
	02	8	20.00	9.28
	03	11	17.00	8.80
	04	19	2.95	7.50
	05	5	22.10	5.67
	06	44	4.93	7.92
	07	16	10.53	9.95
	08	4	17.38	14.30
	09	17	0.94	5.32
	10	10	7.40	10.98
	11	19	13.68	8.30
	12	8	29.94	13.98
	13	10	32.90	12.11
	14	9	25.00	8.81
	15	8	20.19	7.32
	16	19	28.05	12.12
	17	16	26.38	11.30
	18	13	5.46	4.64
	19	5	12.50	9.43
	20	19	37.05	8.75
	21	6	33.50	7.35
	23	11	32.55	8.14
	25	21	30.07	12.25

In Table 6.3, it becomes clear that schools differed vastly in terms of CT, especially when referring to the total score. The scores of some schools were extremely low (see schools number 4, 6, 9 and 18) compared to other schools. The fact that the standard deviation was so high in certain schools indicates that the learners in those schools scored vastly differently in CT compared to one another.

- **Differences between the four groups in the study (Cornell Critical Thinking Test – Level X pre-test)**

In order to establish whether there were any practically significant differences between the four groups (control, experimental groups one, two and three) in the study, hierarchical linear modelling was used to take into account the dependence of learners from the same school. Cohen's d-value was calculated. Table 6.4 illustrates the d-values calculated for each comparison from the CCTT – Level X pre-test.

Table 6.4 Differences between groups for Cornell Critical Thinking Test – Level X (Pre-test)

Construct	Pre/Post	Group	Mean	MSE	Variance of school	p	d		
							Control	CTI	CTI+PP
Induction	Pre	Control	12.83	8.25	3.96	0.348			
		CTI	15.01				**0.62		
		CTI+PP	12.34				0.14	**0.76	
		PP	12.22				0.17	***0.80	*0.03
Credibility	Pre	Control	9.65	6.90	1.17	0.197			
		CTI	10.18				0.18		
		CTI+PP	8.27				*0.49	**0.67	
		PP	8.57				*0.38	**0.57	0.11
Deduction	Pre	Control	6.91	6.13	1.61	0.772			
		CTI	7.43				0.19		
		CTI+PP	6.29				*0.22	*0.41	
		PP	6.97				0.02	0.16	*0.24
Total	Pre	Control	32.14	40.73	25.50	0.503			
		CTI	35.65				*0.43		
		CTI+PP	29.74				*0.29	**0.73	
		PP	30.42				0.21	**0.64	0.08

* small effect
** medium effect
*** large effect

From Table 6.4, it is evident that from the onset of the study, the CTI group scored the highest of the four groups and there was a practically significant difference between this group and the other three groups with reference to *Induction* and the *Total* CT score. The reason for the small statistical significance is the fact that the sample size is quite small. To illustrate the difference between groups during the CCTT – Level X pre-test further, Figure 6.1 graphically shows the mean score of the totals obtained for each of the four groups in the study. The fact that the CTI group differed so much from the other four groups and the ideal was to have all the groups on the same level at the onset of the research, necessitated the use of statistical tests to compensate for these differences in order to level the playing field. This compensation will be discussed in the section on the post-test results.

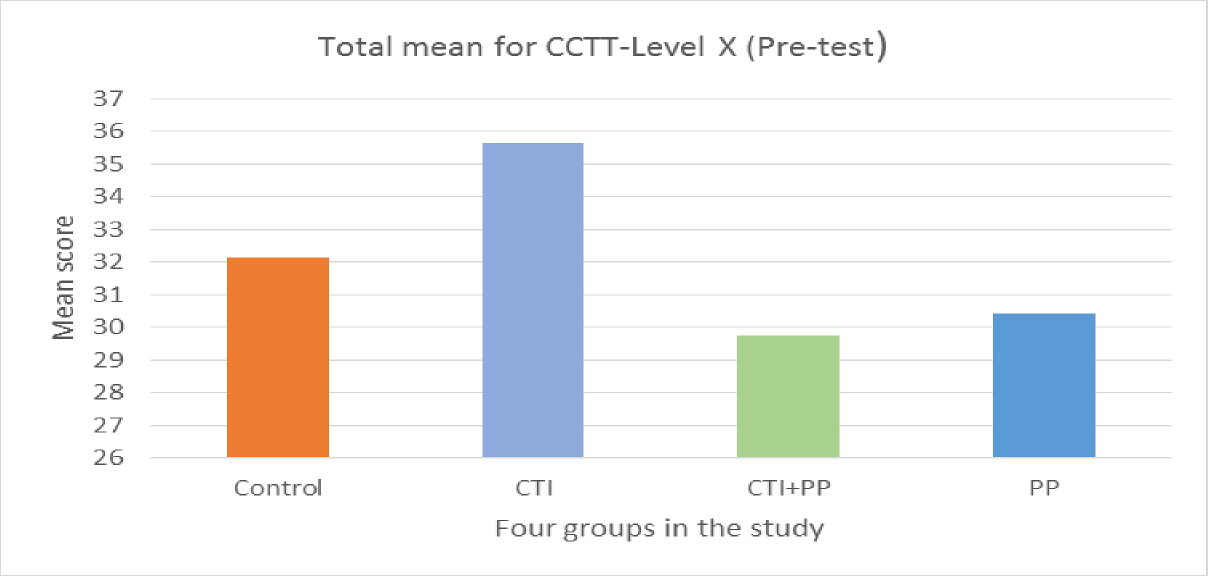


Figure 6.1 Total mean score for Cornell Critical Thinking Test – Level X (Pre-test)

6.2.1.1.2. Test 2 (Post-test)

The CCTT – Level X was once again given to the Grade 10 IT learners approximately six weeks after they had completed the pre-test and after all the groups, except the control group, had received a specific intervention (Chapter 5 (see 5.4)). This section focuses on reporting the statistics calculated from the post-test of the CCTT – Level X.

- **Descriptive statistics**

Table 6.5 summarises the descriptive statistics as extrapolated from the post-test of the CCTT – Level X. The total mean scores were calculated through the average of each school's scores for each construct. The induction construct had a minimum score of 0 and a maximum score of 23. The credibility construct had a minimum score of 0 and a maximum score of 24. The deduction construct had a minimum score of 0 and a maximum score of 14. The total for CT had a minimum value of 0 and a maximum value of 71.

Table 6.5 Descriptive statistics of Cornell Critical Thinking Test – Level X (Post-test)

Construct	School code	N	Mean	Standard deviation
Induction	01	19	15.79	3.31
	02	8	14.25	3.62
	03	11	12.09	3.96
	04	19	9.05	3.79
	05	5	15.40	2.51
	06	44	10.52	3.59
	07	16	11.00	2.83
	08	4	18.00	3.16
	09	17	9.41	2.83
	10	10	9.20	3.16
	11	19	11.68	4.30
	12	8	15.38	1.69
	13	10	16.50	3.06
	14	9	14.67	2.40
	15	8	15.00	1.60
	16	19	16.74	2.62
	17	16	14.94	3.26
	18	13	10.08	1.50
	19	5	14.40	1.82
	20	19	18.63	2.11
	21	6	16.67	1.63
	23	11	16.27	4.50
	25	21	17.33	2.71
Credibility	01	19	11.05	2.93
	02	8	11.50	3.25
	03	11	9.64	3.04
	04	19	8.84	1.71
	05	5	14.60	2.51
	06	44	8.59	2.66
	07	16	9.00	3.03
	08	4	12.25	2.99
	09	17	9.35	3.64
	10	10	8.80	3.16
	11	19	10.32	2.26
	12	8	13.00	3.74
	13	10	13.60	3.13
	14	9	10.67	2.65
	15	8	10.25	2.25
	16	19	13.21	3.46
	17	16	11.13	2.70
	18	13	10.38	2.36
	19	5	11.20	4.66
	20	19	15.95	2.55
	21	6	13.67	4.84
	23	11	13.18	3.49
	25	21	13.10	3.06

Table 6.5 Descriptive statistics of Cornell Critical Thinking Test – Level X (Post-test) (continued)

Construct	School code	N	Mean	Standard deviation
Deduction	01	19	8.05	3.42
	02	8	7.00	2.33
	03	11	6.73	3.29
	04	19	5.00	2.11
	05	5	8.00	1.22
	06	44	5.09	2.59
	07	16	4.56	2.78
	08	4	9.00	2.94
	09	17	5.35	2.42
	10	10	4.80	1.32
	11	19	6.26	2.66
	12	8	9.63	2.33
	13	10	11.30	2.58
	14	9	8.78	2.91
	15	8	6.75	4.50
	16	19	10.58	2.71
	17	16	9.69	3.20
	18	13	5.77	1.79
	19	5	9.40	2.51
	20	19	12.00	2.16
	21	6	10.83	2.48
	23	11	10.82	2.60
	25	21	11.19	2.11
CT total	01	19	23.32	12.16
	02	8	20.38	11.22
	03	11	12.50	13.25
	04	19	3.50	9.33
	05	5	26.90	8.91
	06	44	6.23	9.65
	07	16	5.38	9.91
	08	4	29.75	8.87
	09	17	5.26	10.16
	10	10	2.45	7.11
	11	19	11.95	11.40
	12	8	29.75	12.05
	13	10	35.45	13.44
	14	9	21.67	9.62
	15	8	17.19	8.54
	16	19	31.61	10.43
	17	16	25.34	13.28
	18	13	7.88	5.49
	19	5	22.40	11.84
	20	19	42.18	6.74
	21	6	34.50	10.38
	23	11	32.00	14.01
	25	21	34.14	30.07

Table 6.5 reflects the post-test scores calculated for each school regarding their CT. As with the pre-test scores, it is evident that the schools differed greatly from one another. School number 10, for instance, had the lowest score regarding CT, although this was not the case in the pre-test (see Table 6.3). Schools that generally scored low in the pre-test also scored low in the

post-test although an increase can be observed (see schools number 7, 9 and 18). School number 20 scored the highest in CT during the post-test.

- **Differences between the four groups in the study (Cornell Critical Thinking Test – Level X post-test)**

To determine the practical significance between the four different groups (control, experimental groups one, two and three), Cohen's d-value was calculated. Table 6.6 reflects the d-values of each comparison within the four constructs of the CCTT – Level X (Post-test). The hierarchical linear model is an omnibus test (Garson, 2012), which was used to test whether there was a statistically significant difference between the four groups, taking into account that learners from the same school's data may be correlated and controlling for differences in pre-test scores. Cohen's d-value compares groups pairwise to determine the practically significant difference.

Table 6.6 Differences between groups for Cornell Critical Thinking Test – Level X (post-test)

Construct	Pre/Post	Group	Mean	MSE	Variance of school	p	d		
							Control	CTI	CTI+PP
Induction	Post	Control	12.85	7.51	1.57	0.897			
		CTI	12.73				0.04		
		CTI+PP	12.30				0.18	0.14	
		PP	13.07				0.07	0.11	*0.26
Credibility	Post	Control	9.67	5.70	1.19	0.604			
		CTI	9.72				0.02		
		CTI+PP	9.00				*0.25	*0.27	
		PP	10.29				*0.24	*0.22	**0.49
Deduction	Post	Control	7.82	5.16	1.24	0.771			
		CTI	7.44				0.15		
		CTI+PP	7.23				*0.23	0.08	
		PP	8.15				0.13	*0.28	*0.36
Total	Post	Control	33.27	29.88	8.92	0.684			
		CTI	32.90				0.06		
		CTI+PP	32.14				0.18	0.12	
		PP	35.13				*0.30	*0.36	**0.48

* small effect
** medium effect
*** large effect

From Table 6.6, it is evident that the PP (PP) group scored the highest in all three constructs as well as in the total score of the post-test. Regarding the total score, there was a small to medium practically significant difference between the PP group and all three the other groups. From the above comparisons and practically significant differences, it is evident that only a small to medium practical significant difference was observed between the PP group and all the other groups which confirms that the PP group outperformed all the other groups. To support this notion further, Figure 6.2 reflects the mean scores for each group regarding the CT *total*. Referring to Figure 6.2, it is evident that the PP group scored the highest on the CCTT – Level X and the CT infused into PP (CTI+PP) group scored the lowest. Possible reasons as to why this phenomenon occurred will be discussed in Chapter 7.

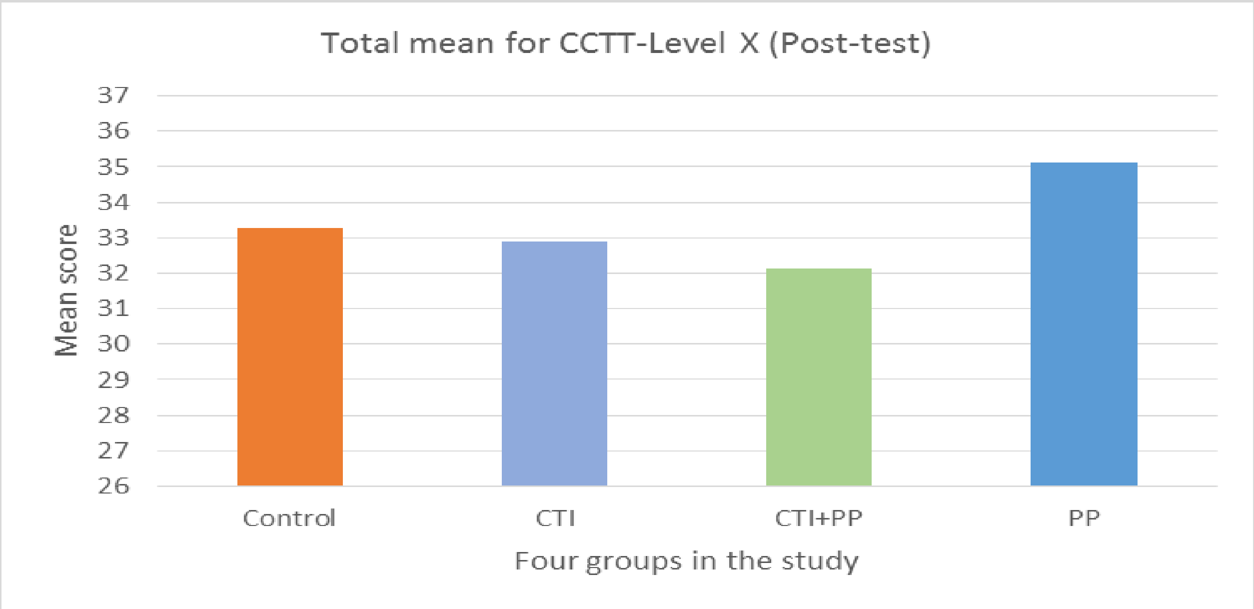


Figure 6.2 Total mean score for Cornell Critical Thinking Test – Level X (post-test)

- **Comparison of four groups' within school change between pre-tests and post-tests (dependent t-tests)**

In order to establish whether there has been any significant increase/decrease in the Grade 10 IT learners' CTS, the effect sizes as calculated by comparing the pre- and post-tests of each group are reported. Table 6.7 reflects the results from conducting dependent t-tests. The table shows the groups (control and the three experimental groups) as well as the schools that fell in each group. Cohen's d-value was calculated to determine the practically significant differences. Due to the small sample sizes, there was not enough power for statistical significance. Cohen's d-value however gives an indication of differences in practice.

Table 6.7 Pre-test versus post-test of Cornell Critical Thinking Test – Level X

Construct	Group	School code	N	Pre/Post	Mean	Standard deviation	p	d
INDUCTION	CONTROL GROUP	5	5	Pre	16.60	2.19	0.438	**0.55
				Post	15.40	2.51		
		7	16	Pre	12.69	2.70	0.124	**0.62
				Post	11.00	2.83		
		10	10	Pre	10.20	3.43	0.074	*0.29
				Post	9.20	3.16		
		14	9	Pre	16.44	2.19	0.009	***0.81
				Post	14.67	2.40		
		18	13	Pre	8.77	2.39	0.160	**0.55
				Post	10.08	1.50		
		19	5	Pre	12.00	2.45	0.193	***0.98
				Post	14.40	1.82		
		20	19	Pre	18.05	2.01	0.305	*0.29
				Post	18.63	2.11		
		23	11	Pre	17.09	1.58	0.530	**0.52
				Post	16.27	4.50		
	CTI	1	5	Pre	16.05	3.57	0.687	0.07
				Post	15.79	3.31		
		2	16	Pre	16.13	3.98	0.110	**0.47
				Post	14.25	3.62		
		3	10	Pre	13.36	2.91	0.394	*0.44
				Post	12.09	3.96		
		11	9	Pre	13.11	3.60	0.210	*0.39
				Post	11.68	4.30		
		12	13	Pre	15.88	3.23	0.613	0.15
				Post	15.38	1.69		
		21	5	Pre	18.33	2.58	0.242	**0.65
				Post	16.67	1.63		
	CTI+PP	4	19	Pre	9.74	3.28	0.479	*0.21
				Post	9.05	3.79		
		6	44	Pre	10.16	3.19	0.477	0.11
				Post	10.52	3.59		
		15	8	Pre	15.25	2.92	0.780	0.09
				Post	15.00	1.60		
		17	16	Pre	16.63	2.16	0.056	***0.78
				Post	14.94	3.26		
	PP	8	4	Pre	13.25	5.91	0.108	***0.80
				Post	18.00	3.16		
		9	17	Pre	10.06	2.70	0.214	*0.24
				Post	9.41	2.83		
		13	10	Pre	16.70	3.09	0.808	0.06
				Post	16.50	3.06		
		16	19	Pre	15.68	2.81	0.047	*0.37
				Post	16.74	2.62		
		25	21	Pre	16.76	2.74	0.244	*0.21
				Post	17.33	2.71		

* small effect

** medium effect

*** large effect

Table 6.7 Pre-test versus post-test of Cornell Critical Thinking Test – Level X (continued)

Construct	Group	School code	N	Pre/Post	Mean	Standard deviation	p	d
CREDIBILITY	CONTROL GROUP	5	5	Pre	12.00	2.55	0.562	***1.02
				Post	14.60	2.51		
		7	16	Pre	9.94	3.09	0.005	*0.30
				Post	9.00	3.03		
		10	10	Pre	10.40	3.41	0.322	**0.47
				Post	8.80	3.16		
		14	9	Pre	11.67	2.74	0.389	*0.37
				Post	10.67	2.65		
		18	13	Pre	9.77	2.09	0.148	*0.29
				Post	10.38	2.36		
		19	5	Pre	10.40	2.19	0.619	*0.37
				Post	11.20	4.66		
		20	19	Pre	15.05	2.99	0.004	*0.30
				Post	15.95	2.55		
		23	11	Pre	12.91	1.87	0.958	0.15
				Post	13.18	3.49		
	CTI	1	5	Pre	12.00	3.30	0.037	*0.29
				Post	11.05	2.93		
		2	16	Pre	10.63	2.92	0.986	*0.30
				Post	11.50	3.25		
		3	10	Pre	10.45	2.07	0.933	*0.40
				Post	9.64	3.04		
		11	9	Pre	11.16	2.63	0.398	*0.32
				Post	10.32	2.26		
		12	13	Pre	13.75	4.03	0.703	*0.19
				Post	13.00	3.74		
		21	5	Pre	13.83	2.64	0.574	0.06
				Post	13.67	4.84		
	CTI+PP	4	19	Pre	7.89	2.69	0.023	*0.35
				Post	8.84	1.71		
		6	44	Pre	8.77	2.51	0.005	0.07
				Post	8.59	2.66		
		15	8	Pre	10.50	2.14	0.011	0.12
				Post	10.25	2.25		
		17	16	Pre	11.56	3.29	0.007	0.13
				Post	11.13	2.70		
	PP	8	4	Pre	11.00	1.83	0.144	**0.68
				Post	12.25	2.99		
		9	17	Pre	7.12	2.06	0.154	***1.09
				Post	9.35	3.64		
		13	10	Pre	12.90	3.00	0.023	*0.23
				Post	13.60	3.13		
		16	19	Pre	12.79	2.80	0.181	0.15
				Post	13.21	3.46		
		25	21	Pre	13.48	3.37	0.252	0.11
				Post	13.10	3.06		

* small effect

** medium effect

*** large effect

Table 6.7 Pre-test versus post-test of Cornell Critical Thinking Test – Level X (continued)

Construct	Group	School code	N	Pre/Post	Mean	Standard deviation	p	d
DEDUCTION	CONTROL GROUP	5	5	Pre	8.00	1.58	1.000	0.00
				Post	8.00	1.22		
		7	16	Pre	5.00	2.10	0.403	*0.21
				Post	4.56	2.78		
		10	10	Pre	5.20	1.99	0.583	*0.20
				Post	4.80	1.32		
		14	9	Pre	8.44	2.51	0.620	0.13
				Post	8.78	2.91		
		18	13	Pre	5.38	2.10	0.628	*0.18
				Post	5.77	1.79		
		19	5	Pre	5.20	3.49	0.089	***1.20
				Post	9.40	2.51		
		20	19	Pre	10.68	2.83	0.052	**0.47
				Post	12.00	2.16		
		23	11	Pre	10.27	2.69	0.534	*0.20
				Post	10.82	2.60		
	CTI	1	5	Pre	7.63	3.18	0.554	0.13
				Post	8.05	3.42		
		2	16	Pre	7.00	3.34	1.000	0.00
				Post	7.00	2.33		
		3	10	Pre	7.18	2.75	0.578	*0.17
				Post	6.73	3.29		
		11	9	Pre	6.32	2.71	0.916	0.02
				Post	6.26	2.66		
		12	13	Pre	9.25	2.43	0.691	0.15
				Post	9.63	2.33		
		21	5	Pre	9.50	1.38	0.158	***0.97
				Post	10.83	2.48		
	CTI+PP	4	19	Pre	4.95	2.30	0.939	0.02
				Post	5.00	2.11		
		6	44	Pre	4.86	1.77	0.550	0.13
				Post	5.09	2.59		
		15	8	Pre	6.63	2.56	0.937	0.05
				Post	6.75	4.50		
		17	16	Pre	8.56	2.56	0.083	*0.44
				Post	9.69	3.20		
	PP	8	4	Pre	7.00	2.94	0.161	**0.68
				Post	9.00	2.94		
		9	17	Pre	4.59	1.97	0.109	*0.39
				Post	5.35	2.42		
		13	10	Pre	10.20	2.35	0.048	**0.47
				Post	11.30	2.58		
		16	19	Pre	9.63	2.91	0.049	*0.33
				Post	10.58	2.71		
		25	21	Pre	9.76	2.61	0.004	**0.55
				Post	11.19	2.11		

* small effect

** medium effect

*** large effect

Table 6.7 Pre-test versus post-test of Cornell Critical Thinking Test – Level X (continued)

Construct	Group	School code	N	Pre/Post	Mean	Standard deviation	p	d
TOTAL	CONTROL GROUP	5	5	Pre	22.10	5.67	0.400	***0.85
				Post	26.90	8.91		
		7	16	Pre	10.53	9.95	0.018	**0.52
				Post	5.38	9.91		
		10	10	Pre	7.40	10.98	0.206	*0.45
				Post	2.45	7.11		
		14	9	Pre	25.00	8.81	0.134	*0.38
				Post	21.67	9.62		
		18	13	Pre	5.46	4.64	0.198	**0.52
				Post	7.88	5.49		
		19	5	Pre	12.50	9.43	0.212	***1.05
				Post	22.40	11.84		
		20	19	Pre	37.05	8.75	0.010	**0.59
				Post	42.18	6.74		
		23	11	Pre	32.55	8.14	0.877	0.07
				Post	32.00	14.01		
	CTI	1	5	Pre	24.50	12.09	0.595	0.10
				Post	23.32	12.16		
		2	16	Pre	20.00	9.28	0.910	0.04
				Post	20.38	11.22		
		3	10	Pre	17.00	8.80	0.315	**0.51
				Post	12.50	13.25		
		11	9	Pre	13.68	8.30	0.361	*0.21
				Post	11.95	11.40		
		12	13	Pre	29.94	13.98	0.957	0.01
				Post	29.75	12.05		
		21	5	Pre	33.50	7.35	0.777	0.14
				Post	34.50	10.38		
	CTI+PP	4	19	Pre	2.95	7.50	0.813	0.07
				Post	3.50	9.33		
		6	44	Pre	4.93	7.92	0.361	0.16
				Post	6.23	9.65		
		15	8	Pre	20.19	7.32	0.451	*0.41
				Post	17.19	8.54		
		17	16	Pre	26.38	11.30	0.661	0.09
				Post	25.34	13.28		
	PP	8	4	Pre	17.38	14.30	0.043	***0.87
				Post	29.75	8.87		
		9	17	Pre	0.94	5.32	0.035	***0.81
				Post	5.26	10.16		
		13	10	Pre	32.90	12.11	0.284	*0.21
				Post	35.45	13.44		
		16	19	Pre	28.05	12.12	0.131	*0.29
				Post	31.61	10.43		
		25	21	Pre	30.07	12.25	0.019	*0.33
				Post	34.14	9.91		

* small effect

** medium effect

*** large effect

From Table 6.7, it is evident that the PP group had the largest increase in CT (*induction* and *deduction* constructs as well as *total*) as measured with the CCTT – Level X. The majority of IT learners from schools in the control group decreased on the *induction* and *deduction* constructs; however, the same number of schools from the control group as well as the CTI+PP group showed an increase and decrease in the *total* for CT. For the CTI group, the majority of learners' CT decreased whereas the majority of the PP group's CT increased.

Learners were asked to complete two questionnaires and were given sufficient time to complete these. For the CCTT – Level X, it was suggested that learners be given 50 minutes to complete the questionnaire. For the SDLI (Cheng), there was no time specified. To see whether the completion time played a role in learners' CT scores, learners who completed the CCTT – level X in 45 minutes or more were extracted, as it was thought that learners who completed both questionnaires in less than 45 minutes might have rushed through the questionnaires. Table 6.8 reflects the results from these learners who completed the two questionnaires in 45 minutes or more. From Table 6.8, it is also evident that some schools had no IT learners who completed the two questionnaires in 45 minutes or more and therefore these schools were omitted in totality.

Table 6.8 Pre-test versus post-test of Cornell Critical Thinking Test – Level X (completion time ≥ 45 minutes)

Construct	Group	School code	N	Pre/Post	Mean	Standard Deviation	p	d
INDUCTION	CONTROL GROUP	5	4	Pre	16.75	2.50	0.689	*0.31
				Post	16.00	2.45		
		14	2	Pre	18.50	2.12	0.344	0.00
				Post	16.00	0.00		
		18	11	Pre	8.73	1.90	0.072	***1.04
				Post	10.27	1.49		
		19	2	Pre	14.00	1.41	0.500	**0.71
				Post	14.50	0.71		
		20	8	Pre	18.38	2.56	0.195	*0.37
				Post	19.25	2.38		
	CTI	1	3	Pre	16.33	3.51	0.423	0.11
				Post	16.00	3.00		
		2	4	Pre	17.25	2.87	0.036	**0.86
				Post	13.50	4.36		
		11	5	Pre	14.00	1.41	0.454	*0.44
				Post	12.60	3.21		
		21	3	Pre	18.33	3.51	0.321	***1.31
				Post	16.33	1.53		
	CTI+PP	4	8	Pre	9.75	3.81	0.468	*0.24
				Post	10.63	3.62		
		6	24	Pre	10.38	3.76	0.567	0.12
				Post	10.79	3.51		
		15	3	Pre	16.33	2.52	0.728	**0.58
				Post	15.67	1.15		
	PP	8	2	Pre	11.00	0.00	0.126	***3.54
				Post	18.50	2.12		
		9	12	Pre	10.83	2.62	0.111	*0.31
				Post	9.83	3.21		
		13	8	Pre	17.13	2.59	0.888	0.04
				Post	17.25	2.87		
		16	3	Pre	13.67	2.08	0.300	***0.80
				Post	15.33	2.08		
		25	2	Pre	13.00	4.24	0.070	***1.27
				Post	17.50	3.54		

* small effect
** medium effect
*** large effect

Table 6.8 Pre-test versus post-test of Cornell Critical Thinking Test – Level X (completion time ≥ 45 minutes) (continued)

Construct	Group	School code	N	Pre/Post	Mean	Standard Deviation	p	d
CREDIBILITY	CONTROL GROUP	5	4	Pre	11.75	2.87	0.084	***2.17
				Post	15.50	1.73		
		14	2	Pre	11.50	3.54	0.000	0.00
				Post	11.50	2.12		
		18	11	Pre	9.73	2.24	0.108	**0.57
				Post	10.91	2.07		
		19	2	Pre	10.00	4.24	0.000	***2.59
				Post	15.50	2.12		
		20	8	Pre	14.63	2.45	0.073	0.14
				Post	14.88	1.73		
	CTI	1	3	Pre	13.00	3.61	0.512	***3.00
				Post	10.00	1.00		
		2	4	Pre	10.00	2.16	0.785	**0.63
				Post	12.25	3.59		
		11	5	Pre	11.00	1.87	0.938	0.00
				Post	11.00	2.74		
		21	3	Pre	13.67	3.21	0.567	***2.60
				Post	16.67	1.15		
	CTI+PP	4	8	Pre	8.50	2.39	0.709	**0.68
				Post	9.75	1.83		
		6	24	Pre	9.38	2.24	0.041	*0.35
				Post	8.46	2.62		
		15	3	Pre	10.33	2.89	0.121	*0.25
				Post	11.00	2.65		
	PP	8	2	Pre	11.50	2.12	0.000	***1.77
				Post	14.00	1.41		
		9	12	Pre	7.25	2.18	0.414	**0.63
				Post	9.83	4.09		
		13	8	Pre	13.00	3.12	0.079	*0.27
				Post	13.88	3.23		
		16	3	Pre	11.67	3.21	0.801	*0.24
				Post	13.00	5.57		
		25	2	Pre	11.50	2.12	0.000	***4.24
				Post	14.50	0.71		

* small effect

** medium effect

*** large effect

Table 6.8 Pre-test versus post-test of Cornell Critical Thinking Test – Level X (completion time ≥ 45 minutes) (continued)

Construct	Group	School code	N	Pre/Post	Mean	Standard Deviation	p	d
DEDUCTION	CONTROL GROUP	5	4	Pre	7.50	1.29	0.252	***1.73
				Post	8.50	0.58		
		14	2	Pre	11.50	0.71	0.705	**0.47
				Post	10.50	2.12		
		18	11	Pre	4.91	1.87	0.414	*0.38
				Post	5.64	1.91		
		19	2	Pre	5.50	6.36	0.437	-
				Post	11.00	0.00		
		20	8	Pre	10.75	3.28	0.314	**0.60
				Post	12.13	2.30		
	CTI	1	3	Pre	7.33	1.15	0.423	**0.65
				Post	8.33	1.53		
		2	4	Pre	5.50	3.00	0.213	***1.39
				Post	7.25	1.26		
		11	5	Pre	8.40	1.82	0.648	*0.21
				Post	8.80	1.92		
		21	3	Pre	9.00	1.73	0.015	***1.28
				Post	11.67	2.08		
	CTI+PP	4	8	Pre	5.25	2.82	0.917	0.06
				Post	5.13	2.17		
		6	24	Pre	4.67	1.99	0.144	*0.33
				Post	5.54	2.64		
		15	3	Pre	8.67	2.08	0.732	*0.21
				Post	7.33	6.43		
	PP	8	2	Pre	7.00	2.83	0.500	0.14
				Post	7.50	3.54		
		9	12	Pre	4.75	1.96	0.000	**0.67
				Post	6.17	2.12		
		13	8	Pre	10.38	2.26	0.045	**0.58
				Post	11.75	2.38		
		16	3	Pre	9.67	2.31	0.130	***1.44
				Post	11.33	1.15		
		25	2	Pre	8.00	5.66	0.126	**0.51
				Post	10.50	4.95		

*small effect

**medium effect

***large effect

Table 6.8 Pre-test versus post-test of Cornell Critical Thinking Test – Level X (completion time ≥ 45 minutes) (continued)

Construct	Group	School code	N	Pre/Post	Mean	Standard Deviation	p	d
TOTAL	CONTROL GROUP	5	4	Pre	37.75	4.03	0.048	***2.12
				Post	44.00	2.94		
		14	2	Pre	46.50	2.12	0.742	*0.39
				Post	43.50	7.78		
		18	11	Pre	26.82	2.56	0.003	***0.94
				Post	29.82	3.19		
		19	2	Pre	33.50	10.61	0.442	***3.39
				Post	45.50	3.54		
		20	8	Pre	47.75	5.75	0.127	***0.90
				Post	51.75	4.46		
	CTI	1	3	Pre	41.67	6.11	0.535	**0.54
				Post	38.67	5.51		
		2	4	Pre	36.50	6.25	0.769	0.15
				Post	37.50	6.76		
		11	5	Pre	36.40	1.00	0.891	*0.29
				Post	36.00	2.07		
		21	3	Pre	46.00	6.25	0.034	***0.99
				Post	50.67	4.73		
	CTI+PP	4	8	Pre	26.63	5.63	0.015	*0.41
				Post	29.13	6.06		
		6	24	Pre	27.54	5.66	0.543	0.15
				Post	28.42	5.82		
		15	3	Pre	40.67	4.16	0.370	***0.85
				Post	35.67	5.86		
	PP	8	2	Pre	35.00	2.83	0.139	***1.59
				Post	44.00	5.66		
		9	12	Pre	25.25	3.65	0.041	**0.49
				Post	28.75	7.15		
		13	8	Pre	46.75	6.90	0.306	*0.23
				Post	48.75	8.66		
		16	3	Pre	38.33	5.03	0.396	**0.69
				Post	43.67	7.77		
		25	2	Pre	35.00	15.56	0.058	***0.78
				Post	46.00	14.14		

* small effect

** medium effect

*** large effect

From Table 6.8, one can deduce that the control group and the PP group showed the greatest increase in CT *total*. The CTI group had two schools that increased in the *total* for CT (only one with a practically significant difference) and two decreased (with a small and medium practically significant difference, respectively). In the CTI+PP group, one school showed an increase in its total CT that was practically significantly different, and one school had a large practically significant decrease in its *total* CT. Overall, when omitting the learners who completed the two questionnaires in less than 45 minutes, there was a difference in the results as compared to when no filtering was implemented. The PP group showed the best results (greatest increase in CT *total*) even when the filtering of time was done.

6.2.1.2. Self-Directed Learning Instrument

The SDLI implemented in the quantitative investigation was used to establish Grade 10 IT learners' self-directedness. Before any inferential statistical tests were conducted, Cronbach's alpha for the SDLI was calculated in order to determine the reliability of the instrument in the given context. Table 6.9 reflects the reliability established for the SDLI.

Table 6.9 Reliability of the Self-Directed Learning Instrument

Construct	Question numbers	Cronbach's alpha
Learning motivation	1, 2, 3, 4, 5, 6	0.674
Planning and implementing	7, 8 ,9, 10, 11, 12	0.749
Self-monitoring	13, 14, 15, 16	0.581
Interpersonal communication	17, 18, 19, 20	0.502

Referring to Table 6.9, it is evident that the SDLI constructs do not prove fully reliable when making use of Cronbach's alpha coefficient (reliability ≥ 0.7). The *planning and implementing* construct proved reliable with a score of 0.749 and the *learning motivation* construct proved partly reliable with a 0.674 score; however, the scores of the *self-monitoring* and *interpersonal communication* constructs were too low to be considered reliable (see 5.3.1.5). For further statistical analyses, only constructs that proved reliable were used; therefore, only the *learning motivation* and *planning and implementing* constructs are reported as well as the total for the SDLI.

6.2.1.2.1. Test 1 (pre-test)

The SDLI, developed by Cheng *et al.* (2010), was given to Grade 10 IT learners to complete in conjunction with the CCTT – Level X in the pre-test. This section reports on the statistics calculated for the pre-test of the SDLI.

- **Descriptive statistics**

Table 6.10 reflects the descriptive statistics of the SDLI pre-test, as completed by the Grade 10 IT learners in the study. The descriptive statistics are reported in terms of the questionnaire construct, the school code, the number of learners in each school, the mean score and the standard deviation. Learners were required to make a choice on a five-point Likert-type scale with a minimum of 1 (never) and maximum of 5 (always). As there were 20 questions (each with a maximum score of 5), the total score for the questionnaire was 100 (20 x 5). The score of each construct was calculated by processing the total for the construct to a score of 5.

Table 6.10 Descriptive statistics of the Self-Directed Learning Instrument (pre-test)

Construct	School code	N	Mean	Standard deviation
Learning motivation	01	19	4.04	0.34
	02	8	4.10	0.57
	03	11	4.52	0.33
	04	19	4.42	0.48
	05	5	3.90	0.35
	06	44	4.52	0.36
	07	16	4.47	0.33
	08	4	4.25	0.42
	09	17	4.37	0.43
	10	10	4.32	0.50
	11	19	4.17	0.68
	12	8	4.21	0.61
	13	10	4.05	0.47
	14	9	4.06	0.46
	15	8	3.90	0.44
	16	19	3.83	0.42
	17	16	3.77	0.56
	18	13	4.37	0.47
	19	5	3.91	0.52
	20	19	4.00	0.42
	21	6	4.17	0.55
	23	11	4.00	0.49
	25	21	4.45	0.33

Table 6.10 Descriptive statistics of the Self-Directed Learning Instrument (pre-test) (continued)

Construct	School code	N	Mean	Standard deviation
Planning and Implementing	01	19	3.74	0.51
	02	8	3.92	0.44
	03	11	3.91	0.59
	04	19	3.91	0.54
	05	5	3.53	0.46
	06	44	4.03	0.43
	07	16	3.90	0.60
	08	4	3.90	0.65
	09	17	3.83	0.54
	10	10	3.77	0.60
	11	19	3.68	0.51
	12	8	4.02	0.76
	13	10	3.35	0.71
	14	9	3.57	0.84
	15	8	3.29	0.77
	16	19	3.18	0.60
	17	16	3.44	0.67
	18	13	3.60	0.54
	19	5	3.73	0.30
	20	19	3.51	0.66
	21	6	3.47	0.62
	23	11	3.92	0.41
	25	21	3.92	0.60

Table 6.10 Descriptive statistics of the Self-Directed Learning Instrument (pre-test) (continued)

Construct	School code	N	Mean	Standard deviation
SDL total	01	19	77.79	6.51
	02	8	78.13	8.66
	03	11	84.39	6.25
	04	19	81.40	9.24
	05	5	74.20	7.05
	06	44	84.45	7.07
	07	16	82.69	6.32
	08	4	80.40	9.85
	09	17	80.41	9.07
	10	10	81.00	10.39
	11	19	77.34	10.25
	12	8	80.38	10.81
	13	10	74.98	9.71
	14	9	77.11	10.60
	15	8	73.88	9.85
	16	19	70.72	7.96
	17	16	72.90	8.10
	18	13	76.87	7.87
	19	5	74.68	7.58
	20	19	74.89	7.39
	21	6	76.33	9.33
	23	11	78.63	6.99
	25	21	82.02	8.25

From Table 6.10, it can be deduced that learners' scores regarding the *planning and implementing* construct of SDL were generally similar with no great differences between schools. The small standard deviation indicates that learners in schools scored quite similar regarding the *planning and implementing* construct.

In the following section, the difference between the four groups in the study regarding their SDL will be discussed.

- **Differences between the four groups in the study (Self-Directed Learning Instrument (pre-test))**

Table 6.11 reflects the differences between the four groups in the study regarding their SDL as measured with the SDLI. As the sample size was small, statistical significance did not have a strong enough power, but the practically significant difference is reported in order to provide an indication of differences in practice.

Table 6.11 Differences between groups for Self-Directed Learning Instrument (pre-test)

Construct	Pre/Post	Group	Mean	MSE	Variance of school	p	d		
							Control	CTI	CTI+PP
Learning motivation	Pre	Control	4.15	0.19	0.00	0.543			
		CTI	4.17				0.03		
		CTI+PP	4.37				**0.51	**0.48	
		PP	4.19				0.08	0.05	**0.43
Planning and implementing	Pre	Control	3.71	0.33	0.03	0.813			
		CTI	3.84				*0.23		
		CTI+PP	3.68				0.05	*0.27	
		PP	3.69				0.02	0.25	0.03
Total	Pre	Control	77.97	65.58	8.15	0.992			
		CTI	78.67				0.08		
		CTI+PP	78.19				0.02	0.05	
		PP	78.54				0.06	0.02	0.04

* small effect

** medium effect

*** large effect

From Table 6.11, it is clear that schools from the four different groups in the study scored similarly to each other in the *planning and implementing* and *learning motivation* constructs as well as in the *total* for the SDLI. In the *planning and implementing* construct, the CTI group however scored the highest with a small practically significant difference when compared to the control group as well as when compared to the CTI+PP group. In the *learning motivation* construct, the CTI+PP group scored the highest. In the graphical representation of the total mean scores, as illustrated in Figure 6.6, it is shown that the four groups did not differ greatly from each other in terms of their pre-test scores for the SDLI however the CTI group scored the highest of the four groups.

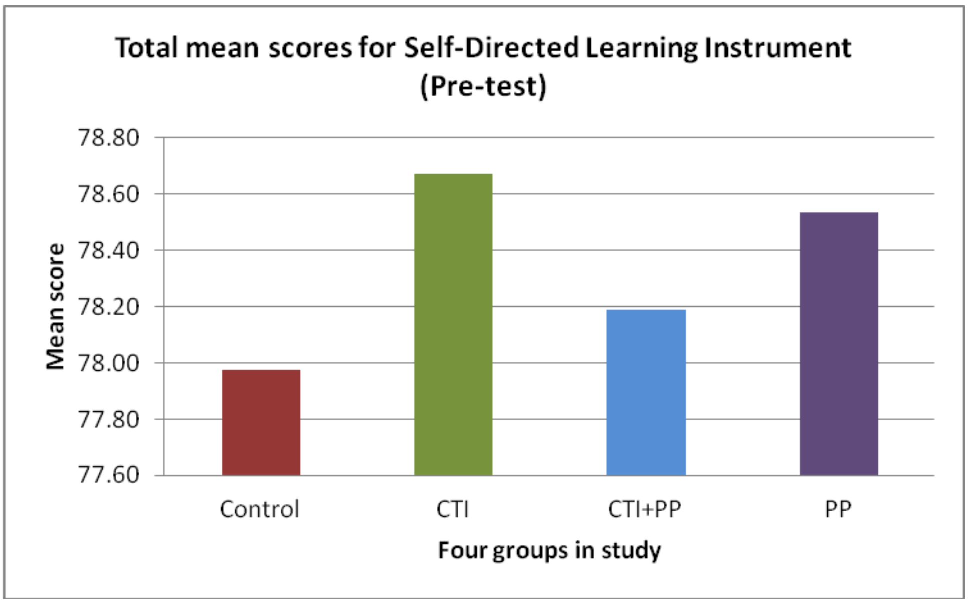


Figure 6.3 Total mean score for Self-Directed Learning Instrument (Pre-test)

6.2.1.2.2. Test 2 (post-test)

The post-test distributed to the learners to measure their SDL was the same as the pre-test. This section focuses on reporting the scores measured on the SDLI (post-test). The descriptive statistics are reported, followed by the results of the dependent t-tests done to compare the change within schools' pre- and post-tests with one another.

- **Descriptive statistics**

In Table 6.12, the descriptive statistics in terms of the questionnaire construct, the school code, the number of participants per school, the mean and standard deviation are presented. In the SDLI used in this study, learners were required to make a choice on a five-point Likert-type scale with a minimum of 1 (never) and maximum of 5 (always).

Table 6.12 Descriptive statistics of Self-Directed Learning Instrument (post-test)

Construct	School code	N	Mean	Standard deviation
Learning motivation	01	19	3.93	0.45
	02	8	4.06	0.31
	03	11	4.45	0.39
	04	19	4.42	0.37
	05	5	4.00	0.49
	06	44	4.63	0.39
	07	16	4.44	0.40
	08	4	4.50	0.49
	09	17	4.44	0.40
	10	10	4.30	0.45
	11	19	4.12	0.62
	12	8	4.23	0.72
	13	10	4.07	0.52
	14	9	3.96	0.64
	15	8	3.92	0.39
	16	19	3.93	0.57
	17	16	3.99	0.53
	18	13	4.41	0.43
	19	5	4.10	0.30
	20	19	4.21	0.46
	21	6	4.00	0.39
	23	11	4.09	0.53
	25	21	4.28	0.41
Planning and Implementing	01	19	3.82	0.60
	02	8	3.80	0.49
	03	11	3.70	0.36
	04	19	3.84	0.52
	05	5	3.53	0.49
	06	44	4.06	0.49
	07	16	3.79	0.47
	08	4	3.92	0.67
	09	17	3.72	0.59
	10	10	3.77	0.87
	11	19	3.31	0.69
	12	8	3.69	0.69
	13	10	3.45	0.54
	14	9	3.69	0.68
	15	8	3.42	0.39
	16	19	3.48	0.62
	17	16	3.39	0.76
	18	13	3.78	0.42
	19	5	3.33	0.47
	20	19	3.59	0.36
	21	6	3.08	0.48
	23	11	3.71	0.55
	25	21	3.95	0.54

Table 6.12 Descriptive statistics of Self-Directed Learning Instrument (post-test) (continued)

Construct	School code	N	Mean	Standard deviation
SDL total	1	19	76.12	9.15
	2	8	76.43	7.04
	3	11	81.80	5.99
	4	19	80.47	9.70
	5	5	75.20	8.17
	6	44	84.89	7.59
	7	16	81.42	7.68
	8	4	83.00	11.49
	9	17	80.86	8.21
	10	10	79.90	11.51
	11	19	73.58	11.31
	12	8	78.38	12.70
	13	10	76.60	10.19
	14	9	76.33	9.53
	15	8	72.25	7.30
	16	19	73.41	10.58
	17	16	74.00	7.99
	18	13	81.11	8.22
	19	5	70.20	6.57
	20	19	76.45	6.66
	21	6	72.63	8.89
	23	11	77.80	7.74
	25	21	81.92	8.90

As with the pre-test of the SDLI and in terms of *planning and implementing* learners scored quite similar in the post-test to one another with no one school scoring vastly different from any other (see Table 6.12). Learners in the schools also scored similar to one another when referring to the small standard deviation observed.

In the next section, a comparison between the four groups in the study regarding their scores on the SDLI (post-test) will be discussed.

- **Differences between the four groups in the study (Self-Directed Learning Instrument (post-test))**

In order to determine the differences found between the four groups in the study (control group and the three experimental groups), Cohen's d-value was calculated. As the four groups did not have the exact same scores during the pre-test (see Table 6.11), the hierarchical linear model (Garson, 2012) was implemented to compensate for differences.

Table 6.13 shows the d-values calculated for each group's comparison. The CTI group scored the lowest on both the *planning and implementing* construct as well as the SDLI *total*, whereas the PP group scored the highest – explaining the small to medium practically significant differences seen between these two groups. Differences between the CTI group and all of the other groups were observed, possibly explained by the fact that the CTI group scored the lowest in the test.

Table 6.13 Differences between groups for Self-Directed Learning Instrument (post-test)

Construct	Pre/Post	Group	Mean	MSE	Variance of school	P	d		
							Control	CTI	CTI+PP
Learning motivation	Post	Control	4.27	0.12	0.00	0.237			
		CTI	4.14				*0.37		
		CTI+PP	4.31				0.12	**0.49	
		PP	4.26				0.03	*0.33	0.16
Planning and implementing	Post	Control	3.70	0.20	0.01	0.819			
		CTI	3.61				*0.19		
		CTI+PP	3.71				0.04	*0.22	
		PP	3.73				0.06	*0.25	0.03
Total	Post	Control	78.93	37.36	0.00	0.181			
		CTI	76.56				*0.39		
		CTI+PP	78.83				0.02	*0.37	
		PP	79.68				0.12	**0.51	0.14

* small effect

** medium effect

*** large effect

To illustrate the differences observed in groups graphically, Figure 6.8 shows the total mean scores for each group. From Figure 6.8, it is clear that although the CTI group scored the highest in the pre-test, the CTI group scored the lowest in the SDLI (post-test).

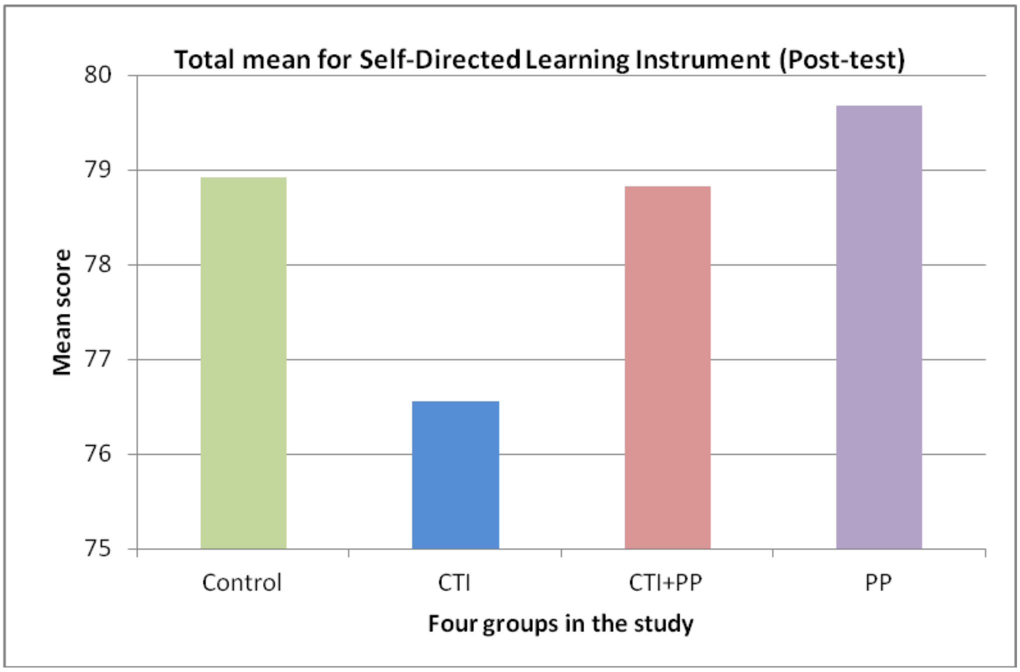


Figure 6.4 Total mean score for Self-Directed Learning Instrument (post-test)

To determine the differences between the participants' pre-test and post-test scores in terms of the SDLI, dependent t-tests were conducted, and these are discussed below.

- **Comparison of four groups' within school change pre-tests and post-tests (dependent t-tests)**

To determine the difference in scores of the SDL pre-test and the SDL post-test, dependent t-tests were conducted. Table 6.14 illustrates the results from these tests. Referring to the mean score (minimum 0 and maximum 5) one can deduce in which school an increase in SDL is evident.

Table 6.14 Pre-test versus post-test of the Self-Directed Learning Instrument

Construct	Group	School code	N	Pre/Post	Mean	Standard Deviation	p	d
LEARNING MOTIVATION	CONTROL GROUP	5	5	Pre	3.90	0.49	0.056	*0.29
				Post	4.00	0.35		
		7	16	Pre	4.47	0.33	0.004	0.11
				Post	4.44	0.40		
		10	10	Pre	4.32	0.50	0.021	0.03
				Post	4.30	0.45		
		14	9	Pre	4.06	0.46	0.032	*0.20
				Post	3.96	0.64		
		18	13	Pre	4.37	0.47	0.000	0.09
				Post	4.41	0.43		
		19	5	Pre	3.91	0.52	0.151	*0.36
				Post	4.10	0.30		
		20	19	Pre	4.00	0.42	0.003	**0.49
				Post	4.21	0.46		
		23	11	Pre	4.00	0.49	0.009	*0.18
				Post	4.09	0.53		
	CTI	1	5	Pre	4.04	0.34	0.016	*0.31
				Post	3.93	0.45		
		2	16	Pre	4.10	0.57	0.051	0.07
				Post	4.06	0.31		
		3	10	Pre	4.52	0.33	0.599	*0.19
				Post	4.45	0.39		
		11	9	Pre	4.17	0.68	0.000	0.07
				Post	4.12	0.62		
		12	13	Pre	4.21	0.61	0.008	0.03
				Post	4.23	0.72		
		21	5	Pre	4.17	0.55	0.023	***3.00
				Post	4.00	0.39		
	CTI+PP	4	19	Pre	4.42	0.49	0.002	0.01
				Post	4.42	0.37		
		6	44	Pre	4.52	0.36	0.005	*0.30
				Post	4.63	0.39		
		15	8	Pre	3.90	0.44	0.042	0.05
				Post	3.92	0.39		
		17	16	Pre	3.77	0.56	0.000	*0.39
				Post	3.99	0.53		
	PP	8	4	Pre	4.25	0.42	0.010	**0.60
				Post	4.50	0.49		
		9	17	Pre	4.37	0.43	0.000	0.15
				Post	4.44	0.40		
		13	10	Pre	4.05	0.47	0.000	0.04
				Post	4.07	0.52		
		16	19	Pre	3.83	0.42	0.023	*0.23
				Post	3.93	0.57		
		25	21	Pre	4.45	0.33	0.003	**0.52
				Post	4.22	0.41		

* small effect

** medium effect

*** large effect

Table 6.14 Pre-test versus post-test of the Self-Directed Learning Instrument (continued)

Construct	Group	School code	N	Pre/Post	Mean	Standard Deviation	p	d
PLANNING AND IMPLEMENTING	CONTROL GROUP	5	5	Pre	3.53	0.46	0.480	0.00
				Post	3.53	0.49		
		7	16	Pre	3.90	0.60	0.374	*0.18
				Post	3.79	0.47		
		10	10	Pre	3.77	0.60	0.257	0.00
				Post	3.77	0.87		
		14	9	Pre	3.57	0.84	0.003	0.13
				Post	3.69	0.68		
		18	13	Pre	3.60	0.54	0.001	*0.34
				Post	3.78	0.42		
		19	5	Pre	3.73	0.30	0.301	***1.32
				Post	3.33	0.47		
		20	19	Pre	3.51	0.66	0.020	0.12
				Post	3.59	0.36		
		23	11	Pre	3.92	0.41	0.324	**0.50
				Post	3.71	0.55		
	CTI	1	5	Pre	3.74	0.51	0.000	0.15
				Post	3.82	0.60		
		2	16	Pre	3.92	0.44	0.646	*0.27
				Post	3.80	0.49		
		3	10	Pre	3.91	0.59	0.059	*0.36
				Post	3.70	0.36		
		11	9	Pre	3.68	0.51	0.009	**0.75
				Post	3.31	0.69		
		12	13	Pre	4.02	0.76	0.009	*0.44
				Post	3.69	0.69		
		21	5	Pre	3.47	0.62	0.064	**0.64
				Post	3.08	0.48		
	CTI+PP	4	19	Pre	3.91	0.54	0.000	0.13
				Post	3.84	0.52		
		6	44	Pre	4.03	0.43	0.000	0.05
				Post	4.06	0.49		
		15	8	Pre	3.29	0.77	0.049	0.16
				Post	3.42	0.39		
		17	16	Pre	3.44	0.67	0.000	0.08
				Post	3.39	0.76		
	PP	8	4	Pre	3.90	0.65	0.236	0.03
				Post	3.92	0.67		
		9	17	Pre	3.83	0.54	0.094	*0.21
				Post	3.72	0.59		
		13	10	Pre	3.35	0.71	0.008	0.15
				Post	3.45	0.54		
		16	19	Pre	3.18	0.60	0.008	**0.49
				Post	3.48	0.62		
		25	21	Pre	3.92	0.60	0.003	0.05
				Post	3.95	0.54		

* small effect

** medium effect

*** large effect

Table 6.14 Pre-test versus post-test of the Self-Directed Learning Instrument (continued)

Construct	Group	School code	N	Pre/Post	Mean	Standard Deviation	p	d
TOTAL	CONTROL GROUP	5	5	Pre	74.20	7.05	0.190	0.14
				Post	75.20	8.17		
		7	16	Pre	82.69	6.32	0.007	*0.20
				Post	81.42	7.68		
		10	10	Pre	81.00	10.39	0.030	0.11
				Post	79.90	11.51		
		14	9	Pre	77.11	10.60	0.002	0.07
				Post	76.33	9.53		
		18	13	Pre	76.87	7.69	0.000	**0.54
				Post	81.11	8.22		
		19	5	Pre	74.68	7.58	0.078	**0.59
				Post	70.20	6.57		
		20	19	Pre	74.89	7.39	0.053	*0.21
				Post	76.45	6.66		
		23	11	Pre	78.63	6.99	0.007	0.12
				Post	77.80	7.74		
	CTI	1	5	Pre	77.79	6.51	0.002	*0.26
				Post	76.12	9.15		
		2	16	Pre	78.13	8.66	0.185	*0.20
				Post	76.43	7.04		
		3	10	Pre	84.39	6.25	0.243	*0.41
				Post	81.80	5.99		
		11	9	Pre	77.34	10.25	0.000	*0.37
				Post	73.58	11.31		
		12	13	Pre	80.38	10.81	0.003	*0.19
				Post	78.38	12.70		
		21	5	Pre	76.33	9.33	0.056	*0.40
				Post	72.63	8.89		
	CTI+PP	4	19	Pre	81.40	9.24	0.000	0.10
				Post	80.47	9.70		
		6	44	Pre	84.45	7.07	0.000	0.06
				Post	84.89	7.59		
		15	8	Pre	73.88	9.85	0.003	*0.17
				Post	72.25	7.30		
		17	16	Pre	72.90	8.10	0.000	0.14
				Post	74.00	7.99		
	PP	8	4	Pre	80.40	9.85	0.121	*0.26
				Post	83.00	11.49		
		9	17	Pre	80.41	9.07	0.002	0.05
				Post	80.86	8.21		
		13	10	Pre	74.98	9.71	0.000	*0.17
				Post	76.60	10.19		
		16	19	Pre	70.72	7.96	0.033	*0.34
				Post	73.41	10.58		
		25	21	Pre	82.02	8.25	0.000	0.01
				Post	81.92	8.90		

* small effect

** medium effect

*** large effect

Due to the small sample in this study, there was not enough power to rely on statistical significance only, but practical significance was still calculated as an indicator. From Table 6.14, it is clear that some IT learners' SDL decreased. In the CTI group, five schools had a decrease in the *planning and implementing* construct and all schools decreased in the *total* for SDL, and the difference between the pre- and post-test is of practical significance. The majority of schools in the PP group increased in the *planning and implementing* construct as well as the SDL *total*; however, for the SDL *total*, only two schools showed a small practically significant difference between the pre- and the post-test.

As with the calculations done regarding the CT scores where the dependent t-tests were calculated for the 317 learners as well as the 107 learners (who completed the questionnaires in over 45 minutes), the same was done for the SDL scores (see 6.2.1.1.2). Table 6.15 reflects the dependent t-test scores between the pre-test and the post-test of the SDL scores. In these tests, the minimum was 0 and the maximum score was 5, as it was a 5-point Likert-type scale. The minimum score for the total was 0 and maximum was 100 (20 questions x 5 points per question).

Table 6.15 Pre-test versus post-test of Self-Directed Learning Instrument (completion time ≥ 45 minutes)

Construct	Group	School code	N	Pre/Post	Mean	Standard Deviation	p	d
LEARNING MOTIVATION	CONTROL GROUP	5	4	Pre	3.92	0.40	0.127	*0.21
				Post	4.00	0.56		
		14	2	Pre	4.00	0.24	0.000	***1.06
				Post	4.25	0.12		
		18	11	Pre	4.36	0.50	0.000	0.10
				Post	4.41	0.45		
		19	2	Pre	4.03	0.90	0.000	0.06
				Post	4.08	0.59		
		20	8	Pre	4.00	0.40	0.038	**0.76
				Post	4.30	0.43		
	CTI	1	3	Pre	4.00	0.17	0.626	**0.67
				Post	3.89	0.75		
		2	4	Pre	4.25	0.39	0.151	*0.32
				Post	4.00	0.18		
		11	5	Pre	4.11	0.59	0.035	0.13
				Post	4.03	0.53		
		21	3	Pre	3.78	0.54	0.433	*0.21
				Post	3.67	0.17		
	CTI+PP	4	8	Pre	4.45	0.39	0.021	0.15
				Post	4.40	0.43		
		6	24	Pre	4.62	0.33	0.001	0.16
				Post	4.57	0.42		
		15	3	Pre	4.17	0.33	0.454	**0.50
				Post	4.00	0.44		
	PP	8	2	Pre	4.33	0.00	-	-
				Post	4.58	0.12		
		9	12	Pre	4.31	0.49	0.000	*0.18
				Post	4.39	0.43		
		13	8	Pre	4.00	0.52	0.000	0.12
				Post	3.94	0.48		
		16	3	Pre	4.06	0.35	0.154	0.16
				Post	4.11	0.19		
		25	2	Pre	4.08	0.59	-	-
				Post	3.92	0.59		

* small effect

** medium effect

*** large effect

Table 6.15 Pre-test versus post-test of Self-Directed Learning Instrument (completion time ≥ 45 minutes) (continued)

Construct	Group	School code	N	Pre/Post	Mean	Standard Deviation	p	d
PLANNING AND IMPLEMENTING	CONTROL GROUP	5	4	Pre	3.46	0.50	0.650	*0.25
				Post	3.58	0.55		
		14	2	Pre	3.50	0.94	0.742	*0.27
				Post	3.75	0.12		
		18	11	Pre	3.62	0.59	0.161	*0.27
				Post	3.78	0.46		
		19	2	Pre	3.50	0.24	0.500	**0.71
				Post	3.33	0.00		
		20	8	Pre	3.63	0.63	0.529	0.13
				Post	3.71	0.42		
	CTI	1	3	Pre	3.22	0.38	1.000	0.00
				Post	3.22	0.92		
		2	4	Pre	4.13	0.53	0.209	***0.91
				Post	3.64	0.61		
		11	5	Pre	3.63	0.63	0.067	***0.90
				Post	3.07	0.92		
		21	3	Pre	3.06	0.63	0.423	*0.18
				Post	2.94	0.59		
	CTI+PP	4	8	Pre	3.88	0.63	0.469	*0.18
				Post	3.76	0.62		
		6	24	Pre	4.06	0.45	0.409	0.16
				Post	3.99	0.54		
		15	3	Pre	3.44	1.13	0.580	0.15
				Post	3.28	0.69		
	PP	8	2	Pre	3.47	0.19	0.742	***1.06
				Post	3.67	0.47		
		9	12	Pre	3.78	0.53	0.826	0.05
				Post	3.75	0.49		
		13	8	Pre	3.33	0.77	0.153	*0.25
				Post	3.52	0.59		
		16	3	Pre	3.39	0.10	0.910	**0.58
				Post	3.44	0.75		
		25	2	Pre	3.92	0.82	0.000	0.00
				Post	3.75	0.82		

* small effect

** medium effect

*** large effect

Table 6.15 Pre-test versus post-test of Self-Directed Learning Instrument (completion time ≥ 45 minutes) (continued)

Construct	Group	School code	N	Pre/Post	Mean	Standard Deviation	p	d
TOTAL	CONTROL GROUP	5	4	Pre	74.75	8.02	0.893	0.06
				Post	75.25	9.43		
		14	2	Pre	73.00	15.56	0.705	*0.26
				Post	77.00	4.24		
		18	11	Pre	77.12	8.09	0.020	**0.47
				Post	80.89	8.47		
		19	2	Pre	73.70	11.74	0.805	0.10
				Post	72.50	6.36		
		20	8	Pre	76.63	8.03	0.580	0.15
				Post	77.83	6.83		
	CTI	1	3	Pre	72.33	3.21	1.000	0.00
				Post	72.33	16.26		
		2	4	Pre	81.00	11.75	0.144	**0.61
				Post	73.85	8.00		
		11	5	Pre	75.84	9.55	0.176	*0.46
				Post	71.40	12.78		
		21	3	Pre	68.67	5.86	0.383	*0.23
				Post	67.33	7.02		
	CTI+PP	4	8	Pre	81.73	8.56	0.111	*0.40
				Post	78.33	9.63		
		6	24	Pre	85.34	7.61	0.497	0.11
				Post	84.50	8.10		
		15	3	Pre	77.00	13.75	0.150	*0.39
				Post	71.67	11.02		
	PP	8	2	Pre	75.80	2.55	0.180	***2.44
				Post	82.00	0.00		
		9	12	Pre	79.08	9.90	0.225	*0.22
				Post	81.22	8.62		
		13	8	Pre	73.85	10.65	0.064	*0.19
				Post	75.88	11.39		
		16	3	Pre	70.33	2.08	0.836	**0.69
				Post	68.89	10.00		
		25	2	Pre	74.00	9.90	0.795	0.10
				Post	75.00	14.14		

* small effect

** medium effect

*** large effect

From Table 6.15, where scores of IT learners who completed the two questionnaires in 45 minutes or more are presented, it is clear that all schools in the CTI+PP group decreased in the *planning and implementing* construct and in the *total* for SDL.

The control group showed the majority of increases in the *planning and implementing* construct and *total*. Only three schools had a practically significant difference from the pre-test to the post-test with the post-test being lower than the pre-test in the *planning and implementing* construct.

Two schools had a practically significant difference when referring to the pre-test and the post-test in the *total* for SDL – both increasing from the pre-test to the post-test.

The PP group also showed the majority of increases in the *total* for SDL – with one school showing a decrease with a practically significant difference. When omitting the learners who completed the questionnaire in less than 45 minutes, more schools showed an increase from the pre- to the post-test, which is practically significant.

With the results from the two separate questionnaires discussed, a comparison between IT learners' CTS and SDL is presented in the following section.

6.2.1.3. Comparison of critical thinking and Self-Directed Learning of total sample

A comparison was made between CT and SDL by comparing all four constructs as well as the totals of the CCTT – Level X and the SDLI. This was done for the pre-tests as well as the post-tests. The correlations were only done on the 107 learners who completed the two questionnaires in 45 minutes or more as it is unlikely to have a reliable score if completed in less than 45 minutes. In Table 6.16, a correlation matrix for the pre-test is given.

Table 6.16 Correlation between Cornell Critical Thinking Test – Level X (pre-test) and Self-Directed Learning Instrument (pre-test) of the total sample

			CT			
			Induction	**Credibility**	**Deduction**	**CT Total**
SDL	**Planning & implementing**	Correlation	-0.164	-0.238	-0.106	
		p-value	0.044	0.000	0.161	
	Learning motivation	Correlation	-0.252	-0.235	-0.167	
		p-value	0.004	0.004	0.135	
	SDL Total	Correlation				-0.202
		p-value				0.006

- Correlation indicates whether a positive or negative correlation is observed
- p-value indicates the magnitude of the difference of the correlation ($p < 0.05$ practically and statistically significant in this case).

From Table 6.16, referring to the *SDL total* compared to the *CT total* for the total sample, it is evident that there is a small to moderate practically and statistically significant negative correlation between the CCTT – Level X (pre-test) and the SDLI (pre-test). There is also a small to moderate practically significant negative correlation between the *induction* and *learning motivation* constructs as well as between the *credibility* and *learning and planning* constructs.

To illustrate the correlation between the CCTT – Level X (post-test) and the SDLI (post-test), Table 6.17 displays the various correlations with their p-values.

Table 6.17 Correlation between Cornell Critical Thinking Test – Level X (post-test) and the Self-Directed Learning Instrument (post-test)

			CT			
			Induction	**Credibility**	**Deduction**	**CT Total**
SDL	**Planning & implementing**	Correlation	-0.052	-0.154	-0.186	
		p-value	0.0002	0.0093	0.004	
	Learning motivation	Correlation	-0.061	-0.180	-0.212	
		p-value	0.0128	0.0319	0.0088	
	SDL Total	Correlation				-0.202
		p-value				0.0011

- Correlation indicates whether a positive or negative correlation is observed
- p-value indicates the magnitude of the difference of the correlation ($p < 0.05$ practically and statistically significant in this case).

As with the correlations indicated for the pre-test, only small to moderate negative practical significances are visible for correlations for the post-test. When referring to the *CT total* for the post-test compared to the *SDL total* for the post-test, only a small to moderate negative practical significance is observed. In 6.3 (Figure 6.5), the differences observed between the separate groups is discussed.

With the quantitative results reported, as collected from the Grade 10 IT learners in this study, the following section reports on the qualitative results obtained from the Grade 10 IT learners as well as the Grade 10 IT teachers.

6.2.2. Qualitative data analyses

Both Grade 10 IT learners and Grade 10 IT teachers were asked to participate in the qualitative investigation. Semi-structured interviews (before and after) were conducted with the three experimental groups of Grade 10 IT teachers, and all four groups of Grade 10 IT learners were asked to complete a narrative during the post-test examination. IT learners were given a definition of a critical thinker and asked to comment on whether they felt that the IT class had developed them to be critical thinkers. Furthermore, IT learners in the experimental groups were asked to comment on their experience of the suggested strategies implemented in the IT class. IT teachers were asked an open-ended question on their experience of the suggested strategies in the IT class.

In a further attempt to elicit answers to research questions 4, 5 and 6 (see 6.1), the qualitative findings from both teachers and learners under the headings of each of the four research groups in the study are reported in this section. An in-depth discussion on the findings from the data will be presented in Chapter 7.

6.2.2.1. Control group

In the control group, IT learners were asked to report on whether they felt that the IT class had developed them as critical thinkers. From these answers, several codes were identified, which in turn were placed in categories and these categories were then grouped into themes assisting the researcher in answering the research questions set for this study. In summary, Table 6.18 reflects all the codes identified in the control group, grouped into specific categories, which in turn formed part of emerging themes.

Table 6.18 Codes, categories and themes identified in the control group

Codes	Categories	Themes
Problem solving	IT class focuses on problem solving	CT aspects
Planning	IT class encourages cognition/metacognition	
Analysis		
Thinking		
Decision-making		
Reasoning		
Evaluation		
Understanding		
Open-mindedness	IT class encourages positive dispositions	
Questioning		
Inquisitiveness		
Creativity		
Using different perspectives	IT class illustrates the use of different perspectives	
Confident	IT increases sense of self	SDL aspects
Open-minded		
Responsible		
Planning	IT class creates a platform for cognition/metacognition	
Evaluation		
Use of resources	IT class addresses use of resources	
Independent learning	IT class stimulates learning flexibility	
Learning with the help of others		

In the discussion to follow, the theme is placed as a main heading, followed by the categories in bullet form and in the discussion, codes are indicated in bold. Quotes to support the discussion are also given.

6.2.2.1.1. Critical thinking aspects identified in control group

The narratives from the control group learners indicated that CT aspects (Facione, 1990; Glaser, 1941; Russell, 1943) were visible in the IT classroom (see Table 2.4). The following categories were identified.

- **The Information Technology class focuses on problem solving**

The most prevalent aspect identified by learners as to why the IT class had developed them into critical thinkers was the fact that IT encompasses **problem solving**. One learner for instance noted, "IT teaches us about problem solving and my problem solving had improved greatly" (Learner from school 14).

- **The Information Technology class encourages various cognitive and metacognitive skills**

A number of learners commented on the fact that the IT class had taught them the importance of **planning** and **analysis**: "Before you can solve a problem, you first have to analyse the problem" (Learner from school 2). The class also encourages them to **think** before making a **decision**, weigh up the advantages and disadvantages (**reasoning)** and in doing so to **evaluate** their progress of problem solving constantly: "[IT] encourages us and myself to use the full thinking power and brain capacity of our minds and our knowledge" (Learner from school 5). A small number of learners also stated that the IT class increased their **understanding** of complex topics.

- **The Information Technology class encourages positive dispositions**

IT learners in this control group generally noted that they were taught to think outside the box and be **open-minded:** "this class 'forces' you to think outside the box" (Learner from school 5). Several IT learners noted that the IT class focused them on their **questioning** as they were encouraged to question constantly throughout the problem solving process and to be **inquisitive** and **creative** about all topics covered. All of the aforementioned codes link with positive dispositions for CT development (see Table 2.4).

- **The Information Technology class illustrates the use of different perspectives**

A large number of learners stated that the IT class taught them that there are several ways of solving a problem and that they should consider every possibility before attempting to solve the problem. Furthermore, learners noted that teachers encouraged them to **use different perspectives**: "we will look at the possible solutions and select the most logical solution" (Learner from school 7) and "You can solve an IT problem in various ways" (Learner from school 8).

From all of the aspects prevalent in the control group's IT learners' narratives regarding their CT development in the IT classroom, it is clear that learners in the control group felt that the IT class had promoted CT as all of the codes mentioned above are CT aspects and positively weighted .

6.2.2.1.2. Self-Directed Learning aspects identified in control group

From the control group learners' responses to whether they experienced CT development in the IT classroom, it became clear that several SDL aspects (Long, 2000; Wood, 1975; see Table 4.1) were also visible. The following codes and categories pertaining to SDL were identified.

- **The Information Technology class increases the sense of self**

One of the advantages noted by several of the IT learners in this control group was the fact that they were able to help others if they had to and that they themselves were able to complete any task if needed, illustrating how their **confidence** had grown in the class. Another aspect that illustrated that the IT learners' sense of self had increased was the notion that the IT classroom encouraged thinking out of the box and being **open-minded**: "The IT class has taught me to think outside the box" (Learner from school 23). One learner noted that the IT classroom increased his/her sense of **responsibility**.

- **The Information Technology class creates a platform for cognition/metacognition**

A large number of learners stated that the IT class had taught them the importance of **planning** in order to complete a task or solve a problem successfully: "Without IT I used to just do things without first thinking about that" (Learner from school 14). Apart from the planning that precedes problem solving in the IT class, a number of learners indicated that the IT class emphasised the importance of **evaluation** both before and after completion of a task: "I recheck the problem and evaluate the problem" (Learner from school 10) and "I begin by evaluating my options first and then taking action" (Learner from school 20).

- **The Information Technology class addresses use of resources**

Only one learner indicated that he/she now had the ability to **use resources** to succeed in the class: "I know how to communicate via internet with other people" (Learner from school 18).

- **The Information Technology class stimulates learning flexibility**

Being able to either work on your own or with others can be described as learning flexibility. A few learners from the control group stated that they felt confident enough in the IT class to work by themselves and be **independent learners** whereas a smaller number of learners noted that they could **learn with the help of others**: “If I must help other people I can” (Learner from school 5).

The possibility of SDL development was visible in the IT classroom as illustrated in learners’ narratives. The following section focuses on describing the experiences noted by learners and teachers in the CTI group as pertaining to CT and SDL.

6.2.2.2. Critical thinking instruction group

As described in the previous chapter, the teacher of this experimental group was asked to implement deliberate CTI in the IT classroom. As with the control group, learners in this experimental group were asked to comment on whether they felt that the IT class had developed them as critical thinkers and also how they experienced CTI. IT teachers from this group were asked in their interview (after implementation of CTI) how they experienced CTI in their classes. Several codes emerged from IT learners’ narratives and the teachers’ interviews which were grouped into categories. The different categories were grouped into different broad themes about CT and SDL and these are discussed in Table 6.19.

In Table 6.19, all the codes, categories and themes that emerged from both IT learners as well as IT teachers are summarised.

Table 6.19 Codes, categories and themes identified in the critical thinking instruction group

IT learners' codes	IT teachers' codes	Categories	Themes
Problem solving	Problem solving	CTI-IT class focuses on problem solving	CT aspects
Metacognition		CTI-IT class encourages cognition/metacognition	
Time management	Logic		
Analysis	Analysis		
Decision-making			
Evaluation			
Planning	Planning		
Reasoning	Reasoning		
Thinking			
Understanding			
Questioning	Questioning	CTI-IT class encourages positive dispositions	
Creativity			
Interested			
Argumentation		CTI-IT class illustrates the use of different perspectives	
Use of different perspectives	Using different perspectives		
Confident	Confident	CTI-IT increases sense of self	SDL aspects
Interested			
Open-minded			
Metacognition	Academic achievement	CTI-IT class creates a platform for cognition/metacognition	
Planning	Planning		
Time management			
Communication	Communication	CTI-IT class addresses use of resources and development of life skills	
Active learning	Active learning		
Life skills	Life skills		
Persistence	Persistence		
	Use of resources		
	Using real-life examples		
Independent learning		CTI-IT class stimulates learning flexibility	
Learning with the help of others			

6.2.2.2.1. Critical thinking aspects identified in the critical thinking instruction group

Several CT aspects (Facione, 1990; Glaser, 1941; Russell, 1943) were identified from learners' and teachers' narratives and interviews (see Table 2.4).

- **The Information Technology class focuses on problem solving**

Several learners in this experimental group stated that the IT class emphasised **problem solving:** "This class has taught me that there is always a solution to a problem" (Learner from school 1) and "It has helped develop [me] because I weigh up the disadvantages and advantages of a solution more than I used to and [it] also helps me make decisions regarding how to solve the problem" (Learner from school 21). Just as IT learners in this experimental group noted that problem solving was evident, so too did the IT teachers in this experimental group. The majority of teachers in this experimental group agreed that problem solving was important and noted that deliberate CTI assisted in the problem solving process. One of the teachers mentioned that she used the Socratic question(s) (on Socratic Method key-ring (Addendum B)) as steps in problem solving and asked learners to tell her at which step they got stuck if the program did not work out as planned.

- **The Information Technology class encourages cognition and metacognition**

Learners in this experimental group gave several indications that focus was placed on cognition and metacognition in the class (although not explicitly stated in those terms).

Cognitive skills like **analysis**, **decision-making, reasoning, thinking and understanding** were all identified and coded from learners' narratives. Supporting quotes like: "We were taught that before we start programming we must plan first, analyse the question critically and interpret the question in my own words" (Learner from school 3), "Before every decision I make I think of the best possible solution and think of all the advantages and disadvantages" (Learner from school 21) and "I gave myself an opportunity to understand and learn more" (Learner from school11) are all evidence of the fact that learners' cognitive skills were implemented in these specific IT classrooms. Apart from the learners' narratives being indicative of cognitive skills being implemented, IT teachers' interviews also revealed trends in cognition although less prominent than in the case of the learners. Some IT teachers stated that their learners were required to explain each line of coding in order to strengthen their **reasoning**. One teacher stated that he/she would "just share a problem with them [IT learners] to just analyse the question, write, think [and] plan possible solutions" (Teacher 3) emphasising **analysis.**

Regarding metacognition, a number of learners made statements suggesting that **metacognition** was addressed in this experimental group's IT classrooms: "We questioned the question [asked questions about the question] and once we got answers, answering the question was easy and fun" (Learner from school 3) and "To ask yourself why you are doing it" (Learner from school 12). **Time management**, although only mentioned by a few learners, also plays a part in metacognition. Furthermore, **planning** and **evaluation** are both metacognitive skills that were noted by a number of learners. Not only did learners mention aspects that pertain to metacognition; half of the teachers in this experimental group also stated that planning had become of greater importance in their IT classes, "… now I am forcing them to say before we do, let's plan and think and let's discuss it as a class or with your partner … I think on that part I have improved" (Teacher 3).

Although much more can be said of cognition and metacognition (see Table 2.4), learners seemed to experience these aspects more in the classroom than what their teachers thought they did as noted from the responses given by learners as compared to responses given by teachers. The most important conclusion from this, however, is that cognition and metacognition implementation were more visible in the CTI group than in the control group.

- **The Information Technology class encourages positive dispositions**

Positive dispositions that promote CT (see Table 2.4) were identified from learners' narratives and teachers' interviews. The majority of learners in this experimental group (CTI) stated that they were **questioning** everything in the classroom and even outside the classroom as the IT class had taught them to question everything. Some learners also made statements that led to the belief that **creativity** was stimulated in the classroom. Lastly, some learners noted that the classroom awakened an interest in computers for them which they never realised they had. Similarly, teachers also specifically commented on how the learners were asking more questions in their classes since the implementation of the deliberate CTI and that the level of questioning had risen as learners were no longer asking mundane questions. This mentioning of questioning and creativity was not evident from narratives of the control group.

- **The Information Technology class illustrates the use of different perspectives**

From the responses of both IT learners and IT teachers it became evident that the IT classes in this experimental group placed additional emphasis on the fact that a problem can be solved by **using different perspectives**: "It has helped me realise that there are many ways to solve a problem" (Learner from school 3), "Everybody in class has its own way of solving problems and my personal way is to know all my codes and understand them, and I am confronted with a problem, I apply my knowledge, and try, until I succeed" (Learner from school 12) and "I think that speaking in tongues [is my favourite], because if I understand it correctly it is when a learner gives you an answer and you give him two alternative answers so he can choose" (Teacher 5).

From the five CT aspects identified in this experimental group from response from both IT learners and IT teachers, it is clear that CT development did occur. More learners and teachers commented on these aspects than what was found in the control group. In this section, focus was placed on IT learners' and teachers' general CT development experience of the IT class. The following section is focused on discussing the SDL aspects identified in the CTI group.

6.2.2.2.2. Self-Directed Learning aspects identified in the critical thinking instruction group

IT learners' narratives and IT teachers' interviews highlighted several SDL aspects (Long, 2000; Wood, 1975) (see Table 4.1).

- **IT increases sense of self**

Self-directed learners have **confidence** and know what they are **interested** in. Several learners in the CTI group stated that this IT class broadened their minds and made them think outside the box and to be more **open-minded**. This notion was not noted by any IT teachers in this group; however, the majority of IT teachers stated that they experienced a greater sense of confidence in their IT learners: “And they don’t feel so daunted anymore. Say there’s a difficult scenario, the CT has really helped because with any program you can break it down into smaller sections as long as you ask yourself those questions on the key-ring” (Teacher 12). Being more confident, interested and open-minded gives IT learners the opportunity to know themselves better and to improve their sense of self.

- **IT class creates a platform for cognition and metacognition**

As stated in 6.2.2.2.1, the IT classroom encourages and creates a platform for cognition and metacognition, two aspects that are simultaneously important in SDL and CT: “We questioned the question (asked questions about the question) and once we got answers, answering the question was easy and fun” (Learner from school 3).

- **IT class addresses use of resources and development of life skills**

A small number of learners stated that in this IT class, they always had to be on their toes as they could be asked a question at any time and they were constantly actively involved in the class (**active learning)**. Active learning in the classroom was emphasised by the majority of IT teachers in this experimental group: “Maybe with the bit I’ve done it’s still early days but if I carry on, which I’m going to be doing because it does make the class more interactive instead of just being one-sided. And often to try and get the class interactive is like trying to swim through syrup, it’s really difficult. Whereas this way I can pose a question and say what do you think about it, instead of me just giving a solution” (Teacher 21). Another aspect stated by both teachers and learners is the fact that they (teachers and learners) can apply things they learnt in this IT class in several other areas of their schooling and lives, hence making this IT class a tool for acquiring **life skills**: “I really am learning about life in the IT class” (Learner from school 11). A small number of learners and teachers also commented on the fact that the IT class had improved the learners’ **communication and persistence** – both skills that are important in SDL success (see section 4.3). IT teachers encouraged the **use of resources** appropriately: “I showed them the DVD and discussed it. Then I gave them the key-rings and told them to keep it with them and every time they struggle they should ask themselves the questions” (Teacher 2). Furthermore, a number of teachers noted that they **made use of real-life examples,** which in turn improved their learners’ ability to bring what they learn in the IT class into reality.

For SDL to occur it is important to have learners actively involved in the learning process (Fisher & Sugimoto, 2006). The following section focuses on IT learners learning flexibility as a SDL aspect.

- **IT class stimulates learning flexibility**

To increase in SDL, it is advisable to have learning flexibility encompassing working alone or working with a number of people (Long, 2000). In this IT class, several learners stated that they had the opportunity to learn how to work on their own (**independent learning)**. Not all learners felt that independent learning was the only evident learning method; some learners noted that they had the opportunity to **learn with the help of others**. SDL requires learners to learn with or without the help of others. By giving learners the opportunity to practice both independent learning and learning with others, they get to practice learning flexibility. No IT teachers did however make mention of any of these elements.

From the discussion, it was evident that aspects that promote SDL were visible in these IT classrooms. When compared to the control group, some aspects were identified in the control group regarding SDL, as in this experimental group. However, the number of comments with regard to SDL were greater in this experimental group than in the control group, indicating that the deliberate CTI may have had an influence on learners' SDL.

6.2.2.3. Critical thinking infused into pair programming group

As described in Chapter 5 (see section 5.3.2), IT teachers in the CTI+PP group were asked to implement deliberate CTI infused into PP (as a CL teaching-learning strategy).

Table 6.20 summarises the above discussion on the codes, categories and themes that have emerged from the IT teachers' interviews as well as the IT learners' narratives.

Table 6.20 Codes, categories and themes identified from critical thinking infused into pair programming group

IT learners' codes	IT teachers' codes	Categories	Themes
Problem solving	Problem solving	CTI+PP-IT class focuses on problem solving	CT aspects
	Real-life example		
Analysis	Analysis	CTI+PP-IT class encourages cognition/metacognition	
Decision-making			
Evaluation	Evaluation		
Logic			
Planning	Planning		
Reasoning			
Thinking	Thinking		
Understanding			
Creativity	Focus	CTI+PP-IT encourages positive dispositions	
Inquisitiveness			
Interested	Interested		
Questioning	Questioning		
Argumentation		CTI+PP-IT class illustrates the use of different perspectives	
Using different perspectives	Use of different perspectives		
Confident	Focus	CTI+PP-IT increases sense of self	SDL aspects
Interested			
Open-minded			
Responsible	Responsibility		
Academic achievement	Academic achievement	CTI+PP-IT class creates platform for cognition/metacognition	
Evaluation	Evaluation		
	Planning		
Active learning	Active learning	CTI+PP-IT class addresses use of resources and development of life skills	
Communication	Work ethic		
Life skills	Life skills		
Persistence	Real-life examples		
Use of resources	Use of resources		
Independent learning	Independent learning	CTI+PP-IT class stimulates learning flexibility	
Learning with the help of others	Learning with the help of others		

6.2.2.3.1. Critical thinking aspects identified from critical thinking infused into pair programming group

As with the control group and the CTI group, codes illustrating CT aspects (Facione, 1990; Glaser, 1941; Russell, 1943) were also identified from IT learners' narratives and teachers' interviews in experimental group two (CTI +PP) (see Table 2.4).

- **IT class focuses on problem solving**

Approximately half of the learners in this experimental group noted that the IT class significantly helped them to develop their **problem solving skills** as the class was structured to solve problems constantly: “It developed me as I am looking at problems differently before solving them and gathering information before solving as well” (Learner from school 15) and “When faced with a new problem, I take time to weigh the pros and cons as well as try to form a structured solution for the problem, these are all thinking processes I have learnt from IT” (Learner from school 17). One IT teacher made mention of the focus on problem solving in her classes and stated that she encouraged learners to ask questions constantly and to ensure that they find the best possible solution to the given problem, while another IT teacher noted that he gave learners **real-life examples** to encourage problem solving.

- **IT class encourages cognition/metacognition**

Cognitive abilities that were noted from this experimental group were **decision-making, analysis, logic, reasoning, thinking and understanding** (see Chapter 2 section 2.2).

These codes were identified from quotes such as:

- “It has helped me a lot because now I know how to make a decision regarding what action should be taken to solve the problem” (Learner from school 6);
- “It [the IT class] helped me work easier and understand things faster” (Learner from school 17);
- “Then from there they were interested and they sat in pairs and from there they analysed the CT strategy and after that it was easy for them to get through the problem” (Teacher 4); and
- “[I tell learners that] I will teach them to think, not only to solve problems but actually to look at it from different angles” (Teacher 17).

Not only did cognitive abilities emerge from this experimental group, but also metacognitive abilities such as **planning** and **evaluation**. One of the IT teachers in this experimental group stated that he emphasised the importance of **planning** throughout the classes. Although the other IT teachers did not specifically make mention of it, a small number of IT learners mentioned that they realised the importance of planning before attempting to solve a problem. One learner and one teacher made mention of the fact that this IT class encouraged the learners to evaluate their work.

- **IT class encourages positive dispositions**

As noted in the other experimental groups certain dispositions were more beneficial for CT development than others (see Table 2.4) and therefore it is encouraging to note that both IT learners and teachers experienced positive dispositions in this class.

Dispositions identified were:

- **creativity**: “It helps me to be creative and informed so that I can be a great thinker to think very fast” (Learner from school 4);
- **inquisitiveness**: “I am a person who likes to know answers for the questions” (Learner from school 15);
- **interest**: “So it was really just an all-round positive response with ma’am this [PP] before I even asked what is the opinion, it was ma’am can we do this again, I’m actually learning something” (Teacher 15); and
- **questioning** (the disposition mostly quoted): both the majority of IT learners and teachers emphatically stated that this IT class encouraged their questioning abilities and made them (the learners) question aspects outside the classroom too.

- **IT class illustrates the use of different perspectives**

Some IT learners in this group noted that they could engage in **argumentation** and **use different perspectives**. The majority of IT teachers in this group stated that learners had the opportunity to **use and experience different perspectives:** “I will teach them to think, not only to solve problems but actually to look at it from different angles” (Teacher 17)**.**

6.2.2.3.2. Self-Directed Learning aspects identified from CT infused into PP group

Several codes pertaining to SDL aspects (Long, 2000; Wood, 1975) were identified in this experimental group (see Table 4.1).

- **IT increases sense of self**

As noted in previous groups, learners and teachers experimental group two illustrated notions that relate to the increase of learners’ sense of self. A small number of IT learners and one IT teacher noted that this IT class increased the learners’ sense of **responsibility**: “the people who get distracted a lot, they were almost held accountable” (Teacher 15). One IT learner stated that this IT class made her more **open-minded** as teachers encouraged her to think outside the box. Other codes that were identified were: **interest** (as learners illustrated that the class addressed their interests) and **focus** (one teacher noted that she felt that because they were actively involved, learners showed greater focus in the class). From the limited number of responses, it was evident that the IT class in this experimental group did not increase learners’ sense of self as much as in the other groups.

- **IT class creates platform for cognition/metacognition**

Cognitive abilities as well as metacognitive abilities are important in SDL. For one IT learner in this experimental group, the IT class increased her **academic achievement**. The majority of teachers in this experimental group noted that learners' academic achievement had increased. Furthermore, only one teacher noted that the learners practiced their **planning skills**. Learners also commented on the fact that they (the learners) were required to **evaluate** their solutions: "It has taught me to evaluate and answer questions easier" (Learner from school 16).

- **IT class addresses use of resources and development of life skills**

The majority of IT learners and teachers in this experimental group noted that **active learning** occurred in class. The PP assisted learners in acquiring **communication skills**, which assisted in sharing the knowledge acquired. Furthermore, both teachers and learners commented on the fact that they could implement the **use of resources** (bookmark and key-rings for example) in this IT class: "the kids like to have something in their hands, it's colourful, it's bright, it looks good, so they kind of place more importance on the lesson as well because they're getting something concrete in their hands" (Teacher 15).

- **IT class stimulates learning flexibility**

A large number of learners stated that they could work **independently** although PP was implemented in the classroom. A large number of learners noted that they experienced that two heads are better than one and that **learning with the help of others** held great advantages: "We use each other's strengths to ensure that a solution is found for any sort of problem" (Learner from school 8). Teachers in this experimental group also noted that learners showed the ability to work individually and/or within pairs: "So at the end of the day both walk out having learned something rather than just achieving a goal" (Teacher 13) creating the foundation for learning flexibility, which in turn increases the application of SDL.

6.2.2.4. Pair programming group

Experimental group three were asked to implement PP without any deliberate instruction regarding CT. Table 6.21 summarises the codes, categories and themes identified from IT learners' narratives and IT teachers' interviews in this experimental group.

Table 6.21 Codes, categories and themes identified from pair programming group

IT learners' codes	IT teachers' codes	Categories	Themes
Problem solving	Problem solving	PP-IT focuses on problem solving	CT aspects
Analysis		PP-IT class encourages cognition/metacognition	
Decision-making			
Evaluation			
Logic			
Planning			
Reasoning	Reasoning		
Thinking	Thinking		
Creativity		PP-IT class encourages positive dispositions	
Inquisitiveness			
Questioning	Questioning		
Use of different perspectives	Use of different perspectives	PP-IT class encourages the use of different perspectives	
Confidence	Confidence	PP-IT increases sense of self	SDL aspects
Introspection	Responsibility		
Open-mindedness			
Academic achievement	Academic achievement	PP-IT class creates platform for cognition/metacognition	
Understanding			
Life skills		PP-IT addresses use of resources and development of life skills	
	Active learning		
	Use of resources		
Share knowledge	Share knowledge	PP-IT class stimulates learning flexibility	
Independent learning	Independent learning		
Learning with the help of others	Learning with the help of others		

6.2.2.4.1. Critical thinking aspects in pair programming group

Learners and teachers in experimental group three mentioned several CT aspects (Facione, 1990; Glaser, 1941; Russell, 1943) (see Table 2.4). Codes pertaining to these aspects were identified and categorised.

- **IT focuses on problem solving**

A large number of IT learners in this experimental group commented on the fact that the IT class had improved their **problem solving** skills: "we are always finding solutions for problems that don't even exist yet" (Learner from school 13). Furthermore, one learner clearly stated that she saw PP as a tool for developing problem solving skills: "I enjoy PP as it is a combination of my brain that work together to solve a problem. It helps to learn and understand the work better" (Learner from school 16). Half of the teachers in this experimental group noted that problem solving had been addressed while the learners were doing PP and that the learners solved some problems much easier when working in pairs: “They seemed to solve the problem with the If-statement quite easily” (Teacher 13).

- **IT encourages cognition/metacognition**

Several cognitive and metacognitive abilities were identified from IT learners’ narratives and teachers’ interviews. IT learners did however illustrate more of these abilities than their teachers. Cognitive abilities like **decision-making, logic, reasoning** and **thinking** were all identified from the responses of the majority of IT learners in this experimental group, whereas only **thinking** and **reasoning** were identified from teachers’ interviews. IT teachers did not illustrate any use of metacognitive abilities from their IT learners, whereas the IT learners mentioned that **planning** was important, that they were taught to **evaluate** their solutions and **analyse** the problems constantly (all of which are seen as metacognitive abilities):

- “To plan ahead and avoid any setback I might have encountered due to poor planning” (Learner from school 25); and
- “When making programs, you have to think more about what the outcome will be and what will change depending on what you do; you then have to think more critically” (Learner from school 13).

- **IT encourages positive dispositions**

Positive dispositions to promote CT (see Table 2.4) were also identified from both IT learners and teachers in this experimental group. The disposition that was most evident was that of **questioning**. One IT teacher and a large number of IT learners emphasised how this IT class had encouraged them to practice questioning, not only in the IT class, but also in everyday situations: “I’m able to ask questions if I don’t understand the teacher” (Learner from school 9) and “The channel was open for all of them to ask any question and give answers, so I think they’re feeling that they are so free to say anything” (Teacher 9). A number of IT learners also commented on the fact that they felt the class made them more **creative** and that they were more **inquisitive**: “It teaches me to be good on thinking and creating something and also to think creatively” (Learner from school 9).

- **IT illustrates use of different perspectives**

By implementing PP and allowing learners to experience other learners’ opinions, IT learners in this class had the opportunity to **use different perspectives**. The majority of learners and teachers commented on the fact that learners acquired different perspectives:

- “the other group definitely learned some other ways of thinking” (Teacher 13);
- “I learnt to solve a problem in more than one way” (Learner from school 8); and

– "I have learnt not to just think in one way but have tried to develop different ways of thinking to have an idea of how the other people's brains works" (Learner from school 13).

CT aspects were evident in this experimental group although no deliberate CTI was implemented.

6.2.2.4.2. Self-Directed Learning aspects in pair programming group

In this section, the codes relating to SDL aspects (Long, 2000; Wood, 1975) (see Table 4.1) identified in experimental group three's narratives and interviews are discussed.

- **IT increases sense of self**

In experimental group three, a large number of IT learners commented on how their **confidence** had increased: "it also helped me to improve my self-esteem when I am communicating with other" (Learner from school 9). Learners also illustrated that **introspection** and becoming more **open-minded** were evident in the IT classes. The majority of IT teachers also noted that learners' confidence had increased. Furthermore, one IT teacher also noted that the learners in her class had learnt to take more **responsibility** for their work as they were held accountable to another learner.

- **IT creates platform for cognition/metacognition**

Cognitive and metacognitive abilities were evident from the responses of IT teachers and learners in this experimental group. A shared cognitive aspect was **academic achievement,** where both IT teachers and learners noted that learners more easily grasped concepts and therefore had a greater likelihood to achieve academically: "I could see when they were doing the tests, the ones that used to be clueless in the first and second term knew more now" (Teacher 16). IT learners also commented on the fact that their **understanding** of the subject had increased greatly.

- **IT addresses use of resources and development of life skills**

Teachers noted that learners were more actively involved **(active learning)** in the learning process which gave them (the learners) an opportunity to apply the knowledge they had acquired: "I saw the learners that were quiet in the classroom are more active now" (Teacher 9).

- **IT class stimulates learning flexibility**

As mentioned in the previous discussion on experimental group two, SDL requires learning flexibility as it is not always possible to **learn with the help of others**. Although the majority of teachers in this experimental group stated that learners had the opportunity to learn to work together and gain knowledge and experience from their peers, it was also evident that learners still acquired the skills to work independently **(independent learning)**.

In experimental group three, CL was implemented in the form of PP and, although no specific or deliberate action was implemented to develop CT or SDL, these two aspects were still evident as with the two experimental groups that received deliberate CTI.

6.3 DISCUSSIONS OF RESULTS

In this study, interesting findings were discovered not only through the quantitative investigation of IT learners, but also through the qualitative investigation of both learners and teachers involved in the study. Figure 6.5 illustrates the increase or decrease observed between the pre-test and post-test for each group for CT and SDL. The blue-shaded bars represent the CT increase/decrease (from pre-test to post-test) and the purple-shaded bars represent the SDL increase/decrease (from pre-test to post-test). The darker shading (both for blue and purple) represents all learners in the study whereas the lighter shading (both for blue and purple) represents the learners who completed the two questionnaires in 45 minutes or more.

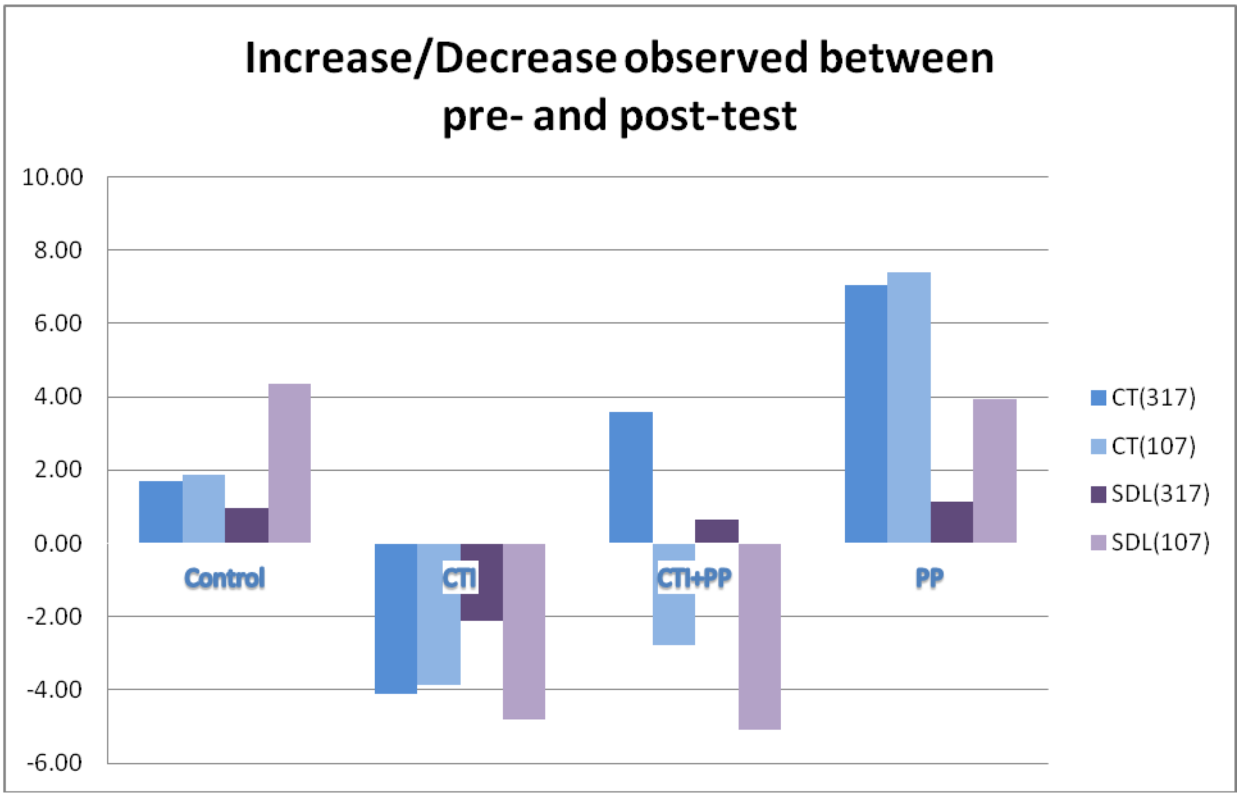


Figure 6.5 Increase/Decrease observed between pre-test and post-test (Unfiltered participants vs. time-filtered participants).

From Figure 6.5 it becomes clear that the PP group had the largest increase in CT (in both the unfiltered and filtered states). Learners need to have a CT modelling agent (as in PP), have the opportunity to engage in deep discussion (as in PP) and engage in structured activity (as in PP) – all possibilities as to why the PP group may have outweighed the other groups. This section, however, intends to elicit why results were evident as is. This discussion focuses on CT and SDL results followed by a synthesis of these two components to lead to the concluding remarks regarding the influence of CL and intentional instruction in CT on CT as well as the implications thereof on SDL.

6.3.1. Critical thinking

When referring to the control group, a slight increase was observed in the control group – this serves as an indication of the natural growth of the Grade 10 IT learners in this study. Fagin *et al.* (2006) note that exposure to computer science will naturally promote CT and may explain the slight increase in these learners' CT scores although no intervention was implemented. Surprisingly, one would think that, as Halpern and Marin (2011) state, learners who were exposed to deliberate CTI would benefit greatly and show an increase in CT; however, this was not the case in the present study at least when observing only the quantitative data. The CTI group received only deliberate CTI and yet had the largest decrease in CTS. In the CTI+PP group, an increase was observed when referring to the non-filtered participants; however, when omitting learners who had completed the two questionnaires in less than 45 minutes (filtered participants), a decrease was observed in CT scores. Regardless of time, the PP group had the largest increase in CT of the four groups, although not receiving any deliberate CTI (as suggested by Halpern and Marin, 2011).

Based on these results, one has to ask the question what happened that made the CTI group decrease (although receiving deliberate CTI) and the PP group increase (although not receiving any deliberate CTI). An investigation into the successes and failures observed in the CTI group may provide the answer.

In the CTI group, it was interesting that learners insinuated that many CT aspects were visible in the class; however, teachers in this group made much less mention of the CT aspects than the learners. As agents of change (Brookfield, 2012), teachers would need to note more CT aspects than learners if the learners had implemented CT as asked. From statements such as –

> "You will never get it practically implemented by me … I just went on teaching the way I always taught" [Teacher 1] and
>
> "So I just implemented it, but not like one period I'm just focussing on one thing, I was just infusing them [into my lessons]" [Teacher 3]

it is not surprising that learners did not improve in CT as not all teachers may have implemented the deliberate CTI intervention as was expected. It must be reiterated here that teachers received a manual with examples and were asked to implement the strategies deliberately in their classes. Teachers were asked to model CT (as emphasised by Van Gelder (2001) and Snyder & Snyder (2008) (see 2.5.2.1.); however, it seemed that not all teachers in this group modelled CT as needed (inferred from teachers' reluctance during their interviews). The CTI group only implemented the Socratic Method and Brookfield's strategies for modelling CT. Both learners and teachers emphasised that the IT class had developed their disposition of questioning. This is a positive aspect that should prove conducive to the development of CT; however, considering the quantitative results of the CTI group, it seems realistic to say that questioning (as well as questioning development) alone is not enough to develop CT. From the narratives and interviews, it was evident that the IT class focused on problem solving, questioning, reasoning and logic; however, on further investigation it was clear that these skills only formed part of the lowest level of Dick's (1991) taxonomy for CT. This may be the reason why learners' CT had decreased as all teachers might not implement the strategies as asked and therefore perhaps never gave learners the opportunity to move beyond the levels of the lower levels of Dick's taxonomy.

In the CTI+PP group, there was an increase in the unfiltered participants' assessment; however, learners who had completed the questionnaires in 45 minutes or more showed a decrease in CT. The decrease observed in the filtered participants was close to the same as in the case of the filtered participants of the CTI group; however, a slightly smaller decrease was observed implying that the infusion of PP could have played an important role. With this in mind, there could be some possibilities as to why these learners experienced a decrease in CT. One possibility is that implementing two strategies could have led to information overload. Another possibility is that teachers might have focused more on one strategy than on infusion of both CTI+PP as a unit. This incorrect implementation of the CTI infused into PP teaching–learning strategy was noted by comments such as "I have been able to use some, not all of them, but some of them" [Teacher 17] and "The major one that we looked at was PP" [Teacher 15]. Perhaps not all teachers therefore implemented the strategy correctly as asked and explained in their manual (and during the professional development session). Considering that the CTI group decreased so much in CT with the implementation of the deliberate CTI, the CTI could have had a similar effect on the CTI+PP group; however, it might have been influenced by the PP implementation. Furthermore, teachers were asked to show learners DVDs regarding CT and PP; yet, some teachers did not do this and started implementing the strategies immediately with no discussion in terms of the theory of CT (as noted in 2.5.2.2.). Another possibility that occurred in CTI and CTI+PP groups was that the CT development was all based on lower levels of Dick's taxonomy (narratives and interviews never speak of the higher levels – see Table 6.19

and Table 6.20) possibly because the strategies were not implemented correctly. Two major concerns were raised in this group (CTI+PP) as well as in the CTI group: did teachers model CT (as emphasised by Brookfield (2012)) and did teachers implement the strategies correctly as asked? These two concerns could hold the key as to why the CT of both the CTI group and the CTI+PP group did not improve. However, from the empirical evidence it seems likely that the inclusion of PP might have played a role in increasing the likelihood of CT development (considering the fact that the CTI+PP group had a smaller decrease). Teachers and learners all agreed that CT had occurred in the IT class; however, teachers were less convincing than learners, which should serve as an indication that teachers were not confident in their implementation of the CT infused into PP intervention. Considering how much the CTI group decreased and how much the PP group increased, it may be interesting to establish whether the implementation of PP had an influence in lessening the decrease that may have been visible had it not been implemented (albeit only in some schools), emphasising the importance of having a PP group alone to determine the effect of PP on CT.

The PP group had the greatest increase in CT in both unfiltered state and filtered state (omitting learners who had completed the questionnaires in less than 45 minutes). Ten Dam and Volman (2004) found that CL could effectively promote CT, which from the results of this current study, is the case. Furthermore, the need for PP to occur within a CL setting is emphasised as stated by Mentz *et al.* (2008) as it becomes evident that with the use of CL comes great advantages. One possibility for CT being promoted by CL is the fact that learners have the opportunity to focus on questioning, engage in classroom discussion, have debates and (if planning is implemented correctly) participate in written assignments. These four elements all contribute to CT development, according to Walker (2003). Another possibility for the great success of the PP group is the fact that PP has been implemented nationally by several subject coordinators for IT. This implied that some teachers were already familiar with PP and may have felt more comfortable to implement it in their classes. Interestingly though, when referring to teachers' interviews and learners' narratives, fewer CT aspects are noted; however, learners and teachers did not know about the CT aspect of the research and therefore would probably had made less mention of CT than learners and teachers who were deliberately busy with CT strategies. It is surprising that the PP group outweighed the other three groups although not receiving deliberate CTI. Spencer and Gillies (2008) state that learners' CT develop due to the opportunity learners have to model CT themselves, learn from other's ideas and give and receive immediate feedback. These are all important aspects of CT development which support the finding that the PP group had achieved CT development. The fact that learners possibly had a CT model, could learn from others and received immediate feedback may also shed some light as to why the CTI+PP group outweighed the CTI group as the learners in the CTI+PP group at least also would have had some opportunity of experiencing the advantages of PP for CT development.

From the discussion above it becomes evident that CTI does not necessarily have to occur deliberately, as done with this Socratic Method including Brookfield's strategies for modelling CT. It is also clear that learners need to have a CT modelling agent (as in PP, for instance), have the opportunity to engage in deep discussion (as in PP), and they should engage in structured activity (as in PP). Nevertheless, the qualitative data indicated that the intentional CTI also had a positive effect on learners' CT development.

This study aimed at determining how CT development in the Grade 10 IT class could occur and what effect this development has on SDL. With the results of the CT development discussed, the following section is focused on discussing the results observed regarding SDL.

6.3.2. Self-Directed Learning

In Figure 6.5, the total increase/decrease observed between the pre-test and the post-test for the four groups in the study are displayed. From the results (as illustrated in this figure), it is clear that a distinct relationship was observed between the CT development and SDL development. In this section, the findings of the SDL as observed in the different groups are discussed.

The control group had the largest increase for the filtered participants indicating that the natural change of the participants in this study was an increase in SDL. IT as a subject focuses on problem solving and is a subject where learners often work in isolation and have to take responsibility for their own learning (one of the main focus points of SDL). This practice together with the natural maturity levels of the learners could have led to the increase in SDL. In the CTI group, the SDL decreased dramatically compared to the control group. Several factors could have caused this decrease. Firstly, the fact that the learners were asked to implement set strategies (directed by rigid questions, as is the case with the Socratic Method) implies that learners' freedom to take responsibility for their own learning may have been delimited. Secondly, teachers who did not implement the deliberate CTI (as noted in 6.3.1) as asked may have caused learners to feel uncertain about what had to be done. As with the CTI group, the CTI+PP group had a drastic decrease in SDL (as noted in the filtered participants). The CTI+PP group had the largest decrease in SDL, which could have been caused by several factors. Learners may have experienced the CT strategies (e.g. questions that needed to be asked) as too rigid (as in the CTI group), and when communicating with one another (where PP was implemented) they may have influenced each other negatively.

When learners only work together with no specific focus on the CL elements, they do not have the opportunity to engage in deep learning. CL, when implemented correctly, gives learners the opportunity to learn with each other in order to become more self-directed. From the results in this study, however it became evident that when only PP is implemented (as in the PP group), learners' SDL increases significantly (and especially significantly more than what it would have, had it been placed in conjunction with CT strategies).

Referring to Table 4.1 where the four elements of SDL development are described, it seems possible that some elements were missing in some of the groups in this study (otherwise SDL would have increased theoretically). The elements described include student-controlled, faculty-controlled, administration-controlled and inexplicitly controlled elements – all of which play a part in a learners' SDL development. The element where the intervention of this study was placed was the faculty-controlled element (as it is here where teachers were asked to implement changes). The faculty-controlled element includes classroom climate, curriculum design, professionalism and teaching–learning strategies. It seems possible to say thus that the faculty-controlled element plays the most important role in SDL development and that it is in this element that the CTI and CTI+PP groups failed as evident from the decrease in SDL. When noting, however, that a clear relationship between CTS and SDL is observed, it may be safe to say that the student-controlled element also played an important role as it seems evident that the Grade 10 IT learners' CT had an influence on their SDL.

6.3.3. Synthesis of critical thinking and Self-Directed Learning

In the control group, CT increased slightly and then regarding the SDL results, a greater increase was once again observed in the filtered participants. However, what is important to note here is the fact that when CT scores increased, SDL scores also increased. In the CTI group, a decrease in CT was observed in non-filtered participants as well as in the filtered participants. As with the CT scores, a similar trend was visible in SDL scores. In both non-filtered and filtered participants', SDL decreased. The CTI+PP group's SDL scores decreased in relation to the CT scores. The non-filtered participants had an increase in CT and also an increase in SDL whereas the filtered participants had a decrease in CT and in SDL. The filtered participants, however, seemed to have taken the questionnaires more seriously and therefore yielded more noteworthy (and expected results). Lastly, the same trend was visible in the PP group where there was an increase in CT and SDL in filtered and non-filtered participants.

From the discussion above it is possible to deduce that CT development has a relational effect on SDL while if CT increases, SDL will probably increase, and when CT decreases, SDL will decrease. Furthermore, the results also speak of the effect the interventions had on SDL development. The CTI group and CTI+PP group showed decreases in SDL while the control group and the PP had similar increases in SDL. As has been noted, some teachers possibly did not implement the suggested strategies as asked, and one can deduce that the possible lack of implementation had a negative effect on the learners' SDL as well.

CT and SDL are two important skills in the IT classroom, proving that PP could hold great advantages for both skills was noteworthy.

6.4 CONCLUSION

In this chapter, the results obtained from the empirical investigation were discussed. It became clear that IT learners in this study were generally aged between 15 and 16 years, mostly male and Setswana-speaking. Most schools in the study were situated in urban areas in North-West although the Eastern Cape and the Free State were also included.

Regarding the quantitative investigation, reliability of questionnaires was firstly established. Three constructs in the Cornell Critical Thinking – Level X test proved reliable: *Induction, credibility* and *deduction*. For the SDLI (Cheng), only two constructs proved reliable: *Learning motivation* and *planning and implementing.*

Initially, CT scores were quite low (maximum 37.05 out of a possible score of 74). The CTI group scored the highest in the pre-test; however, in the post-test, the PP group scored the highest. Practically significant differences between the pre-test and post-test were observed mostly in the *induction* and *credibility* constructs, although practically significant differences could also be observed in the *total for CT* from the pre-test to the post-test. It became evident that some learners may have rushed through the answering of questionnaires and therefore it was decided to filter down the results to only learners who took longer than 45 minutes to complete both questionnaires (CT and SDL questionnaires). Large practically significant differences were observed when learners who completed the questionnaires in less than 45 minutes were excluded. The control group's CT increased most; however, in none of the schools did the PP group show decreases regarding CT.

SDL scores were high in the pre-test with the minimum sore being 70.72 out of a possible 100. Groups scored quite similar in the pre-test. In the post-test, scores were similar again; however, the PP group scored highest in the SDL post-test. The CTI group's SDL decreased and they scored the lowest out of all four groups in the post-test although scoring highest in the pre-test. Mostly small to medium practically significant differences were observed between the pre- and post-test of SDL in all the schools. When omitting the learners who took less than 45 minutes to complete the two questionnaires, a number of large practically significant differences were observed.

When comparing the questionnaires' constructs for correlations, it became evident that small statistically significant differences existed between the *induction* (CT construct) and *learning motivation* (SDL construct) constructs as well as between the *credibility* (CT construct) and *planning and implementation* (SDL construct) constructs and the *credibility* (CT construct) and *learning motivation* constructs for the pre-tests. For the post-tests, statistically significant differences were observed between *induction* (CT construct) and *planning and implementing* (SDL construct) and between *deduction* (CT construct) and *planning and implementing* (SDL construct) constructs as well as between the *CT total* and *SDL* total. All correlations found were negative, implying that when CT scores increased, SDL decreased (when focussing on the total sample)

In the qualitative investigation, several CT and SDL aspects emerged in all four groups. Although CT and SDL were visible in all four groups, it was more evident in the CTI+PP group and PP group. With the empirical investigation in mind, it became evident that the PP group illustrated the greatest changes from their pre-test scores to the post-test scores.

With the results that emerged from the investigation discussed and presented, the following chapter will be focused on answering all the research questions, including research questions 4, 5 and 6. The following chapter will also conclude the study.

CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS

7.1. INTRODUCTION

The previous chapters were focused on eliciting answers to accomplish the objectives of the study. This chapter is focused on firstly discussing the conclusions that can be drawn from the body of scholarship consulted as well as the conclusions that can be drawn from the empirical investigation. As the primary research question that guided this research was *How can critical thinking be fostered in the Information Technology class and what is the influence thereof on learners' Self-Directed Learning?* this chapter ultimately is focused on answering this question and on making recommendations (as noted from research question 7) from lessons learnt through answering this question.

7.2. CONCLUSIONS REGARDING BODY OF SCHOLARSHIP

In this section, the conclusions drawn from the investigation of the body of scholarship on CT are provided, as the first three research questions of the study were focused on investigating this topic.

7.2.1. Conclusions with regard to research question 1: What do critical thinking and Self-Directed Learning entail?

In this section, the answers pertaining to what critical thinking (CT) and SDL (SDL) entail (as established from the investigation into the body of scholarship) are discussed. In order to establish what CT skills entail, CT in the broader sense was firstly investigated followed by a narrowing view of CT.

7.2.1.1. What does critical thinking entail?

CT has its origins in the times of the Greek philosophers Socrates, Aristotle and Plato (see 2.2.1). Although it was determined that these philosophers did not coin the term 'critical thinking', their methods of teaching and views on how knowledge should be constructed pointed to what we now see as CT. CT then (although not explicitly called so) was characterised by the ability to think systematically (Socrates), make use of reasoning (Aristotle) and ascertain whether a claim was true or false (Plato) (see 2.2.1). Somewhat related to the Greek philosophers' views, John Dewey also focused his views of learning on CT, firstly calling it ‘reflective thinking’ and then later going on to say that CT and reflective thinking are the same. From John Dewey’s reflective thinking, the term ‘critical thinking’ was born (see 2.2.2).

Reflective thinking was defined as the active consideration of any belief based on the grounds that support the belief and the conclusions to which it leads (see 2.2.2.1). Per definition it was established that a close relationship between reflective thinking and the Greek philosophers existed. Socrates focused on thinking systematically, – Dewey focused on thinking reflectively; Aristotle focused on reasoning – Dewey also focused on reasoning but also on inference from reasoning, and lastly, Plato emphasised establishing whether a claim was true or false – Dewey also saw the establishment of judging whether a conclusion was true or false as the outcome of thinking (see 2.2.2). From this infusion between Dewey and the Greek philosophers, it becomes clear that CT has been around for ages and that the views of these philosophers were relevant to how we see CT. It is important to note, however, that Dewey was only the first to coin the term ‘critical thinking’, but that researchers after him brought a clearer view on what CT entails.

After establishing the origins of CT, the interim research between then and now was discussed (see 2.2.2.2–2.2.3). Researchers like Glaser further placed CT on the foreground in 1941. His views of CT coincide with that of Dewey in that they both view CT steps as follows (see 2.2.2.2):

- awareness of the problem;
- emphasis on process of logic and reasoning to work through the problem;
- investigating grounds for inference; and
- end of process with judgement.

After Glaser, the next prominent researcher noted was Russell. Russell, Dewey and Glaser all highlighted knowledge, questioning, scientific method and drawing conclusions that influence future thinking. Furthermore, these three researchers (Russell, Dewey and Glaser) as well as the Greek philosophers all place CT within a focus of the process of thinking (see 2.2.3) whereas another forerunner, Ennis was especially concerned with CT as the assessment of statements and making judgements on each level of thinking.

Apart from CT being seen as a process of thinking (by some) and an assessment of thinking (by others), Benjamin Bloom and his colleagues placed CT within a taxonomy of cognitive abilities (see 2.2.3.1). Bloom’s taxonomy is used to set learning objectives for intellectual abilities and skills. It is Bloom himself who noted that CT and his taxonomy are synonymous and that teachers need to ask questions that would lead learners to move through each of these levels. Moving from Bloom’s taxonomy, Facione conducted a Delphi study, where the definition of CT was established. Facione’s definition draws heavily on Bloom’s taxonomy in that it infuses the higher levels of the taxonomy (interpretation, analysis, evaluation) and includes aspects from other researchers focused on CT (inference, explanation and self-regulation) (see 2.2.4.1). CT is therefore defined as a "purposeful, self-regulatory judgement that results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological or contextual considerations upon which that judgment is based" (Facione, 1990:2). Facione's definition includes views from Socrates, Plato and Aristotle regarding thinking (emphasis on the systematic approach, makes use of reasoning and determines whether a claim is true/false) and furthermore also includes Dewey's reflective thinking.

CT therefore entails both CTS and CTD as illustrated in Figure 7.1

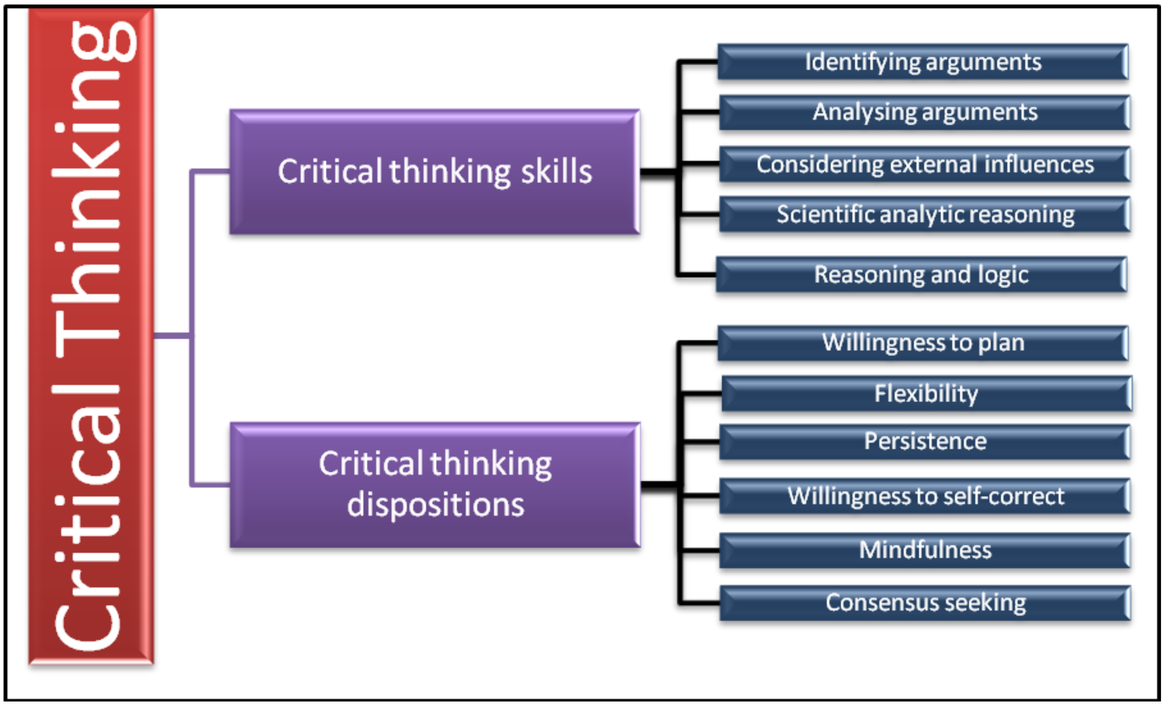


Figure 7.1 Critical thinking composing of critical thinking skills and critical thinking dispositions

From Figure 7.1, it is clear that CTS differ from CTDs; however, as noted from the body of scholarship, both skills and dispositions make up CT. Facione's definition also encompasses both CTS and CTDs, therefore supporting the use of this definition as the definition for CT in this study.

7.2.1.2. What does Self-Directed Learning entail?

In the investigation of scholarship regarding SDL, it became evident that this type of learning has been defined differently by several researchers; however, the definition of what SDL entails, which is accepted by most, is that of Malcolm Knowles, which states that SDL is a process where the learner takes initiative for his/her own learning, sets his/her own learning goals, identifies appropriate resources needed for his/her learning, chooses appropriate learning strategies and evaluates learning outcomes (see 4.3). In accordance to Knowles' definition, it was evident that SDL entails having a learner choose what to learn, how to learn, when to learn and how to evaluate (see 4.3).

From the investigation into the body of scholarship on SDL, it became clear that SDL is focused on putting the responsibility of learning in the learner's hands and setting the learning stage in such a manner that it becomes learner-centred and no longer teacher-centred (as traditionally done) (see 4.3).

SDL is a complex concept entailing various elements, such as influences on learning, learning contexts as well as learning processes. The self-directed learner takes responsibility for his/her learning although being influenced by several external influences (see 4.7). Influences that effect learners' SDL are noted in Table 4.1 and include 'student'-controlled, 'faculty'-controlled, administration-controlled, and inexplicitly controlled elements. These influences imply that the learner in the IT class can only control certain elements in the SDL process whereas other elements ('faculty' [IT teacher], administration [school] and inexplicitly [parents and environment outside the school system] are not controlled by the learner.

CT and SDL are closely related in that both are concerned with being learner-centred, focused on cognitive aspects (such as Bloom's taxonomy) and emphasise metacognition (as seen from both focusing on reflection, for example). The elements that influence learners' SDL can also influence their CT. Both SDL and CT also play a major role in education and are necessary for effective education – the importance of CT and SDL in education and specifically in the IT class are discussed in the next section.

7.2.2. Conclusions with regard to research question 2: What is the importance of critical thinking and Self-Directed Learning in education and specifically the Information Technology classroom?

With the conclusion regarding what CT entails established, this section is focused on discussing the conclusions regarding the importance of CT in education and especially in the IT classroom. To illustrate this importance, Figure 7.2 shows the value of CT in the context of the world, South Africa and then the IT classroom.

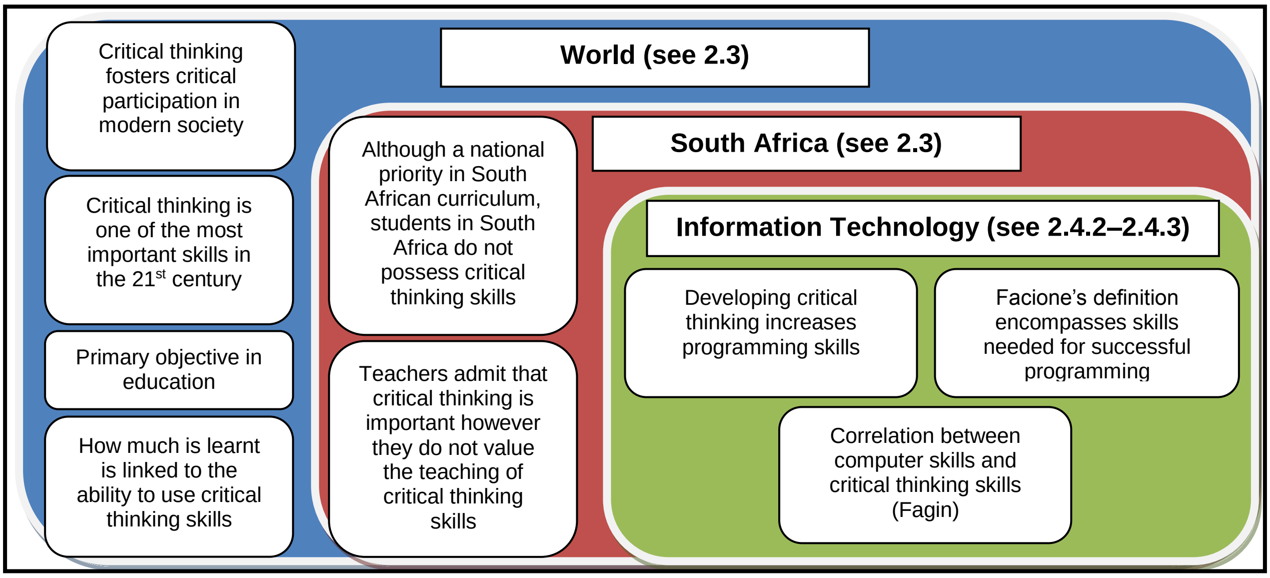


Figure 7.2 Value of critical thinking in the world, South Africa and the Information Technology classroom

From the body of scholarship it became evident that CT has been emphasised in education globally and in South Africa and has an important place in the IT classroom. From around the world, CT research has elicited many advantages regarding CT development. It was established that CT fosters critical participation in modern society. Therefore, if a learner possesses CTS, he/she can make better choices regarding the society within which he/she lives. CT has been prioritised as one of the most important skills in education across the world as it holds so many benefits. Furthermore, CT is also seen as a primary objective in education. It was also determined that several studies prove that how much a learner learns is linked to his/her ability to use CTS (see 2.3).

A number of South African studies were consulted regarding the importance of CT in the country. The national strategic plan (see 2.3) emphasises CT across all scopes of education. Furthermore, the Department of Education also emphasises CT as a core skill in all subjects (see 2.3). From specific studies conducted regarding CT in South Africa, it became evident that although teachers in South Africa value CT as important; they (the teachers) do not value the teaching of CTS. It is no surprise then that students in South Africa lack CTS (although prioritised in South Africa and seen as important). CT is as important in South Africa as in the rest of the world; however, it is not evident from previous studies that CT development occurs in South Africa. One subject where CT is especially important is Information Technology.

The bulk of the IT subject is focused on programming (see 2.4); therefore, the premise is that if programming skills can be increased, success in IT will also increase. For an individual to succeed in programming several elements are required: language skills, a good deal of practice, mathematics (problem solving skills) and planning. These aforementioned elements are all encompassed in CT leading to the notion that CT can contribute to success in programming. It was also established that developing CT increases programming skills (2.4.2). Facione's definition of CT (as accepted in this study) encompasses skills needed for successful programming: cognitive abilities and metacognitive abilities. There is also a correlation between computer skills and CTS as was noted in the body of scholarship. CT also supports two main facets of programming in that it supports problem identification and general computer skills.

Apart from CT promoting programming, it also promotes SDL. With the ever-changing programming languages in schools in South Africa and with access to information expanding rapidly, the fact that CT can increase learners' SDL supports the importance of CT in the IT class (see 1.2.2).

SDL has been noted as an educational goal globally (just as in the case of CT). This educational goal supports the fact that SDL allows for lifelong learning and independent learning. Furthermore, SDL caters for the inherent human nature of inquisitiveness (just as in the case of CT) and helps in keeping up with the ever-changing world within which we live (see 4.2).

With CT illustrated as an important aspect for programming (see 2.4.2), it is reasonable to state that it is important to develop CT in order to increase the likelihood of success in the IT classroom. The following section is focused on the discussion of research question 3, concerned with the development of CT (see 2.4).

7.2.3. Conclusions with regard to research question 3: How can critical thinking skills be developed in the IT classroom?

As CTS are important globally, in South Africa and especially in the IT class, this section is focused on discussing how CT can be developed in order to address this important skill. Figure 7.3 provides a summary of the conclusions drawn regarding the development of CTS (without separating SDL from the IT context) (see 2.5. and Table 4.1).

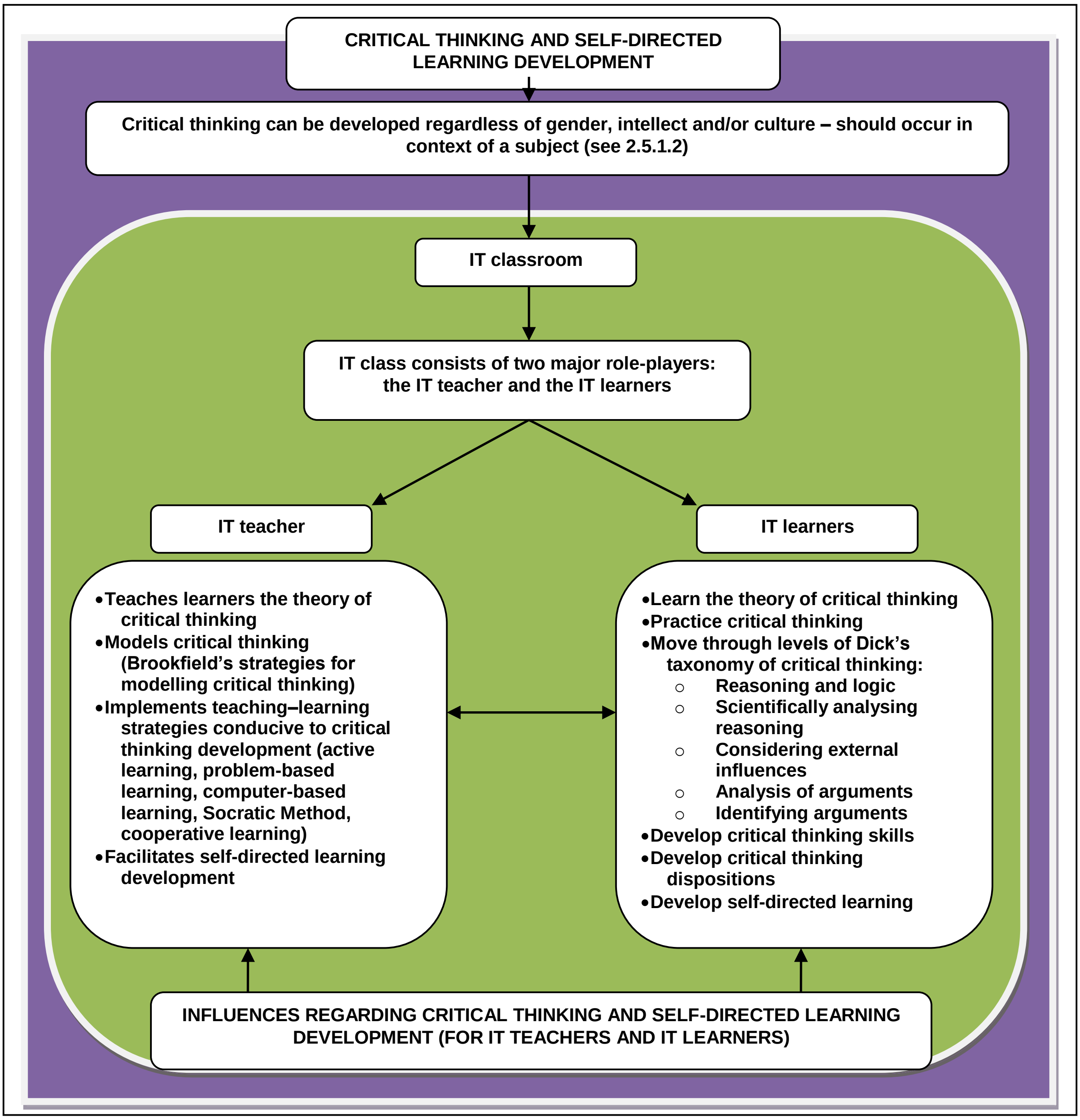


Figure 7.3 Critical thinking development and Self-Directed Learning in the context of the Information Technology classroom

From Figure 7.3, several aspects regarding CT development are evident. Firstly and most importantly, it is evident that CT can indeed be developed; however, the way it is developed needed to be explored more deeply (see 2.5).

CT should be developed deliberately, which implies that it is addressed explicitly, although not necessarily in isolation from subject content. To the contrary, CT should be developed in the context of a subject (see 2.5.1.2). In this study, the subject was IT and specifically Grade 10 IT.

In the IT class, the two major role-players are the IT teacher and the IT learners. It is therefore sufficient to deduce that these two role-players each need to accomplish certain tasks to encourage the CT development process.

7.2.3.1. The role of the Information Technology teacher in the development of critical thinking

From the investigation into the body of scholarship it became evident that the most important aspect in CT development is the role of the facilitator. Several researchers emphasise that CT development will not take place if the facilitator does not model CT him/herself (see 2.5.2.1). Strategies to assist the facilitator in modelling CT were also evident, e.g. Brookfield's (2012) strategies for modelling CT. In the IT class, IT teachers are responsible for modelling CT if they want their learners to develop CTS; however the body of scholarship indicated that facilitators often do not possess CTS themselves and therefore cannot model CT (see 2.5.2.1). It thus became clear that IT teachers need to be assisted in firstly developing their own CTS before they will be able to model CT to their IT learners.

IT teachers play a role in implementing the CT strategies in the classroom; however, during professional development, these teachers should be trained to use strategies that are conducive to CT development. Teaching–learning strategies that were discovered in the body of scholarship were: problem-based learning, computer-based learning, Socratic Method and CL (all pointing to one common goal – active learning in the classroom). Apart from the teaching–learning strategies, other teaching strategies were noted (see Table 2.3) which teachers should adhere to when attempting to develop CT in their classes: teaching learners the theory of CT, giving students authentic and challenging problems, giving students oral and written assignments, promoting questioning in class and not under-emphasising metacognition (see 2.5.3.1).

When IT teachers model CT, have the right attitude toward CT, possess CT themselves and implement active teaching–learning strategies learners will most probably develop good CT skills (see 2.5).

7.2.3.2. The role of the Information Technology learner in the development of critical thinking and Self-Directed Learning

The role of the IT learner is first and foremost to participate in the CT development process. Participating means being actively involved in the learning process (if appropriately done by the teacher). Learners are also required to adopt the correct attitudes toward CT in order to open themselves up to the change of thought from narrow-mindedness to open-minded CT. The attitudes described are called CTDs – therefore it can be said that IT learners play a role in changing their CTD so as to allow CTS to be developed. Apart from the CTD, IT learners also have a responsibility to focus their attention on developing their CTS.

As described in Table 4.1, learners control certain elements when it comes to SDL development. These elements are: proactivity, metacognition, academic achievement, self-regulated learning, and motivation. Although these elements describe learner-controlled elements for SDL development, they also play a role in CT development as learners also control these elements in their CT development process – also emphasising why CT and SDL cannot be separated.

7.3. CONCLUSIONS REGARDING EMPIRICAL INVESTIGATION

In order to answer research questions 4, 5 and 6, an empirical investigation was conducted. This section discusses the conclusions drawn regarding these three research questions.

7.3.1. Conclusions with regard to research question 4: What is the influence of a cooperative learning environment on the development of critical thinking skills?

Before concluding research question 4, it is important to note again that the CL strategy that was implemented in this study was PP. Although PP is not traditionally placed in the light of CL (but rather within the collaborative learning school of thought) (see 3.2.3.1), it has been given a place in the CL school of thought by scholars like Mentz, who argues that when implementing the CL elements in PP, chances of success in learning increase. In this study, PP as a CL strategy was therefore implemented to determine the influence of CL on CT development.

IT teachers were asked to implement PP as explained in their professional development session. In the current study, PP was seen as a CL strategy where two learners work together on the same problem/task using one computer (see 3.2.3.1.1.). From the empirical investigation of the study, it was clear that teachers who were asked to implement this strategy, did as asked (see 6.2).

In establishing that PP was the CL strategy implemented in this study and that IT teachers did implement the strategy as asked, the question regarding the influence of CL on CT development remains.

From the four groups tested in this study, the group that implemented only CL (PP) showed the greatest improvement in CT. This gave rise to the conclusion that CL has a positive influence on CT possibly due to the fact that learners have the opportunity to learn from peers modelling CT, practicing questioning, practicing metacognition and communicating to improve reasoning (see 6.3.1).

7.3.2. Conclusions with regard to research question 5: What is the influence of the intentional development of critical thinking in the IT classroom on IT learners' critical thinking skills?

The empirical investigation resulted in new knowledge regarding the influence of CTI on IT learners' CTS. As noted in section 6.3, the group that received deliberate CTI (CTI group) noted the lowest results in their CT scores. The answer as to why this group did not improve as expected was discovered in the qualitative investigation of learners and teachers. It was established that possibly not all teachers implemented the proposed strategies as instructed during the professional development session (see 6.3). Another reason why the CTI group showed a decrease in CT was possibly due to the learners not using the resources provided to them correctly. In summary, IT teachers were asked to teach learners the theory of CT (which some stated they did not do), model CT to their learners (which only some teachers did) and implement the suggested deliberate CTI (which some teachers may not have done even after being asked to do so). Furthermore, the addition of the deliberate CTI may have been too much when combined with the work of the IT subject whereas in the PP group, learners may not have been so deliberately focused on the additional resources and things to do (just as is the case with CTI and/or CTI+PP groups).

7.3.3. Conclusions with regard to research question 6: To which extent, if any, do critical thinking skills foster Self-Directed Learning?

The empirical investigation conducted in this study yielded surprising results regarding the relationship between CT and SDL. It was established that SDL increases naturally in the IT classroom (in the context of this study) due to learners' natural growth in age and maturity perhaps, or due to the nature of the IT subject. Interestingly, though, it was concluded that a relational increase/decrease between IT learners' CT and SDL is evident. When CT scores increased, SDL scores increased and when CT scores decreased, SDL scores decreased (see 6.3; see Figure 6.5). What is also interesting is the influence of CL on SDL. If we say that CL (PP) is the major cause of the increase in CT, and then notice that the SDL scores also increased in the PP group, we can safely deduce that CL (as implemented in this study) increases SDL.

The conclusion therefore regarding research question 6 is that CTS foster SDL skills (as noted by the relational increase in SDL as compared to CT); however, the deliberate CTI implemented in this study did not yield the desired effects on SDL as the groups who had been asked to implement these strategies showed significant decreases in SDL (see 6.3.2.). It is possible to note though, that if one can increase IT learners' CT, chances are good that you will increase their SDL too.

From the investigations into the body of scholarship as well as the empirical investigations, important conclusions were drawn (as discussed in the sections noted above). Most importantly, it became clear that PP holds great advantages for both CT and SDL and proved to be the most efficient strategy from the suggested strategies in this study. The following section is focused on discussing recommendations that can be drawn from this study in order to assist future implementations of strategies to develop IT learners' CT.

7.4. RECOMMENDATIONS FROM LESSONS LEARNT IN THE STUDY

Recommendations from the study include answers to research question 7. These recommendations will be discussed in the sections that follow.

7.4.1. Conclusions with regard to research question 7: How should the Information Technology teacher support learners to develop critical thinking skills?

From the answers yielded for the first six research questions, research question 7 can be answered. In order to answer this research question and to make recommendations regarding how the IT teacher should support his/her learners to develop CTS, Figure 7.4 provides a synopsis of how CT should be developed.

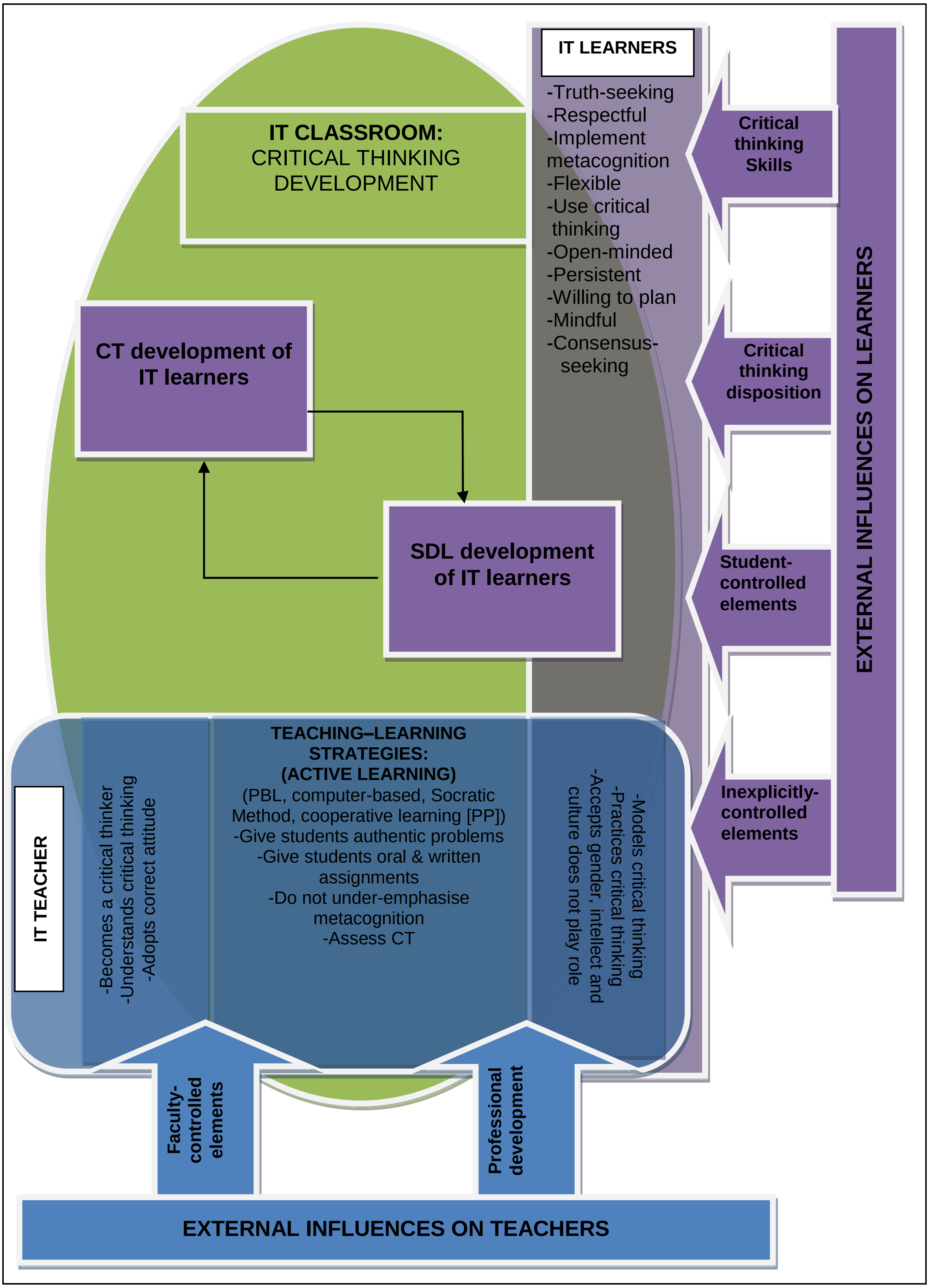


Figure 7.4 Synopsis of conclusions regarding the development of critical thinking in the Information Technology classroom

From Figure 7.4, it is evident that CT development should occur in the context of the IT classroom. In order to make sure this CT development is successful, it was established that it should occur in a CL environment.

Firstly, it was shown that IT learners have external influences that play a role in their CT and SDL development. These influences include the learners' disposition toward CT, the student-controlled elements and the inexplicitly controlled elements that influence SDL development (as discussed in Table 4.1). The learners are part of the IT classroom context but are also influenced (in the classroom) by the IT teacher (see 7.3.1).

The IT teacher, however, is externally influenced by the professional development he/she received as well as the faculty-controlled elements that play a role in SDL development (see Table 4.1). The IT teacher, in the context of the classroom, implements the teaching–learning strategy (which should be active learning if they [the teachers] want to develop CT (see 2.4)). An important influence that plays a role in the context of the IT classroom is the influence teachers have on IT learners through modelling of CT, practicing CT and accepting that gender, intellect and culture do not play a role in CT development (see 7.3.3 and 2.5.1.1).

At the centre of the IT classroom context, is the relational process of CT development and the SDL development. As noted from the empirical investigation, it is evident that when CT increases, so does SDL and vice versa.

The implication this conclusion has on the CT development is significant. Not only has it been established that CT does not have to be explicitly taught to learners to develop their CT, but also that the instructor may not necessarily have to model CT if learners could learn from each other through modelling. By having the opportunity to engage in conversation, argue with one another, question together, model CT and practice metacognition, learners in this study had the opportunity to develop their CTS more than any other group in the study.

7.5. LIMITATIONS OF THE STUDY

Certain limitations were notable in this study and these are discussed in this section.

Although the number of participants in the sample were not sufficient for generalisation to all Grade 10 learners (in South Africa), it is sufficient to generalise to Grade 10 IT learners in the three provinces used in the current study. It is also probable that other Grade 10 IT learners would have a similar response to the research.

Another limitation that was observed in the study was the fact that the duration of the intervention was relatively short. A small number of teachers noted that the time-span of the interventions was quite short. IT learners needed a longer period to gradually adapt to the new ways of thinking. It is suggested that a similar study should be done over a longer period of time.

The final limitation observed was the fact that the researcher could not ensure that the teacher implemented the suggested teaching–learning strategies correctly. The researcher had to take the teachers' word that they actually implemented the deliberate CT strategies on a regular basis and that they assisted learners in doing so.

7.6. RECOMMENDATIONS FOR FURTHER RESEARCH

Apart from the recommendations made regarding how IT teachers should develop CT to foster SDL, certain recommendations regarding further research became evident.

Research regarding the suggested teaching–learning strategies (CTI and PP) can be done in greater depth, perhaps including a larger sample and re-thinking the professional development sessions (so as to have more time to change teachers' attitudes toward active learning strategies).

Further research in this regard could also focus on implementing only one teaching–learning strategy at a time (either PP or CT strategies).

7.7. FINAL REMARKS

In this study, an investigation into the body of scholarship regarding CT, CL and SDL was conducted. In the investigation of the body of scholarship, it was established that CT is one of the most important skills today and especially so for IT learners due to the Information Age within which they find themselves. The Socratic Method and Brookfield's strategies for modelling CT proved to yield possibilities for CT development (see 7.3.4). CL was also suggested as an effective strategy for CT development. In the ever-changing world within which we find ourselves, learners' SDL should be developed in order to have learners take responsibility for their own learning, use resources effectively and work with others.

From the empirical investigation, it became evident that CL (in the form of PP) held the greatest advantages for IT learners in this study as evident from the CT increase as well as SDL increase. A relational increase/decrease was noted between CT development and SDL development indicating that if CT increases so does SDL.

This study yielded new findings regarding the relationship between CT and SDL for Grade 10 IT learners. Furthermore, it was established that Grade 10 IT learners can benefit greatly from CT development, especially within a CL environment. Not only has it been established that CT does not have to be explicitly taught to learners to develop their CT, but also that the instructor may not necessarily have to model CT if learners could learn from each other through modelling. By having the opportunity to engage in conversation, argue with one another, question together, model CT and practice metacognition, learners in this study had the opportunity to develop their CTS more than any other group in the study. Future research endeavours could broaden the sample in order to cater for generalisation to other IT learners.

In this study, new knowledge regarding CT and SDL in the South-African Grade 10 IT class was brought to the fore. Furthermore, the study established why CT and SDL should be deliberately addressed in the Grade 10 IT class. Finally, it was confirmed that both CT and SDL are best developed by making use of CL (in the form of PP for this context).

To answer the primary research question – *How can critical thinking be fostered in the Information Technology class and what is the influence on learners' Self-Directed Learning?* – CT should be fostered by implementing CL strategies, such as PP, and this will most likely increase the Grade 10 IT learners' SDL as well.

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LIST OF ADDENDA

ADDENDUM A: PROFESSIONAL DEVELOPMENT MANUALS

Addendum A1: Critical thinking manual (developed by R Bailey)

Addendum A2: Pair programming manual (developed by E Mentz)

Addendum A1: Critical thinking manual (developed by R Bailey)
This manual was distributed to IT teachers in the CTI group as well as the IT teachers in the CTI+PP group.

DEVELOPING CRITICAL THINKING

An IT teacher's guide to developing learners' critical thinking skills

TABLE OF CONTENTS

1. WHAT IS CRITICAL THINKING?

To define critical thinking is a complex task. The foundations of critical thinking emanate from as early as 2500 years ago when philosophers like Socrates, Plato and Aristotle viewed learning in a way similar to how we see critical thinking. Educational researchers like John Dewey and Benjamin Bloom coined the phrase “critical thinking” after extensive research was conducted (Bailey, 2014). From all of the works of these forerunners, a concise definition of critical thinking was developed. The most widely used definition of these developed definitions is that of Facione (1990), as discussed in his Delphi study. The definition states that **critical thinking is a purposeful, self-regulatory judgement that results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual consideration upon which that judgement is based**. From the study of the body of scholarship on critical thinking, it was also established that critical thinking consists of certain skills and certain attitudes (also referred to as “disposition”) conducive to critical thinking (Bailey, 2014).

1.1. Critical Thinking Skills

The critical thinking skills identified include being able to:

- identify arguments;
- analyse arguments;
- consider external influences;
- use scientific analytic reasoning; and
- apply reasoning and logic.

(Dick, 1991)

1.2. Critical Thinking Dispositions

Dispositions toward critical thinking that have been identified as conducive to critical thinking are:

- willingness to plan;
- flexibility;
- persistence;
- willingness to self-correct; and
- being mindful and consensus seeking.

(Facione, 1990; Bailin *et al.*, 1999; Halpern, 2003 & Lau, 2011).

2. WHY IS CRITICAL THINKING IMPORTANT?

Critical thinking has been proved important not only in general education but also in IT education.

2.1. Critical Thinking in General Education

Critical thinking is noted as one of the most important skills in this day and age; it is necessary in all learning environments. Researchers have expressed the positive effects of critical thinking, which include:

- the depth of learning positively correlates with the effective use of critical thinking skills (Lorenzo and Dziuban, 2006);
- critical thinking skills are an indication of students' success (Ennis, 2008); and
- critical thinking is seen as a vital skill similar to literacy and numeracy (Fisher, 2001)

In South Africa, critical thinking skills are also emphasised in the Strategic Plan for 2011 to 2014 (Department of Basic Education, 2011). The South African National Curriculum Statement Grades R–12 emphasise that it is based on, amongst others, a principle to encourage an active and a critical approach to learning rather than an uncritical learning of given truths (Department of Basic Education, 2012).

2.2. Critical Thinking in IT education

With the ever-changing times and technology expanding at a rapid pace, IT learners specifically need to possess critical thinking skills as they are expected to differentiate between truths and apply appropriate methods during problem solving. The IT curriculum expects learners to evaluate resources and their impact on the environment effectively as well as to solve problems with the use of a software developing tool (Department of Basic Education, 2012). Critical thinking skills assist learners in their attempt to master the knowledge and skills required to complete the subject successfully as such knowledge and skills promote the following aspects in the IT curriculum.

✓ Critical thinking supports problem-identification

Fuller *et al*. (2007:163) argue that the essence of computer science is problem identification and finding the most effective and efficient way to solve it. This relates to critical thinking as described by Sosu (2013:107) in that critical thinking focuses on the individual's ability to identify a problem and give a reasonable solution for the problem. The Department of Basic Education (2012:23) also emphasises the importance of problem identification and problem solving in the success of IT as the problem-solving steps of Polya are prescribed in the Grade 10 syllabi.

Apart from critical thinking relating to problem identification and problem solving, critical thinking also assists in the success of computer programming as described in the next section.

✓ Critical thinking supports computer programming

Computer programming has been noted as being difficult (Teague & Roe, 2008) whether at high school level or tertiary level. In order to foster successful programming skills, teachers need to shift the focus of their classes from teaching the memorisation of programming syntax to the facilitation of the development of skills conducive to successful programming. One of the skills proposed to contribute to the success of programming is critical thinking skills. While assisting learners with the development of critical thinking skills, Fagin *et al.* (2006) noted that computer programming skills increased significantly.

In her book, *Studying programming*, Sally Fincher (2006:35–38) states that there are certain skills that are necessary when learning programming. She describes similarities between learning a natural language and learning a programming language firstly, and secondly, she notes that learning to program takes a lot of practice. Fincher continues to describe the coherence between mathematics and computer programming as both are focused on problem-solving skills where the individual needs to identify the problem, break it down into smaller problems and then find the best solution. Lastly, she points out that, in order to complete a programming task successfully, the individual will need to be able to plan the solution as one cannot simply start right away but have to plan first. When referring to the definition of critical thinking (Facione, 1990) we see that the skills needed for programming (language skills, willingness to persist, problem-solving skills and creative skills) are all encompassed in the definition as quoted at the beginning of this section .

✓ Critical thinking supports general computer skills

McMahon (2009:280) describes that in his study, which investigated 150 girls at an Australian school with focus on their computer skills as well as critical thinking skills, he found that there was a statistically significant correlation between computer skills (as tested by the Australian Schools Computer Skills Competition) and the girls' critical thinking skills (as tested by the Ennis-Weir Critical thinking Essay Test).

With the importance of critical thinking in education in general and IT education in particular explained, the following section describes the development of critical thinking skills. Critical thinking has been demonstrated as an important component in successful computer programming (Fagin *et al.*, 2006) and computer programming plays an integral part of Information Technology as school subject.

3. HOW DOES ONE DEVELOP CRITICAL THINKING?

You as the teacher hold in your hands the ability to develop each learner's critical thinking skills. Bear the following in mind when developing critical in your class.

3.1. Model Critical Thinking

If learners do not see you practicing critical thinking in your own work, they will not value critical thinking. Brookfield (2012) describes several techniques, which she has found useful when attempting to model critical thinking in the classroom. These are explained in the following subsections.

✓ Speaking in tongues

This technique of modelling critical thinking involves showing students how ideas and facts can be interpreted in different ways. In order to do so, Brookfield (2012:62) explains that teachers should post several signs around the classroom stating a different perspective that may reflect a view of a certain topic. After explaining the topic at hand, the teacher moves to the first sign, which states the first perspective and explains how a person with that perspective might view the topic. Brookfield (2012:63) continues to note that this activity can be expanded by dividing the class into groups and having each group represent one of the several perspectives posted on the classroom wall.

✓ Compiling an "assumptions inventory"

By making use of an assumption inventory, teachers present an audit of the assumptions that informed the material they had just presented. Teachers' assumption inventory can be focused on the reasoning behind the way a topic was presented, explaining how an activity was designed, describing how they discerned between several meanings, summarising causal chains regarding topic, reviewing how topic is applied in real life and justifying why certain theories are chosen over other theories (Brookfield, 2012:64).

✓ Engaging in structured devil's advocacy

In structured devil's advocacy the teacher constantly presents arguments that counters his/her own assertions (Brookfield, 2012:66). By playing devil's advocate, the teacher is able to present several perspectives and model critical analysis by illustrating that a point does not necessarily have only one correct perspective.

✓ Ending lectures and discussions with questions

Good teachers end the learning process by raising awareness as to which questions have immerged from the content or topic discussed during the lesson (Brookfield, 2012:68). To implement the questions strategy, Brookfield (2012:68) suggests that teachers spend about ten minutes at the end of the lesson asking students to write down all the questions that have been posed to them during the lesson followed by a method of sharing the questions in the class, either in small group or with the whole class.

3.2. Teaching Learners the Theory of Critical Thinking

For learners to understand the value of critical thinking, it is important that you expose them to critical thinking. Teaching them what critical thinking is and why it would benefit them to develop these skills and attitudes would make the development of their skills in your classroom much more effective. Three strategies you can use to teach learners about critical thinking is to show them a quick video or giving them handouts to remind them of the important concepts.

✓ Show students a quick video to introduce critical thinking

Included in this manual, is a short introductory video that you can show to your IT learners before implementing critical thinking development in the class. The video illustrates what critical thinking is, why it is important and what learners can expect once they have developed critical thinking skills.

✓ Discuss the implementation of critical thinking development with your learners

Sit down with your learners and ask their opinion about how critical thinking skills can be fostered in the IT class. Learners will often have great ideas regarding how a new approach to learning can be implemented.

✓ Give handouts to remind them of important concepts

Included in this manual, is one example of a handout that you can give to your learners in order to remind them of the most important concepts of critical thinking. Learners could be asked to make their own notes, which will help them internalise the concept of critical thinking. Posters in the classroom are also a viable idea.

3.3. Facilitating Critical Thinking Skills in the IT Class

✓ Give students authentic problems

Authentic problems are real-world problems that hold relevance to the individual, which in turn engages the individual in the learning process as he/she can make a direct connection with what is required of him or her (Mims, 2003:2). Mims (2003) continues to note that authentic learning features several characteristics, which include:

- tasks are learner-centred and focused on what the learner is interested in;
- learning is not bound to the experience of the classroom;
- students engage with others in social discourse regarding problems; and
- students make use of higher-order thinking such as analysing, synthesising, designing, manipulating information and evaluation information.

From Mims' explanation of authentic learning and the characteristics described, relevance between critical thinking and authentic problems are noticeable. Lai (2011:2) notes that facilitators should give students open-ended, real-world or authentic problems when attempting to promote critical thinking. Depending on the perspective, these problems could have more than one solution devisable. Dunn, Halonen and Smith (2012:56) suggest that critical thinking skills be fostered in the classroom by providing students with a problem for each of the topics in the syllabi and thus not only giving straightforward questions. Pierce (2005) also emphasises giving students assignments that require them to apply thinking skills, and which are primarily focused on thinking abilities. Another aspect that can be focused on to assist in the development of students' critical thinking skills is to give students examples from everyday life that require the use of critical thinking (Dunn *et al.*, 2012). The teacher could also focus on why a specific suggestion to the problem is better suited than another, as well as on the persuasive techniques that were needed (Halpern, 2003).

✓ Give students oral and written assignments

Joughin (2010) explains that during oral assessment, students' learning as executed by word of mouth in part or in whole is assessed. He continues to illustrate that there are many theories that emphasise making use of oral assignments where students articulate their ideas.

Written assignments refer to assignments that require students to write answers, arguments and solutions. This is the most commonly used form of assessment in traditional learning (Joughin, 2010:3).

Pierce (2005) notes that having students execute oral and written assignments can contribute to their development of critical thinking skills. This can also be done by having students draw a diagram, such as a mindmap, to organise information before starting the assignment (Halpern, 2003:19).

✓ Promote questioning in class

Students should acquire and practice effective questioning skills (Pierce, 2005). Lau (2011) describes his fourfold path to good thinking which include practicing questioning. To practice questioning, Lau, states that students should ask four questions when faced with a problem:

- What does it mean?
- How many supporting reasons and objections?
- Why is this important or relevant? and
- Which are the other possibilities to consider?

By asking these questions, students can identify the most important concepts and why these concepts are important, categorise findings in meaningful ways and design two solutions to the problem (Halpern, 2003:19).

Brookfield (2012:203) lists the following questions as questions that sometimes intimidate students, but hold great value in the learning process:

- What assumption are you making that you are least confident about?
- What assumption are you making that you are the most confident about?
- What is a good example of what you are talking about?
- What do you mean by that?
- Can you explain the term you just used?
- Why is your conclusion accurate?
- What data is your claim based on?
- Can you put that in another way?
- Why do you think that is true?
- Can you give a different illustration of your point?
- What do you think you are leaving out?
- What do you think you might have missed?
- Whose point of views might you have missed?

✓ Do not under-emphasise metacognition

Beth Black (2012:108) describes metacognition as thinking about one's own thinking. She continues to note that being able to think critically requires metacognitive skills in that it involves improving one's own thinking, spotting weaknesses and finding flaws in reasoning. Metacognition can either be described as a core critical thinking skill or a subconscious sub-skill or disposition.

Halpern (2003:19) stresses the importance of metacognitive processes by stating that students should present two reasons as support to conclusions made and two reasons as opposed to the conclusions that they have made. She [Halpern] continues to say that students should also present two actions they would do differently to improve their solution or conclusion. These steps described by Halpern correspond with Pierce's (2005) notion that students' metacognitive abilities should be improved to assist in the development of their critical thinking skills.

3.4. Using Appropriate Teaching Strategies

Several teaching strategies have been proven to promote critical thinking in the classroom. Two of these strategies are the Socratic method and cooperative learning. For this manual we will only focus on the Socratic method.

▪ The Socratic Method

The Socratic method is an approach where the truth is discovered by means of question and answer (Whiteley, 2006:66). Schiller (2008:41) describes the Socratic method as a pedagogical method that pursues the truth by means of analytical discussion.

Benefits of the Socratic method include:

- it involves learners in their learning process;
- it helps learners understand difficult concepts;
- it helps teachers introduce new concepts;
- it gives learners the opportunity to realise different perspectives which encourages critical thinking;
- it can be used in any setting and for as much or as little time as needed;
- it helps to involve quieter learners; and
- it motivates learners to participate as they get a feeling that their opinion and perspectives count.

By making use of Socratic questioning as a strategy of the Socratic method, learners have the opportunity to engage in the learning process. The following illustrates the six types of Socratic questions learners should be asking throughout a problem.

1. Questions for clarification:
Why do you say that?
How does this relate to our discussion?
2. Questions that probe assumptions
What could we assume instead?
How can you verify or disapprove that assumption?
3. Questions that probe reason and evidence
What would be an example?
What is A analogous to?
What do you think causes B to happen? Why?
4. Questions about viewpoints and perspectives
What would be an alternative?
What is another way to look at it?
Would you explain why it is necessary or beneficial, and who benefits?
Why is C the best?
What are the strengths and weaknesses of D?
How are E and F similar?
5. Questions that probe implications and consequences
What generalisation can you make?
What are the consequences of that assumption?
What are you implying?
How does G affect H?
How does I tie in with what we have learned before?
6. Questions about the questions
What was the point to this question?
Why do you think I asked this question?
What does J mean?
How does K apply to everyday life?

Action plan given only to CTI group

ACTION PLAN

When planning your lesson

1. Plan authentic problems

Choose topics that are related to learners' everyday life – this includes giving learners authentic problems which include:

- tasks that are learner-centred and focused on what the learners are interested in;
- learning tasks that are not bound to the experience of the classroom;
- having learners engage with others in social discussions regarding problems; and
- allowing learners to make use of higher-order thinking such as analysing, synthesising, designing, manipulating information and evaluating information.

EXAMPLES FROM SCRATCH

Poor question: You are going to create your own scene (it could be a joke, dialogue from a movie, or your own original writing). In addition to using the "say" command, you also need to have your characters change their perception (move, costume) and feel free to add your own voice(s). You can work on this project on your own or with a partner

Better question: You recently saw an advertisement for competition where you could win R5 000 for writing the script for a short animated movie (5 minutes) on a your favourite IT topic using a programming language of your choice. Knowing that the Scratch programming language is visually based, you decide to make use of Scratch. This is what the judges' score sheet looks like:

Criteria	0	1	2
Originality of script			
Motion of characters			
Plausibility of scenes			
Voice over quality and authenticity			

IMPORTANT:
Although it is suggested that you implement and plan a variety of assignments, these do not all have to be done for one lesson. Do not burden yourself but use this guideline to engage your learners in a variety of assignments

2. Plan a variety of assignments

In computer programming, learners especially have the opportunity not only to do physical coding but also to be engaged in written and oral assignments:

- Give learners an opportunity to plan the programs they have to code on a piece of paper as a written assignment (USE SOCRATIC QUESTIONS Numbers 1–5).

3. Plan critical thinking strategy

- Decide which critical thinking strategy you want to apply during class: speaking in tongues, compiling an "assumptions inventory", playing devil's advocate or specifically focusing on the Socratic questions during class time.

IMPORTANT:
This discussion does not have to be a lengthy one; it is just a way of introducing your learners to the strategy. They might be a bit apprehensive at first but will soon realise the fruits they will reap from being actively involved.

During class time

1. Introduce learners to critical thinking

- If it is the first time you are introducing learners to critical thinking, show them the critical thinking video included in this manual and give them the handouts that are included.
- Explain the different strategies that may be used in class to foster critical thinking (speaking in tongues, compiling an "assumptions inventory", engaging in structured devil's advocacy, ending lectures and discussions with questions, and Socratic questioning).
- Give learners the handouts that will assist them during programming and Socratic questioning.

IMPORTANT:
Although it is suggested that you implement and plan a variety of assignments, these do not have to be all done for one lesson. Do not burden yourself but use this guideline to engage your learners in a variety of assignments

2. Facilitate critical thinking in programming

- All of the strategies for promoting critical thinking can be successfully implemented in programming.
  - Speaking in tongues – have learners give different perspectives on how a problem can be solved through programming.
  - Compiling an assumptions inventory – have learners complete a quick journal entry where they describe the assumptions that may have misled them in their answering of questions and assignments.
  - Engaging in structured devil's advocacy – during programming you can constantly ask learners questions and scrutinise each statement they make.

3. Implement the suggested strategies

IMPORTANT:
Always ask learners to describe the advantages and disadvantages of the approach they are discussing so as to give them an opportunity to engage in critical thought.

- Speaking in tongues
    - Take the topic you are dealing with, for example a program that requires repetition. You can write down different perspectives of how the program could be written by means of different reiteration structures (for, while, repeat, etc.).
    - Have several learners discuss a different approach. The discussion need not be lengthy and can be a quick introduction followed by the implications these results might hold for the program.
    - Another example is to ask learners, to illustrate how a program would differ if they take the bottom-up approach rather than the top-down approach and vice versa.

IMPORTANT:
Have learners complete the assumptions inventory at home when working individually

- Compiling an "assumptions inventory"
    - One way of implementing an "assumptions inventory" in the IT class, is to have the learners revise programs they have written. Ask learners to comment on the assumptions they have made that caused them to make a mistake, for instance, assuming that the random numbers run indefinitely or that the user should be allowed to choose different inputs. Also ask learners to comment on how the program could be applied in a real-life situation.

IMPORTANT:
Make the devil's advocacy a game between learners and yourself.

- Engaging in structured devil's advocacy
    - The devil's advocate states all different sides and constantly asks learners to consider different perspectives and the consequences each perspective will hold for a program. You can have learners list as many different questions and perspectives as they can and compete with each other.

- Another method is to always counteract a learner's questions with another question or perspective.

IMPORTANT:
Have learners keep their key rings handy so they can refer to the six types of Socratic questions.

- Socratic questioning
  - During programming, ask learners to make use of the six types of questions described.
  - TYPE 3 questions can be implemented during the structured devil's advocacy for instance.
  - TYPE 4 questions are ideal for use in the speaking in tongues strategy.
  - TYPE 2 questions can be used during the assumptions inventory.
  - At the end of a lesson, you can ask learners to tick off QUICKLY which questions they asked and were asked during that lesson.

Wrapping up the lesson

IMPORTANT:
Ask learners to journal their questions for reference when studying for tests. Also emphasise the fact that a good question is just as important as a good answer.

1. Ending the lesson with questions and emphasising metacognition
   - During the last five minutes of class, ask learners to describe quickly what the most challenging question was they were asked during class-time and which answer proved helpful. You can also ask learners to jot down all the questions that they had during the lesson and how they plan on answering these questions.
   - A good question is just as important as a good answer.

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Addendum A2: Pair programming manual (Developed by E. Mentz)

Given to IT teachers in CTI+PP group and IT teachers in PP group

"Two heads are better than one"

1. GENERAL BACKGROUND

Researchers and academics responsible for the education of students in programming are in agreement that pair programming is a viable strategy for the teaching and learning of programming skills (Williams & Kessler, 2003, McDowell *et al.* 2003b, Mentz *et al.* 2008). It is against the background of general cooperative learning, as outlined by Johnson & Johnson (2006), that learners work together so that they can achieve better results than working as individuals. From the provisional results of a pilot study which Mentz did in the North West province in 2008, it can be deduced that pair programming can also be used to the advantage of learners at school level.

1.1 What is pair programming?

Pair programming is a teaching and learning approach in which two learners work side by side on the same computer in order to solve a programming problem. The two learners work together continuously to develop the algorithms, to encode and to test. One of the learners is the "driver," and the other one is the "navigator." The driver handles the pen, keyboard and mouse and is responsible for writing the algorithms or design, and typing the code, whilst the navigator plots the direction which the programming must take. The navigator is in charge of the reference sources, sets strategies for the solution of the problem, thinks of alternatives and is actively involved in the checking and correcting of mistakes in the driver's work (Williams & Kessler, 2003; Bipp *et al.*, 2008). The two roles, that of driver and navigator, should be switched around every now and again, so that they can both learn the skills of each particular role.

The philosophy of pair programming, which is a form of cooperative learning, is that the individual, although in interaction with another, is still responsible for his/her own learning, but respects the capabilities and contributions of the other (Panitz, 1997).

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1.2 General principles of pair programming

Pair programming demands specific social skills and active communication in order to be able to share one's thinking processes with another partner. The fact that learners have to communicate what they know and understand strengthens the learning situation. To share with a partner what you know also indicates to your own self what you don't know. Each member of a pair serves as a resource for the other partner (Yerion & Rinehart, 1995). A pair that functions well should, in the solution of a problem, constantly communicate with each other, listens to what is being said and reacts to what is being said. Each member of a pair should have the confidence to ask a question when he/she does not understand, and ensure that the other one understands what he/she is doing. Throughout, they should respect each other's opinion and point of view. In the interest of maintaining good relations, and the fact that a specific skill is being learnt by both members of the pair, the navigator should not use the mouse or keyboard without the driver's consent, and, *vice versa,* the driver should not use the manual or reference resources. Both members of the pair should get equal opportunities to be driver and navigator. It is accepted as normal that there will be differences between the navigator and the driver from time to time, but these should be solved amicably between them. Respect for each other's point of view and opinion should be maintained throughout, and there should be specific times when they should reverse roles in one programming session.

1.3 Advantages of pair programming

From several research projects which were done mainly on students at tertiary level, one can deduce the following advantages in pair programming:

- It raises academic achievement in programming and improve throughput figures (Bevan *et al.,* 2002; Nagappan, 2003);
- It produces better quality programs (McDowell *et al.*, 2003a; Jensen, 2005);
- Less errors are made (Jensen, 2005);
- Better-designed programs are obtained (Lui *et al.*, 2008);
- Tasks take less time to perform (Williams & Upchurch, 2001; Chaparro *et al.*, 2005) ;
- It promotes the 'enjoyment factor' in programming (McDowell *et al.*, 2003b);
- It motivates learners and makes them positive towards programming (Jensen, 2005; Howard, 2006);
- It reduces frustration during programming (Chaparro *et al.*, 2005);
- It promotes self-confidence in programming (Williams *et al.*, 2000);

- It helps with the development of skills in solving problems (Sanders, 2002);
- It improves the grasp of programming concepts (McDowell *et al.*, 2002);
- It reduces the marking of tasks and the workload of teachers (cf. Williams & Upchurch, 2001);
- Programming skills are learnt much faster (Williams & Upchurch, 2001);
- Essential cooperative and communication skills are developed (cf. Cliburn, 2003);
- Learners learn more by exchanging ideas with one another and find advantage in the insights thus created (Ferzli *et al*., 2002);

From the pilot study done by Mentz (2008) on pair programming in the North-West province, the following advantages became apparent:

- It improves independent thinking.
- Fewer unnecessary questions put to the teacher.
- All the learners are actively involved in the learning process all the time – thus promoting active learning.
- Learners are motivated to really want to work, knowing they will not have to tackle the problem on their own.
- The weak learner improves considerably as a result of the help and motivation received.
- Learners enjoy the subject more.
- A learner's questions are immediately answered by his/her partner and they don't have to wait until a teacher gets round to them with the answer.
- Because most pairs can solve the problems between themselves, it gives the teacher more time to deal with more serious problems and to get to those pairs that are really struggling.
- Increased self-confidence in learners who work in pairs.
- Improved understanding of programming skills.
- Learners learn to think for themselves and do not so easily give up or ask for help.
- Bright learners demonstrate clever techniques or shortcuts to others and this spreads quickly through the whole class.
- Most learners give their best in order not to disappoint their partners or leave them in the lurch.
- A more relaxed atmosphere prevails in the classroom and thus promotes better learning.
- Disciplinary problems are greatly reduced as everyone has a goal which must be reached in a short time.
- Helps teachers to monitor learners' progress.
- Improved programming style in learners.
- Can be applied at a higher level because learners are more prepared to tackle more difficult problems when they know they are not alone.
- The value of the discussion of problems and solutions after the pair programming is done is at a higher level because, after the known solutions have been applied, the teacher can propose and

discuss extensions of the problem. Furthermore, the discussion is at a higher level because the basic questions have already been answered by the partners and they are now ready for more advanced applications and challenges arising from the problem they have just solved together.

- Improvement of communication skills.
- Teaches learners to put their own thinking into words and express their thoughts verbally.

Teachers who were involved in the project were overwhelmingly positive about the application of pair programming. Although some gaps in the implementation of pair programming at school level were addressed after the pilot study was done, the overwhelming reaction of the teachers was that they would apply this in future, and one teacher stated that he/she regretted not knowing about this technique earlier.

1.4 Disadvantages of pair programming

Although the literature can show a wealth of advantages for pair programming, there are nevertheless some limitations, of which teachers should take note. If pair programming is correctly applied, the disadvantages can be kept to a minimum. The following are problems which frequently occur when pair programming is not correctly utilised:

- Some learners find it difficult to work with others;
- One person in the pair does all the work;
- It is especially the stronger learners who are not keen to work with weaker ones and prefer to do it alone;
- Personality clashes can occur which can be destructive and negatively affect the class situation.

Pair programming which takes place outside scheduled class period presents more disadvantages and it is not recommended, for the following reasons:

- Outside of classroom control, each individual's involvement cannot be exactly determined, and one of the pair could have done all the work.
- The roles of driver and navigator cannot be monitored.
- The switching of driver and navigator cannot be controlled.
- Communication and handling of any conflict cannot be dealt with by the teacher.
- No time limit can be set for the task, which leads to less focussed and motivated learners.
- It is sometimes difficult for the two partners to schedule a time which suits both of them.

2. THE APPLICATION OF PAIR PROGRAMMING IN THE IT CLASS.

2.1 General principles for the application of cooperative and collaborative learning

Because pair programming can be considered as a form of cooperative learning, the general educational principles of cooperative learning need also to be applied. The basic components of effective collaborative or cooperative learning include **positive interdependence, individual accountability, social skills, promotive face-to-face interaction and group processing** (Johnson & Johnson, 2009). In the following paragraphs it will be indicated how each of these principles can be implemented in pair programming.

To assure positive interdependence in pair programming, both the driver and the navigator need to work together in such as way that they realise that the one cannot achieve success unless they both achieve success (cf. Johnson & Johnson, 2009). This is achieved by the two of them jointly assuming ownership of the task that must be performed (Werner *et al.*, 2004). The key to positive interdependence lies in the mutual goals set for the pair, as well as the method used to assess their work. Clear goals and good assessment methods lead to a situation in which the learners realise that effective learning is the collective responsibility of both of them, where resources must be shared and in which support and encouragement for each other will contribute to their success (Veenman *et al.*, 2002). If, for example, they set the goal that a particular task must be completed by the end of the period, when it will be assessed, both members will realise that they have a mutual aim on which they must work. Assessment of the end product is necessary, as well as assessing each individual's contribution to the end product. Positive interdependence works against competitive behaviour and allows learners to realise that they depend on each other for their success as individuals and as partners.

Individual accountability exists when each partner contributes his/her knowledge and skills, to the advantage of the pair (LeJeune, 2003). Each of them should realise that he/she will be held responsible for his/her work and inputs within the partnership and each of them must individually achieve the desired outcomes (cf. Johnson & Johnson, 2006). The realisation of individual responsibility is important for the success of the pair. Mechanisms should be put in place which will force both members of the pair to be actively involved and to ensure that no one member is going to have an easy ride on the other's back, or to completely withdraw, or to dominate the situation (Gross Davis, 1999). In order to engender individual accountability in learners, each member, on completion of the pair programming task, should be assessed individually to determine if each has achieved the outcomes. The end product of the pair must also be collectively assessed. Feedback about individual assessment should be given to both the pair as well as the individual, so that they can reflect on what they have achieved. Each member of the pair needs to realise that they must achieve the goal, namely to write a correct program, not on their own, but that they should support each other in such a way that both of them could solve a similar problem by themselves. Therefore the contribution of each partner to the achievement of the outcomes should also be assessed within the pair. This is done by the teacher or by the pair themselves. When learners are expected to assess each others' inputs, knowledge and skills and this evaluation is compared with the individual achievement of each member made in the individual assessment, then partners are forced to assess each other honestly. The teacher can build in some kind of penalty if the two marks do not correlate with each other.

Successful **social skills and interaction** are necessary for effective pair programming. Interpersonal interaction in pair programming results in the pair giving each other help and support, to develop the confidence to ask questions, to question each others' reasoning, to make suggestions for the improvement of the program code, and to gain self-confidence to mutual solution of problems. Effective communication is important and therefore each member of the pair should be motivated to develop social skills in order to learn to know each other, to trust each other and to communicate ideas accurately and clearly. They must learn to formulate ideas and thoughts about problem solving and explain these to their partners, as well as to avoid or manage conflict constructively. Partners should be prepared to consider each other's alternative solutions, ideas and proposals and to possibly accept these and to investigate various solutions. Each member of the pair must be prepared to accept that his/her idea is not necessarily the best. Errors pointed out by one of them should not be taken as criticism, but seen as helping to achieve the goal together (Williams & Kessler, 2003). Therefore it is important that both members of the pair should listen critically to one another and give feedback to each other so that their efforts are improved. The application of pair programming forces the driver and navigator to interact with each other. As their social skills improve, they begin to enjoy the task and are accordingly more motivated. Social skills can be learned and it is the task of the teacher to support learners in this.

Promotive face-to-face interaction includes the exchange of resources and the mutual exchange of assistance to support each other and to encourage each other to succeed. This includes the fact that they need to question each others' reasoning and actively discuss this in order to increase quality decisions and insight. As soon as the pair challenges each others' reasoning and solutions, the motivation to learn is enhanced. Effective face-to-face interaction results in mutual motivation and the creation of trust in each others' opinions and actions, developing confidence to venture and communicate and reducing learner stress and anxiety. According to Johnson and Johnson (2006) there are cognitive activities which only develop when students are involved with each others' learning.

Group processing takes place when, after the completion of the task, the two reflect on how well their cooperation went and how they could have improved it. It is necessary for the pair to reflect on whether they functioned to their full potential and what inputs were of value, so that they can be implemented in future. It is also necessary that the pair tell each other what actions did not work or were not acceptable. Feedback from the pair can also give an indication to the teacher about which aspects were difficult and therefore need extra attention. Self- and partner-assessment can also be discussed during this reflection.

2.2 The role of the teacher

In order to successfully apply pair programming, the teacher needs to keep the following guidelines in mind:

2.2.1 Explain pair programming to learners in advance

It is necessary that learners know precisely what pair programming is all about and what is expected of them. Often learners are reluctant to work in pairs because they have a negative perception about group work from previous experiences. It is essential that the advantages of pair programming are explained to them, as well as what measures are taken to prevent one learner from taking a free ride while the other does all the work. They must understand what the role of the drivers and navigators are and how they are to meet their individual responsibilities, share resources, set goals, communicate effectively and resolve conflict if necessary (McWhaw *et al.*, 2003). It must be clearly explained to learners that the purpose of pair programming is to enhance the learning of programming skills.

2.2.2 Be prepared

The teacher facilitator must be fully prepared by planning tasks which can be successfully accomplished in pair programming, and any program which is aimed at practicing specific programming principles should be one suitable for pair programming. Carefully plan what measures need to be put in place in order to promote positive interdependence and individual accountability in learners. Clear and specific aims should be set to achieve the desired outcomes. Ensure that sufficient time is allowed for learners to complete the task. **It is preferable that a task should be completed in one single or double period or contact session.** A time framework serves as motivation and creates a sense of urgency in the pair and thus promotes an active learning process in the classroom.

2.2.3 Divide the group into pairs in advance

There is little research available about the compatibility of different personality types and skills levels in pairs at school level. Many studies at tertiary level indicate that skills levels or personality types can be used as criteria for the combination of pairs. Williams *et al.* (2003) as well as Chaparro *et al.* (2005) found indications that students work better when matched with someone of the same skills level. In contrast Katira *et al.* (2004) have found that the compatibility of pairs in beginner programming courses improves when different personality types are combined. Jensen (2005) also established that having the same abilities and the same experience within a pair was often counterproductive. They found that a pair functioned better when one was more competent that the other. It is true that two high achievers will approach a problem differently from a good and a weak achiever or from two weaker achievers, but in any case positive learning experiences can still be gained from this. During the pilot study it was revealed that the pairs which functioned best were those who did not have the same skills level.

A reasonably poor achiever with a reasonably good achiever, or a strong achiever with an average achiever worked better than two strong or two weak performers together.
There is no agreement amongst researchers whether self-selecting pairs or allocated pairs work best. The biggest disadvantage of a self-selecting pair is that learners usually pick ‘buddies’ that they know well and therefore cover for each other if the one does not perform up to scratch. Initially pairs that know each other have more confidence to ask questions and to communicate with each other, but even pairs that do not know each other, learn to question each others’ work and make critical judgements. During the pilot study it was also revealed that teacher-appointed pairs worked the best. Learners must also get the opportunity to learn to work with as many different personality types as possible. In that way they learn to know each other better and gain more confidence to ask questions in class and participate in discussions.

Within a teaching-learning environment where beginners are learning programming skills, it is more important that pairs are matched by the teacher and regularly reassigned, rather than matching pairs with the same abilities. When regular reassignment of partners takes place, it appears that there is not a significant difference in achievement and capacity in how pairs are matched. According to Williams and Kessler (2003), the differences in gender and culture in pairs at tertiary level do not appear to provide any problems. Yet gender differences at high school level can possibly be problematic and teachers need to be sensitive in such cases if pairs are randomly combined. Males are inclined to dominate the learning situation.

There are various reasons that pairs are sometimes unsuitable and incompatible. Teachers should be sensitive to such cases and identify these early on, and switch pairs, if the conflict cannot be resolved, to avoid any counter productivity in the classroom.

2.2.4 Rotate the roles regularly

The pairs should switch roles at regular intervals. The switching of roles is an informal process and the interval depends greatly on the task being performed and the time allocated for it. Some researchers state that a good interval is about every 20 minutes, others prefer that a specific task or section of the program should first be completed before switching is done. When short programming tasks are given, it can also work well to give learners two tasks to perform, but get them to switch after one is completed. The advantage of this is that the strategic thinking process of the navigator is not interrupted. When pairs rotate they must physically stand up and change positions (Hanks *et al.*, 2004). The navigator always sits on the opposite side of the mouse, with the screen turned so that both can see it clearly.

2.2.5 Giving support

During the execution of pair programming activity the teacher/facilitator must be available for help, support and assessment. Help learners by asking questions which will lead learners to the solution to the problem, rather than by direct answers. Encourage them to seek answers by themselves and praise them when good cooperation occurs. The roles of the navigator and driver must be constantly monitored to ensure that each member plays his/her role successfully and that switching takes place when it should. The facilitator should observe the pair and constantly give feedback about their cooperative abilities. Help them to understand that there is not only one correct way, algorithm or program solution. When conflict arises which the pair cannot solve themselves, it is important that the teacher helps them find a way out. It is not recommended that a pair should immediately be separated, since learners will not learn to deal with their conflict themselves. General errors which are spotted can be dealt with at the end of the assignment. It is important that a specific time allocation be provided at the end so that the teacher can reflect on problems which learners had and solutions that learners found. It serves as a valuable learning opportunity for everyone in the class, since everyone has already been involved in thinking and reasoning about the relevant problems. Frequently learners realise during these discussions that there was in fact a shorter method for the solution of the problem and they thus gain better insight and understanding. Teachers have also found that during these discussions learners show more willingness to share their experiences and solutions with the class. During this time allocation, the opportunity can also be created for students to demonstrate their work to the class. To strengthen positive interdependence, the class can even award a mark for the pair for their demonstration. If the teacher selects any one person from a pair to demonstrate their work, it can also foster individual responsibility.

2.2.6 Continual assessment

Assessment of pair programming implies that the outcomes as well as the process must be assessed. The success of assessment determines the end result of the process and it is very important that this should be done correctly. Assessment in pair programming can be done by the teacher, the two members of the pair, the peer group (learners in the class) and each individual learner.

- **Self-assessment**: Each member of the pair assesses him/herself in terms of the achievement of the set outcomes and their cooperation skills. This is compared with what the individual learner obtained in the individual test. An unrealistic mark which deviates too much from the individual mark can be ignored or the learner can be further penalised for this.
- **Partner assessment**: Members of the pair assess each other's participation in terms of the achievement of the outcomes and their cooperation skills. This can also be compared with the mark which was given in the individual test, in order to foster honest assessment by learners.
- **Peer group assessment**: One member of the pair can be selected to demonstrate the program to the class, after which a peer assessment, using a specific marking sheet, is done by the class. The average of the peer assessment can also form part of the pair's assessment mark.
- **Teacher assessment**: The teacher assesses the pair on the outcomes of the assignment, as well as the manner in which the pair cooperated.
- **Individual assessment**: Everyone in the class is assessed individually on the outcomes that were achieved in the pairs by completing a similar programming task individually. This is a good indication of how the pairs have functioned and if every member did his/her bit during the execution of the task. It is important that the mark for every learner's individual test is also communicated to the pair.

All assessment can be done according to a predetermined marking sheet (see Appendix 1 and 2) which lists the specific outcomes. The marking sheet also helps the learners to identify their errors, to show them their own progress and to see where there are weak areas. All the above kinds of assessment can be counted together to determine the learner's marks. The following is an example of a possible method of recording marks in pair programming.

Table 1: Example: Assessing of pair programming

NAME OF THE LEARNER	SELF ASSESSMENT (10)	PARTNER ASSESSMENT	PEER ASSESSMENT (10)	TEACHER ASSESSMENT (10)	INDIVIDUAL TEST (10)	BONUS MARKS
Jan Nel	8	8	7	7	8	**-**
Piet Smit	7	6	5	7	5	**-**

To foster individual responsibility and positive interdependence the pair can also be rewarded with bonus points if both cooperate in the completion of an assignment, both achieve 80% or more in the individual tests or complete the task within the time frame. All the above-mentioned methods of assessment of the pair contribute to the development of a feeling of dedication to the task and prevent the situation of only one learner doing all the work. If assessment is carried out correctly, then the competitiveness between the partners will give way to **true cooperation and mutual help**. Only then can pair programming be of value in the IT class.

Feedback after assessment is of cardinal importance. By giving feedback to the learners, they know what outcomes they have achieved and what still needs more attention.

2.2.7 Create opportunity for group processing

Every pair should be given time to be able to reflect on their cooperation after completion of the assignment. Depending on the time available, learners can do this in the form of a journal, or simply discuss this with each other. Initially it will be necessary for the teacher to structure the reflection with the following questions:

- What worked well?
- What did not work well?
- What I learnt from you that I can use next time?
- What you did that I did not like?

Later learners will be able to structure and broaden this discussion by themselves, to give feedback to each other about where gaps exist and where outcomes have not been fully reached.

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3. SOME GENERAL COMMENTS FOR STUDENTS ABOUT PAIR PROGRAMMING

There are some studies which mention the perceptions that students have about pair programming. At the beginning their perception can be negative since they do not know what to expect in pair programming and many students prefer to work on their own as a result of negative experiences of group work in the past. It is especially the brighter student who is scared that she/he will be disadvantaged by having to work with a weaker student. After they have done some pair programming they usually change their tune and in fact prefer to work in pairs rather than alone. The following are examples of students' perceptions of pair programming:

(Howard 2006):

- *I think that using pair programming while working on the programming assignments helped me better understand the concepts.*
- *Pair programming is an excellent way to program. I was very impressed with how well two programmers can complement each other's strengths and weaknesses.*
- *My partner and I spent ample time on our programming assignment debugging our code. I would have torn my hair out trying to figure out the little quirks by myself. Luckily I had someone there to help me out.*
- *I like doing this project with the pair programming method, because it helped me to find errors that were made during the coding process.*
- *Sometimes I tend to do things in an erratic order, and this helped me to organize myself.*
- *We both helped out on areas that we were better at and we both helped to do the interface.*
- *I do think two heads are better than one.*
- *I think we got it done sooner than I would have by myself.*

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Appendices
for pair programming

APPENDIX 1

Assessment of pair programming of partner and self								
Name and surname: Self								
Name and surname: Partner								
1=Not at all; 2=To a lesser extent, 3=To a great extent, 4=Fully								
Assess yourself and your partner as honestly as possible with regard to the following criteria								
Knowledge and skills	**Self**				**Partner**			
1. Planning	1	2	3	4	1	2	3	4
2. Algorithm design	1	2	3	4	1	2	3	4
3. Screen layout	1	2	3	4	1	2	3	4
4. Program syntax	1	2	3	4	1	2	3	4
5. Debugging and evaluation	1	2	3	4	1	2	3	4
6. Reaching the set outcomes	1	2	3	4	1	2	3	4
Criteria with regard to cooperative learning								
7. Communication skills	1	2	3	4	1	2	3	4
8. Listening skills	1	2	3	4	1	2	3	4
9. Cooperation and participation	1	2	3	4	1	2	3	4
10. Managing role as driver/navigator	1	2	3	4	1	2	3	4
Total mark out of 40 (÷ 4 for mark out of 10)								

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APPENDIX 2:

Assessment of individuals in pairs by teacher
1=Not achieved; 2=Partially achieved, 3=Almost fully achieved, 4=Fully achieved

Name	**Screen layout**				**Def of variables**				**Program syntax**				**Correctness**				**User friendly**				**Cooperation**				**Total**
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
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	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	

APPENDIX 3:

Assessment of learner/pair demonstration								
Name of learner/pair who demonstrated	Correctness				Clarity of demonstration			
	1	2	3	4	1	2	3	4
	1	2	3	4	1	2	3	4
	1	2	3	4	1	2	3	4
	1	2	3	4	1	2	3	4
	1	2	3	4	1	2	3	4
	1	2	3	4	1	2	3	4

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APPENDIX 4

The role of the driver and navigator during pair programming

Steps of programming	The role of the driver	The role of the navigator
Program analysis		
Objective of program	Write the objective of the program on a piece of paper	Communicate with teacher/facilitator to clarify the objective of the program
The IPO-table	Write the input, processing and output in the particular spaces of the IPO table. Modify table as needed	Verify if data is written in the correct spaces. Ensure that the processing that is written, will produce the necessary output required. Use resources to find alternative methods. Propose alternatives.
General		
Program design	Write an algorithm on paper	Evaluate every step written in the algorithm. Determine whether it is the most logical route that can be followed.
Validation of design	Compile the trace. Complete the trace table and compare answers with expected output	Supply test data and expected output for each set of data. Find logical errors and correct the errors.
Implementation of design	Control the keyboard and mouse. Responsible for the typing of programming code.	Reflect on code and process. Ensure that programming happens according to plan. Propose corrections.
Test of solution	Implement corrections on programming code and/or algorithm, where needed.	Compare the algorithm with the program. Propose alternative ways to correct errors.
Document the program	Compile documentation on the functionality of the program. Delete "dead coding"	Adjust other documentation. Ensure that documentation is clear and understandable to the teacher/facilitator and other programmers/pairs.

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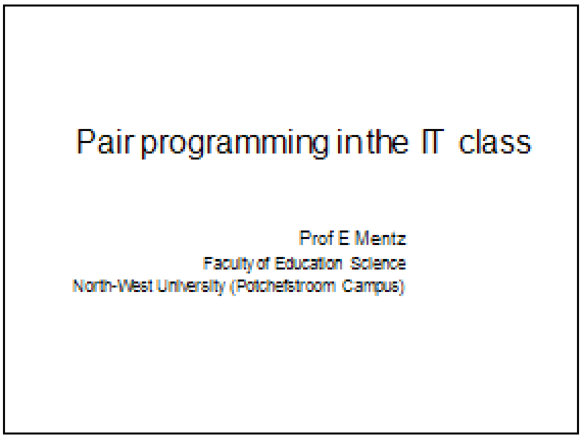
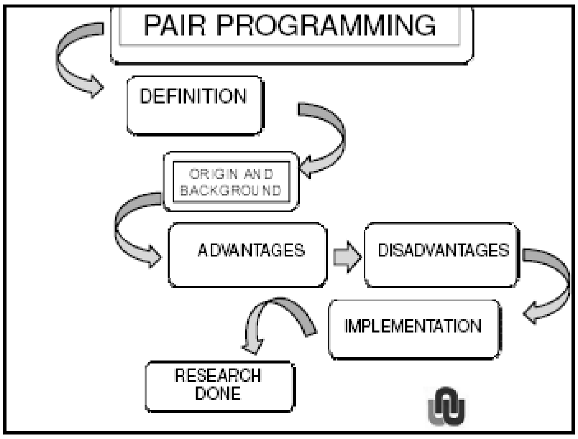
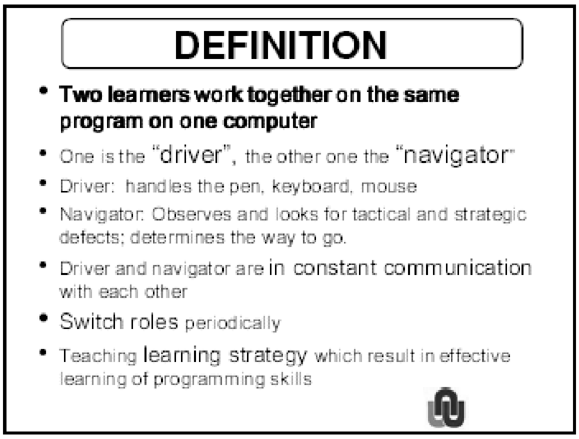
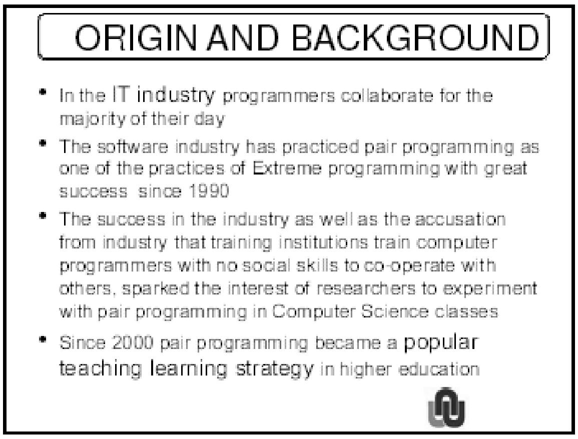
APPENDIX 5

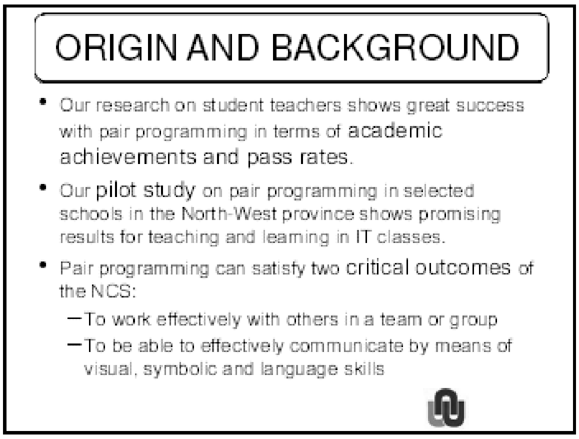
Pair programming information slides

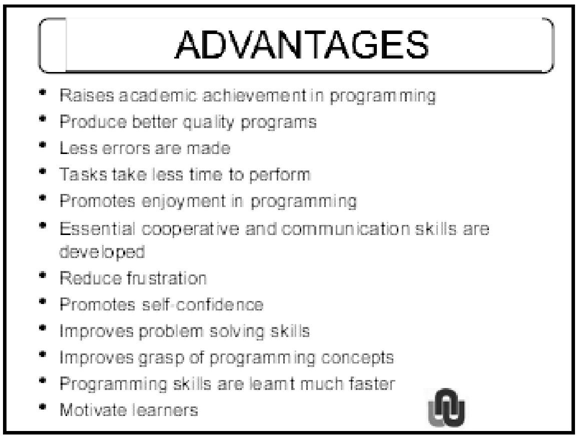












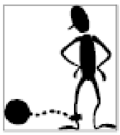
Mentz, E. 2011. Pair programming. In Mentz, E., Breed, E. & Havenga, H.M. Teaching-learning strategies for the IT classroom: SANPAD Manual. p21–p42

ADVANTAGES (2)

- Learners are more prepared to tackle difficult problems when they know they are not alone.
- Fewer unnecessary questions put to the teacher
- All the learners are actively involved – promote active learning
- Weak learners improve considerably as a result of the help and motivation they received
- Learner's questions are immediately answered and they do not have to wait until the teacher gets around
- Gives teachers more time to deal with pairs that are really struggling
- Bright learners demonstrate clever techniques or shortcuts to others and this spreads quickly through the class
- A more relaxed atmosphere prevails in classes and this promotes better learning
- Improves independent thinking

DISADVANTAGES

- Some learners find it difficult to work with others – especially strong learners
- Personality clashes may occur
- If the principles of cooperative learning are not adhere to, one person can do all the work
- Assessment may be difficult



IMPLEMENTATION

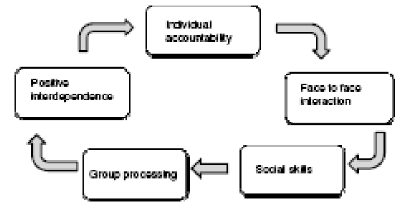
Principles of cooperative learning

Role of the teacher

Role of the learner

Principles of cooperative learning

- Only when the principles of cooperative learning are incorporated into the implementation of pair programming, it can serve as an effective teaching-learning strategy for mastering computer programming.



POSITIVE INTERDEPENDENCE

- Create a learning atmosphere in which the success of the group is dependent upon the success of every individual in the group.
- Group goals, reward systems and roles of group members must be structured to foster positive interdependence.

"All sink or swim together"

"All share a common fate"

INDIVIDUAL ACCOUNTABILITY

- Personal responsibility;
- Assessing individual students' work within the group effort;
- Feedback to entire group of individual performances;
- Individual assessment;
- Random report back

"We can not do it without you"

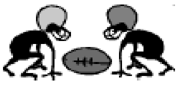
"No social loafing"

"Everybody has something to offer"

Mentz, E. 2011. Pair programming. In Mentz, E., Breed, E. & Havenga, H.M. Teaching-learning strategies for the IT classroom: SANPAD Manual. p21–p42

FACE TO FACE INTERACTION

- Engage the learners in explanations of their learning process to fellow learners;
- Teaching one's knowledge to others;
- Checking for understanding;
- Connecting present with past learning

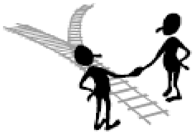


"Let us discuss this"

"Two heads are better than one"

SOCIAL SKILLS

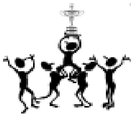
- Understand group dynamics – active listening;
- Conflict management;
- Good communication skills; leadership;
- Decision-making;
- Trust building.



"Why do you think so?"
"Can you explain that?"

GROUP PROCESSING

- Engage students in a self-evaluation exercise – what did each member do that was helpful to the group, what could they do even better next time?
- How well did they achieve their goals?
- A way to encourage them to apply meta-cognitive skills in the learning process;
- Celebrating group success.

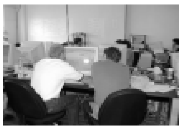


"Your success benefits me and my success benefits you"

ROLE OF THE TEACHER

- Explain pair programming to learners in advance
- Select the pairs in advance
- Rotate the roles regularly
- Apply the principles of cooperative learning
- Assess after each session
- Create opportunity for group processing
- Give support

ROLE OF THE LEARNER



- Communicate
- Listen to your partner
- Be sensitive
- Cooperate
- Be patient
- Explain your work to your partner
- Speak up if you disagree
- Don't constantly tell other people what to do
- Don't be intimidating

FURTHER RESEARCH

- NRF Thuthuka project on group work in the IT class continue with implementation of pair programming in schools in North-West and Eastern Cape provinces.
- Teachers willing to participate will receive training and a manual as well as support when needed.
- In return we need to refine our model for implementation, get new ideas from teachers by interviewing teachers and learners.
- Apart from articles in international and national journals on the findings of this project, 3 Master students and one PhD student also completed or is still working on their studies in this project on:
  - Assessment in pair programming
  - Secondary school girl's experiences of pair programming
  - Meta-cognitive teaching learning strategies for pair programming
  - Social skill training for pair programming

Mentz, E. 2011. Pair programming. In Mentz, E., Breed, E. & Havenga, H.M. Teaching-learning strategies for the IT classroom: SANPAD Manual. p21–p42

Action plan given only to CTI+PP group

ACTION PLAN

When planning your lesson

1. Plan authentic problems

Choose topics that are related to learners' everyday life – this includes giving learners authentic problems which include:

- tasks that are learner-centred and focused on what the learners are interested in;
- learning tasks that are not bound to the experience of the classroom;
- having learners engage with others in social discussions regarding problems; and
- allowing learners to make use of higher-order thinking such as analysing, synthesising, designing, manipulating information and evaluating information.

EXAMPLES FROM SCRATCH

Poor question: You are going to create your own scene (it could be a joke, dialogue from a movie, or your own original writing). In addition to using the "say" command, you also need to have your characters change their perception (move, costume) and feel free to add your own voice(s). You can work on this project on your own or with a partner

Better question: You recently saw an advertisement for competition where you could win R5000 for writing the script for a short animated movie (5 minutes) on their favourite IT topic using a programming language of your choice. Knowing that the Scratch programming language is visually based, you decide to make use of Scratch. This is what the judges' score sheet looks like:

Criteria	0	1	2
Originality of script			
Motion of characters			
Plausibility of scenes			
Voice over quality and authenticity			

IMPORTANT:

Although it is suggested that you implement and plan a variety of assignments, these do not all have to be done for one lesson. Do not burden yourself but use this guideline to engage your learners in a variety of assignments

2. Plan a variety of assignments

In computer programming, learners especially have the opportunity not only to do physical coding but also to be engaged in written and oral assignments:

- Give learners an opportunity to plan the programs they have to code on a piece of paper as a written assignment (USE SOCRATIC QUESTIONS Numbers 1–5).
- When implementing the Socratic method as well as pair programming, learners have the opportunity to complete oral assignments as they could present their experience of the assignment to the class – plan the implementation of oral assignments carefully.

3. Plan the pairs for pair programming

- Learners can be divided into pairs before the class starts, saving you time during class.
- Divide learners randomly or specifically.
- DO NOT let learners choose their own partners.
- Rotate partners for every new pair programming lesson.

4. Plan critical thinking strategy

- Decide which critical thinking strategy you want to apply during class: speaking in tongues, compiling an “assumptions inventory”, playing devil’s advocate or specifically focusing on the Socratic questions during class time.

During class time

IMPORTANT:
This discussion does not have to be a lengthy one; it is just a way of introducing your learners to the strategies. They might be a bit apprehensive at first but will soon realise the fruits they will reap from being actively involved.

1. Introduce learners to critical thinking

- If it is the first time you are introducing learners to critical thinking, show them the critical thinking video included in this manual and give them the handouts that are included.
- Explain the different strategies that may be used in class to foster critical thinking (speaking in tongues, compiling an "assumptions inventory", engaging in structured devil's advocacy, ending lectures and discussions with questions, pair programming and Socratic questioning).
- Give learners the handouts that will assist them during pair programming and Socratic questioning.

IMPORTANT:
Although it is suggested that you implement and plan a variety of assignments, these do not have to be all done for one lesson. Do not burden yourself but use this guideline to engage your learners in a variety of assignments

2. Facilitate pair programming

- If it is the first time you are introducing pair programming in your class, show learners the pair programming video included in this manual.
- All of the strategies for promoting critical thinking can be successfully implemented by using pair programming.
  - Speaking in tongues – have each pair share a different perspective to the rest of the class.
  - Compiling an assumptions inventory – have pairs complete a quick journal entry where they describe the assumptions that may have misled them in their answering of questions and assignments.
  - Engaging in structured devil's advocacy – have the navigator scrutinise each statement the driver makes and vice versa. Also let pairs constantly point out the different perspectives that were missed by their fellow pairs during the group processing activity.
  - End lessons with questions and discussions – during group processing learners can discuss the questions that arose during the pair programming session and the way they dealt with these questions.

3. Implement the suggested strategies

IMPORTANT:
Always ask learners to describe the advantages and disadvantages of the approach they are discussing so as to give them an opportunity to engage in critical thought.

- Speaking in tongues
  - Take the topic you are dealing with, for example a program that requires repetition. You can write down different perspectives of how the program could be written by means of different reiteration structures (for, while, repeat, etc.).
  - Have several pairs of learners discuss a different approach. The discussion need not be lengthy and can be a quick introduction followed by the implications these results might hold for the program.
  - Another example is to ask learners, again in their pairs, to illustrate how a program would differ if they take the bottom-up approach rather than the top-down approach and vice versa. In other words, have several pairs work on a presentation for the bottom-up approach and several pairs work on a presentation for the top-down approach.

IMPORTANT:
Have learners complete the assumptions inventory at home when working individually or during group processing when working in pairs.

- Compiling an "assumptions inventory"
  - One way of implementing an "assumptions inventory" in the IT class, is to have the learners revise programs they have written. Ask learners to comment on the assumptions they have made that caused them to make a mistake, for instance, assuming that the random numbers run indefinitely or that the user should be allowed to choose different inputs. Also ask learners to comment on how the program could be applied in a real-life situation.

IMPORTANT:
Make the devil's advocacy a game between learners and yourself.

- Engaging in structured devil's advocacy
  - The devil's advocate states all different sides and constantly asks learners to consider different perspectives and the consequences each perspective will hold for a program. You can have pairs list as many different questions and perspectives as they can and compete with each other.

- Another method is to always counteract a learner's questions with another question or perspective.

IMPORTANT:
Have learners keep their key rings handy so they can refer to the six types of Socratic questions.

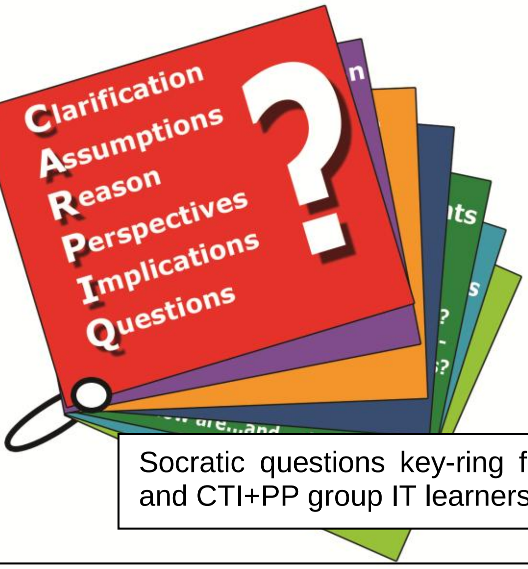
- Socratic questioning
  - During pair programming, ask learners to make use of the six types of questions described.
  - TYPE 3 questions can be implemented during the structured devil's advocacy for instance.
  - TYPE 4 questions are ideal for use in the speaking in tongues strategy.
  - TYPE 2 questions can be used during the assumptions inventory.
  - At the end of a lesson, you can ask learners to tick off QUICKLY which questions they asked and were asked during that lesson.

Wrapping up the lesson

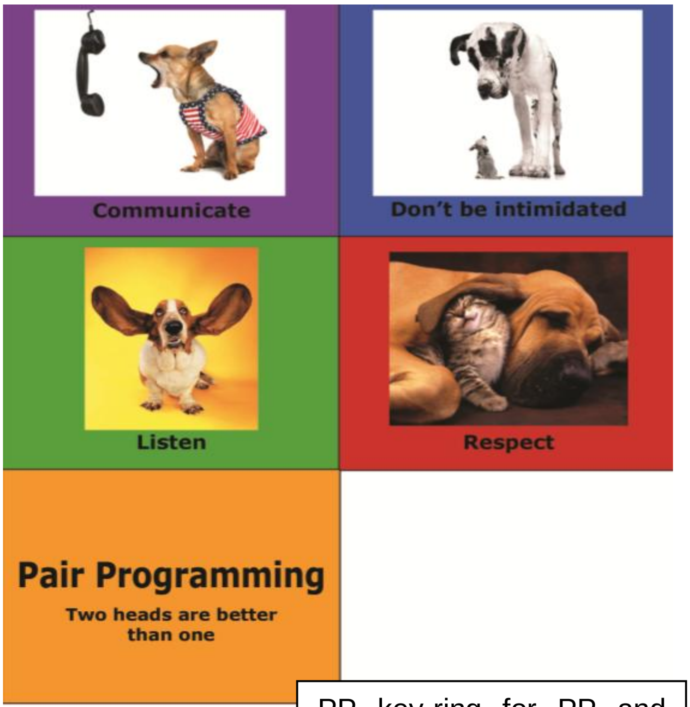
IMPORTANT:
Ask learners to journal their questions for reference when studying for tests. Also emphasise the fact that a good question is just as important as a good answer.

1. Ending the lesson with questions and emphasising metacognition
   - During the last five minutes of class, ask learners to describe quickly what the most challenging question was they were asked during class-time and which answer proved helpful. You can also ask learners to jot down all the questions that they had during the lesson and how they plan on answering these questions in their pairs or individually.
   - A good question is just as important as a good answer.

ADDENDUM B: LEARNING SUPPORT MATERIAL



Socratic questions key-ring for CTI and CTI+PP group IT learners



PP key-ring for PP and CTI+PP group IT learners

CT bookmark for CTI and CTI+PP group IT learners

https://www.youtube.com/watch?v=rG_U12uqRhE : Introduction to Pair Programming – Laurie Williams

https://www.youtube.com/watch?v=39wsZ8rrG5w : Critical thinking – Roxanne Bailey

Videos illustrating PP and CT for IT teachers and learners in CT group (only CT video); CTI+PP group (both videos) and PP group (only PP video)

ADDENDUM C: ETHICAL APPROVAL LETTER (NWU)

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

Private Bag X6001, Potchefstroom
South Africa 2520

Tel: (018) 299-4900
Faks: (018) 299-4910
Web: http://www.nwu.ac.za

Ethics Committee
Tel +27 18 299 4852
Email Ethics@nwu.ac.za

1 July 2013

ETHICS APPROVAL OF PROJECT

The North-West University Ethics Committee (NWU-EC) hereby approves your project as indicated below. This implies that the NWU-EC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the project may be initiated, using the ethics number below.

Project title: TEACHING AND LEARNING STRATEGIES TO PROMOTE SELF-DIRECTED LEARNING

Project Leader: : Prof E Mentz

Ethics number: N W U - 0 0 0 1 0 - 1 3 - A 2 (Institution – Project Number – Year – Status)

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Approval date: 2013/02/14 **Expiry date:** 2018/02/13

Special conditions of the approval (if any): None

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- *The project leader (principle in vestigator) must report in the prescribed format to the NWU-EC:*
  - *annually (or as otherwise requested) on the progress of the project,*
  - *without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.*
- *The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the NWU-EC. Would there be deviated from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.*
- *The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-EC and new approval received before or on the expiry date.*
- *In the interest of ethical responsibility the NWU-EC retains the right to:*
  - *request access to any information or data at any time during the course or after completion of the project;*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the project are revealed or suspected,*
    - *it becomes apparent that any relevant information was withheld from the NWU-EC or that information has been false or misrepresented,*
    - *the required annual report and reporting of adverse events was not done timely and accurately,*
    - *new institutional rules, national legislation or international conventions deem it necessary.*

The Ethics Committee would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the Ethics Committee for any further enquiries or requests for assistance.

Yours sincerely

Prof Amanda Lourens
(chair NWU Ethics Committee)

ADDENDUM D: DEPARTMENT OF EDUCATION APPROVAL LETTER

education

Lefapha la Thuto la Bokone Bophirima
Noordwes Departement van Onderwys
North West Department of Education
NORTH WEST PROVINCE

Quality Assurance Building
No.: 861 Modiri Molema Drive, Montshiwa
Private Bag X2044,
Mmabatho 2735
Tel.: (018) 397-3011
Fax: (018) 397-3047
e:mail: ephetlhu@nwpg.gov.za

CHIEF DIRECTORATE: QUALITY ASSURANCE

Enq : Godisamang Poti
Tel : 018 397 3016/44
Email : GPoti@nwpg.gov.za

TO : DISTRICT DIRECTORS
AREA MANAGERS
CIRCUIT MANAGERS

DATE : 29 OCTOBER 2013

SUBJECT : PERMISSION TO CONDUCT RESEARCH

This serves to inform you that Ms Roxanne Bailey registered PhD student at the North- West University has requested and has been granted permission to conduct research in the schools of the North-West Province.

The collection of data is subject to the following conditions:

- that it should not interfere with teaching and learning at schools; and
- that the Department will receive a final copy of the research and summary of the research findings be made available.

Your cooperation in this regard will be appreciated.

Thanking you in anticipation.

....
Dr MC Teu
Director-WSD

....
Mr MN Motlhabane
Chief Director- Quality Assurance

education
Lefapha la Thuto la Bokone Bophirima
Noordwes Departement van Onderwys
North West Department of Education
NORTH WEST PROVINCE

Quality Assurance Building
No.: 861 Modiri Molema Drive, Montshiwa
Private Bag X2044,
Mmabatho 2735
Tel.: (018) 397-3011
Fax: (018) 397-3047
e:mail: ephetlhu@nwpg.gov.za

CHIEF DIRECTORATE: QUALITY ASSURANCE

Enq : Godisamang Poti
Tel : 018 397 3016/44
Email : GPoti@nwpg.gov.za

29 OCTOBER 2013

Miss Roxanne Bailey
P O Box 19655
Noordbrug
POTCHEFSTROOM
2522

Madam

RE: PERMISSION TO CONDUCT RESEARCH

This serves to inform you that permission for Ms Roxanne Bailey, registered PhD student at the North-West University to conduct research is herewith granted, subject to the following conditions:

- that it should not interfere with teaching and learning at schools; and
- that the Department will receive a final copy of the research and summary of the research findings be made available.

We wish you all the best in your research study.

....
Dr MC Teu
Director-WSD

....
Mr MN Motlhabane
Chief Director- Quality Assurance

education
FREE STATE PROVINCE

Enquiries: BP Mojau
Reference: 16/4/1/49- 2013

Tel: 051 404 9287
Fax: 086 725 7588
E-mail: research@edu.fs.gov.za

2013 – 12 - 20

101 Villa Louanne
Potchefstroom
2531

Dear Me R Bailey

REGISTRATION OF RESEARCH PROJECT

1. This letter is in reply to your application for the registration of your research project.
2. Research topic: **Developing Information Technology learners' critical thinking skills: Implications for self-directed learning.**
3. Your research project has been registered with the Free State Education Department.
4. Approval is granted under the following conditions:-

4.1 The name of participants involved remains confidential.

4.2 The questionnaires are completed and the **interviews are conducted outside normal tuition time**.

4.3 This letter is shown to all participating persons.

4.4 A bound copy of the report and a summary on a computer disc on this study is donated to the Free State Department of Education.

4.5 Findings and recommendations are presented to relevant officials in the Department.

5. The costs relating to all the conditions mentioned above are your own responsibility.
6. **You are requested to confirm acceptance of the above conditions in writing to:**

DIRECTOR: STRATEGIC PLANNING, POLICY AND RESEARCH,
Old CNA Building, Charlotte Maxeke Street OR Private Bag X20565,
BLOEMFONTEIN, 9301

We wish you every success with your research.

Yours sincerely

MJ MOTHEBE
DIRECTOR: STRATEGIC PLANNING, POLICY AND RESEARCH

Directorate: Strategic Planning, Policy & Research - Private Bag X20565, Bloemfontein, 9300 – Room 301, Old CNA building, Maitland Street, Bloemfontein 9300 - **Tel: 051 404 9283** / Fax: **086 6678 678** E-mail: **research@edu.fs.gov.za**

Enquiries: Motshumi KK
Reference:
Tel: 051 404 9290
Fax: 086 667 8678
E-mail: motshumikk@edu.fs.gov.za

education
Department of Education
FREE STATE PROVINCE

OFFICE OF THE DIRECTOR:
STRATEGIC PLANNING, POLICY DEVELOPMENT & RESEARCH

20 December 2013

Dear Me R Bailey

RE: APPROVAL TO CONDUCT RESEARCH IN THE FREE ST ATE DEPARTMENT OF EDUCATION

1. This letter serves as an acknowledgement for receipt of your research request in the Free State Department of Education towards PHD in Computer Science Education .

2. Research topic: **Developing information Technology learners' critical thinking skills: implications for self-directed learning**

3. Approval is granted for you to conduct research in the Free State Department of Education.

4. This approval is subject to the following conditions:-

   4.1 The names of participants involved remain confidential.

   4.2 The questionnaires are completed and the **interviews are conducted outside normal tuition time or during free periods**.

   4.3 This letter is shown to all participating persons.

   4.4 A bound copy of the research document and a soft copy on a computer disc should be submitted to the Free State Department of Education (Strategic Planning, Policy Development & Research).

   4.5 You will be expected, on completion of your research study, to make a presentation to the relevant stakeholders in the Department.

   4.6 The attached ethics document must be adhered to in the discourse of your study in our department.

5. The costs relating to all the conditions mentioned above are your own responsibility.

6. You are requested to confirm acceptance of the above conditions in writing, within seven days after receipt of this letter. Your acceptance letter should be directed to:

   DIRECTOR: STRATEGIC PLANNING, POLICY DEVELOPMENT AND RESEARCH, Old CNA Building, Maitland Street OR Private Bag X20565, BLOEMFONTEIN, 9301

Thank you for choosing to research with us. We wish you every success with your study.

Yours faithfully

MJ MOTHEBE (DIRECTOR: STRATEGIC PLANNING, POLICY DEVELOPMENT & RESEARCH)

Directorate: Strategic Planning, Policy Development & Research - Private Bag X20565, Bloemfontein, 9300 – Room 301, Old CNA building, Charlotte Maxeke, Bloemfontein 9300 - Tel: 051 404 9283/ Fax: 086 6678 678 E-mail: research@edu.fs.gov.za education

Department of Education
FREE STATE PROVINCE

Enquiries: PB Mojau
Reference no. : 16/4/1/49 - 2013
Email:research@edu.fs.gov.za

Tel: 051 404 9287
Fax: 086 725 7588

2013-12 -20

TO: The District Director:

- Motheo Distinct;
- Xhariep District;
- Lejweleputswa District;
- Fezile Dabi District;
- Thabo Mofutsanyane District.

Dear District Director

NOTIFICATION OF A RESEARCH PROJECT IN YOUR DISTRICT

Please find attached copy of the letter giving **Me R Bailey** permission to conduct research in all Education District.

Me R Bailey is a Full time student .

Yours sincerely

MJ MOTHEBE
DIRECTOR: STRATEGIC PLANNING, POLICY AND RESEARCH

Directorate: Strategic Planning, Policy & Research; Old CNA Building, Maitland Street, Private Bag X20565, Bloemfontein, 9300 - **Tel: 051 404 9287** / 9275; **Fax: 051 404 9274 - E-mail: research@edu.fs.gov.za**

Province of the
EASTERN CAPE
EDUCATION

STRATEGIC PLANNING POLICY RESEARCH AND SECRETARIAT SERVICES
Steve Vukile Tshwete Complex • Zone 6 • Zwelitsha • Eastern Cape
Private Bag X0032 • Bhisho • 5605 • REPUBLIC OF SOUTH AFRICA
Tel: +27 (0)44 604 45 37 • Fax: +27 (0)40 608 45 74• Website: www.ecdoe.gov.za

Enquiries: Dr Heckroodt Email: bornetia@iafrica.com

30 January 2014

Ms. Roxanne Bailey
PO Box 19655
Noordbrug
POTCHEFSTROOM
2522

Dear Ms. Bailey

PERMISSION TO DO RESEARCH IN THE EASTERN CAPE DEPARTMENT OF EDUCATION FOR A DOCTORAL DEGREE: DEVELOPING INFORMATION TECHNOLOGY LEARNERS' CRITICAL THINKING SKILLS: IMPLICATIONS FOR SELF-DIRECTED LEARNING

1. Thank you for your application to conduct research.
2. Your application to conduct the above mentioned research at schools which have Information Technology as a Subject is hereby approved. The Eastern Cape Department of Education will supply a contact list of these schools on or before 5 February 2014 to you.

   The research is approved on condition that:

   a. there will be no financial implications for the Department;

   b. institutions and respondents must not be identifiable in any way from the results of the investigation;

   c. you present a copy of the written approval letter of the Eastern Cape Department of Education (ECDoE) to the Chief Directors and Directors before any research is undertaken at any institutions within that particular district;

   d. you will make all the arrangements concerning your research;

30 January 2014

PGDP EASTERN CAPE

building blocks for growth

Page 1 of 2

Ilizwe eliqaqambileyo!

e. the research may not be conducted during official contact time, as educators' programmes should not be interrupted;

f. should you wish to extend the period of research after approval has been granted, an application to do this must be directed to the Director: Strategic Planning Policy Research and Secretarial Services;

g. the research may not be conducted during the fourth school term, except in cases where a special well motivated request is received;

h. your research will be limited to those schools or institutions for which approval has been granted, should changes be effected written permission must be obtained from the Director – Strategic Planning Policy Research and Secretariat Services;

i. you present the Department with a copy of your final paper/report/dissertation/thesis free of charge in hard copy and electronic format. This must be accompanied by a separate synopsis (maximum 2 – 3 typed pages) of the most important findings and recommendations if it does not already contain a synopsis. This must also be in an electronic format.

j. you are requested to provide the above to the Director: The Strategic Planning Policy Research and Secretarial Services upon completion of your research.

k. you comply to all the requirements as completed in the Terms and Conditions to conduct Research in the ECDoE document duly completed by you.

l. you comply with your ethical undertaking (commitment form).

m. You submit on a six monthly basis, from the date of permission of the research, concise reports to the Director: Strategic Planning Policy Research and Secretariat Services.

3. The Department reserves a right to withdraw the permission should there not be compliance to the approval letter and contract signed in the Terms and Conditions to conduct Research in the ECDoE.

4. The Department will publish the completed Research on its website.

5. The Department wishes you well in your undertaking. You can contact the Chief Director, Mr GF Mac Master Heckroodt on mobile number 083 275 0710 and landline 040 608 4773 and email: gregferdmacmaster@gmail.com and greg.macmaster@edu.ecprov.gov.za, should you need any assistance.

DR. AS HECKROODT
DIRECTOR: STRATEGIC PLANNING POLICY RESEARCH AND SECRETARIAT SERVICES

30 January 2014

building blocks for growth. Page 2 of 2 PGDP Eastern Cape *Masa siSebenzisane!*

ADDENDUM E: LETTER TO SCHOOL PRINCIPAL AND INFORMATION TECHNOLOGY TEACHER

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Faculty of Education Sciences

Miss Roxanne Bailey
P.O.Box 19655
Noordbrug
Potchefstroom
2522
sanpadcomp@nwu.ac.za

Principal of "School"

PERMISSION TO CONDUCT RESEARCH IN "SCHOOL'S NAME"

I am enrolled for a PhD in Computer Science Education at the North-West University (Potchefstroom Campus), under the supervision of Prof Elsa Mentz. For my doctoral study I am conducting research on the development of critical thinking skills of Grade 10 Information Technology (IT) learners in three provinces in South Africa.

With the rapid changes in access to information learners need to acquire the skills necessary to be self-directed and in doing so take responsibility for their own learning and become lifelong learners. One of skills that have been proven to assist learners in their self-directedness is critical thinking skills. Critical thinking skills have been shown to be necessary not only for success in computer programming but also in everyday life.

In order to assist IT learners in their endeavour to succeed in the subject as well as assisting IT teachers in teaching the subject, I hereby request you to allow me to conduct research at your school in Grade 10 IT class[es] as this will help me build theory regarding the impact of critical thinking on IT learners' self-directed learning.

In 2014 I plan on conducting a pre-test with two questionnaires (Cornell Critical thinking test Level X and the Self-Directed Learning Instrument (SDLI) designed by Cheng *et al*. (2010)), implementing an intervention on the development of critical thinking skills and conducting a post-test afterwards. The intervention will include having some of the schools partake in a voluntary after school short course on critical thinking skills. Other schools will partake in the voluntary short course on critical thinking skills in conjunction with the teacher implementing pair programming in the IT class. Another group of schools will only implement pair programming without any deliberate critical thinking skills development. In order to successfully conduct a research project of this nature, a control group will also be used where learners will only complete the two questionnaires and no interventions will be done. I cannot yet say in which group your school will fall as this is yet to be determined by the sampling process of the research project.

All data gathered regarding schools, IT teachers and IT learners will be kept confidential. Results from the study will be made available to you upon request. It is also important to note that I will, as far as possible, not disrupt any teaching time apart from the two times (Once at the beginning of 2014 and once at the end of 2014) where learners complete the questionnaires.

I would appreciate it greatly if you would grant me permission to conduct this research in your school. I am convinced that this research will contribute to more effect IT education in South Africa and will also strengthen the relationship between the university and schools.

If you would be so kind as to complete the return slip with your decision and send it back to me via email, I will appreciate it greatly. I also included a return slip with your IT teacher's decision as to whether he/she would be willing to participate in the research.

Feel free to contact me if you need any more information or if you would like me to contact you in any regard.

Contact details:

Miss Roxanne Bailey (Researcher)

Cell: 084 066 2084

Prof Elsa Mentz (Promoter)

Tel: 018 299 1858

Miss Roxanne Bailey (Researcher) **Date**

RETURN SLIP FROM PRINCIPAL

I _________________________ (principal of school) hereby grant/do not grant (underline the appropriate statement) Miss Roxanne Bailey permission to conduct research in my school.

Comments:

____

____

____

__________________ ______________

Principal signature **Date**

RETURN SLIP FROM IT TEACHER

I _________________________ (IT teacher's name) hereby grant/do not grant (underline the appropriate statement) Miss Roxanne Bailey permission to conduct research in my IT class.

Comments:

____

____

____

__________________ __________________ ______________

IT teacher signature **Cell phone number** **Date**

I will be contacting you to arrange details regarding appropriate times for my visits to your class and other arrangements.

ADDENDUM F: INFORMED CONSENT FORM FOR PARTICIPANTS

NORTH-WEST UNIVERSITY ®
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS
Private Bag X6001, Potchefstroom
South Africa 2520
Tel: (018) 299-1858/4769
Web: http://www.nwu.ac.za

VOLUNTARY CONSENT FORM

PARTICIPATION IN INFORMATION TECHNOLOGY EDUCATION RESEARCH PROJECT

Dear Parent/Legal guardian

For my PhD study I am conducting research on the development of critical thinking skills for Grade 10 Information Technology (IT) learners. IT learners often struggle with the programming component of the subject which makes up 60% of the IT syllabi. With my research on the development of critical thinking skills, I aim at addressing this problem and assisting IT learners in South Africa with the successful mastery of IT as a subject but also to become more self-directed learners to cope with the challenges of life. As this study will grant me insight into IT learners' needs and experiences of critical thinking skills it is of utmost importance that **all** IT learners participate in the research.

For learners to be able to participate, parents' written consent is required. Will you be so kind to complete this form as soon as possible? If you do not wish to have your child participate in this research, it will not be held against him/her, as participation is voluntary, but participation will benefit them greatly.

Yours sincerely
Miss Roxanne Bailey

Section 1: General project information

1. **Project title:**

Developing Information Technology learners' critical thinking skills: implications for Self-Directed Learning.

2. **Institution:**

North-West University (Potchefstroom Campus)

3. **Names and contact information:**

PhD student	
Title, name, surname	Miss Roxanne Bailey
Qualification	MEd
Cell phone	0840662084

Voluntary informed consent form

4. Purpose of the project:

To support and develop IT teaching and learning, in particular critical thinking skills development in South Africa.

5. What will be expected of the participants:

Learners will be expected to complete two questionnaires twice (Once at the beginning of 2014 and once at the end of 2014). Participation in the project is voluntary and learners may withdraw from the research at any time.

6. Participants' confidentiality will be ensured in the following way:

The researcher will ensure that the information on ALL questionnaires is treated confidentially. No personal information of any learner will be disclosed in any way. Data will be extracted immediately after completion and will only be used for scientific purposes. Results will be kept in storage, and only researchers in the project will have access to this data.

Section 3: Consent

Permission for Research Project:

Developing Information Technology learners' critical thinking skills: implications for Self-Directed Learning

STATEMENT OF CONSENT: PARENT'S OF LEARNER

I,________________________(mother's full name and surname) and I, __________________________ (father's full name and surname) of __________________________ (learner's full name and surname) hereby grant permission that ______________________(name of learner) may participate in the research project and understand the above mentioned information.

I understand that my child does not have to participate in this research and that this will not be held against him/her.

________________________________ ___________________________

Signature of Mother Date

________________________________ ___________________________

Signature of Father Date

OR

________________________________ ___________________________

Signature of Legal Guardian Date

ADDENDUM G: STATISTICAL ANALYSES LETTER:

(NWU STATISTICAL CONSULTATION SERVICES)

SKD
SCS

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Private Bag X6001, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Web: http://www.nwu.ac.za

Statistical Consultation Services
Tel: +27 18 285 2447
Fax: +27 0 87 231 5294
Email: monique.vandeventer@nwu.ac.za

21 October 2015

Re: Thesis/dissertation/mini-dissertation, Ms R Bailey, student number: 20403593

We hereby confirm that the Statistical Consultation Services of the North-West University analysed the data involved in the study of the above-mentioned student and assisted with the interpretation of the results. However, any opinion, findings or recommendations contained in this document are those of the author, and the Statistical Consultation Services of the NWU (Potchefstroom Campus) do not accept responsibility for the statistical correctness of the data reported.

Kind regards

Dr SM Ellis (Pr. Sci. Nat)
Head: Statistical Consultation Services

Original details: Monique van Deventer(12256307) Q:\Algemeen - nie konsultasie\Stylblaaie_Style sheets\Brief verhandeling_Eng.docm
23 April 2014

ADDENDUM H: LANGUAGE EDITOR CONFIRMATION LETTER

Jackie Viljoen
Language Editor and Translator
16 Bergzicht Gardens
Fijnbos Close
STRAND 7140

Accredited member of the South African Translators' Institute
No APSTrans 1000017
Member of the Professional Editors' Group (PEG)

☎ +27+21-854 5095 082 783 0263 086 585 3740
Postal address: 16 Bergzicht Gardens, Fijnbos Close, STRAND 7140 South Africa

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DECLARATION

I hereby certify that the thesis by **ROXANNE BAILEY** was properly language edited but without viewing the final version.

The track changes function was used and the author was responsible for accepting the editor's changes and for finalising the reference list.

Title of thesis:
DEVELOPING INFORMATION TECHNOLOGY LEARNERS' CRITICAL THINKING SKILLS: IMPLICATIONS FOR SELF-DIRECTED LEARNING

JACKIE VILJOEN
Strand
South Africa
21 October 2015