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How teachers actualise critical thinking skills in the Technology classroom

by

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Abstract

The purpose of this study was to investigate the manner in which technology teachers actualise critical thinking skills while supporting learners to solve technological problems. Technology as a subject was introduced in South African schools by the Department of Basic Education (DBE) with the intention to, *inter alia*, develop learners' critical thinking skills while using the prescribed design process. The Curriculum and Assessment Policy Statement (CAPS) for technology stipulates that technology should provide learners with the opportunity to solve authentic problems that are embedded in real-life experiences. Solving these authentic technological problems requires learners to engage with critical thinking skills. This entails learners interpreting, analysing, evaluating information, drawing inferences, providing an explanation, and conducting self-regulations.

While the importance of critical thinking is widely acknowledged, it seems that teachers find it difficult to actualise these critical thinking skills in the classroom. In addition to this, the literature suggests that technology teachers limit their teaching to the lower cognitive levels, failing to develop learners' higher-order thinking abilities. This is problematic and a reason for concern. This study thus sought to investigate this problem.

The conceptual framework used in the study was based on the design process as prescribed by the DBE (2011) and Facione's (1990) critical thinking skills framework. The design process involves the following skills, to: Investigate, Design, Make, Evaluate, and Communicate (IDMEC). Facione's critical thinking skills encompass: Interpretation, Analysis, Evaluation, Inference, Explanation, and Self-Regulation. These critical thinking skills were linked to the DBE design process to demonstrate the way in which critical thinking skills could be actualised within the different steps of the design process.

This study engaged in qualitative research using a multiple case study design. Purposive sampling was used to select the participants. Technology teachers who obtained a Bachelor of Education in technology education with at least four years of experience teaching technology were considered as suitable participants. Data was collected by means of structured interviews and observations. Data was analysed using the conceptual framework.

The research findings revealed that the sampled technology teachers had a limited understanding of what critical thinking entails. Also, the selected technology teachers were unable to explain how they support their learners in developing critical thinking skills. While the DBE outlines how technology teachers should use the design process, the observations indicated that the participants did not engage with the design process as stipulated in the CAPS document for technology.

This study recommends that technology teachers' understanding of critical thinking, critical thinking skills and the disposition of critical thinking should be deepened. A proper understanding of critical thinking, and its associated skills and dispositions, are required to ensure that the specific aims of teaching technology are achieved. It is also recommended that technology teachers use the design process as prescribed by the DBE. Using the design process as intended may provide teachers with opportunities to develop critical thinking skills in the classroom.

Key words: Analysis; Critical Thinking Skills; Design Process; Dispositions of Critical Thinking; Evaluation; Inference; Inquisitiveness; Interpretation; Social Cognition; Social Learning.

Declaration of originality

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DECLARATION OF ORIGINALITY

Full names of student: **Malose Isaac Kola**

Student number: **99228255**

Declaration

"I declare that the dissertation, which I hereby submit for the degree Master of Education at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution"

Signature of student..…………………………………………………..…….

Signature of supervisor……………………………………………………..

Signature of co-supervisor………………………………………………….

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Dedication

I dedicate this study to my loving and supportive wife, Nare and my adorable children, Tshegofatso, Kgabo Matjutla, Phuti Lethabo, and Tumisho.

"I am the vine; you are the branches. The one who remains in Me and I in him produces much fruit; because you can do nothing without Me" **(**John 15:5).

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List of Acronyms

ACE	Advanced Diploma in Education
CAD	Computer Aided Drawing
CAPS	Curriculum Assessment and Policy Statement
DBE	Department of Basic Education
IDMEC	Investigate, Design, Make, Evaluate, and Communicate
LED	Light Emitting Diode
NCS	National Curriculum Statement
PAT	Practical Assessment Task
2D	Two - dimensional
3D	Three - dimensional

Chapter 1: Orientation of the study

1.1 Overview of the chapter

The purpose of this study was to investigate how technology teachers actualise critical thinking skills in the classroom. It is hoped that the findings from this study will inform researchers and teachers about the way technology teachers understand critical thinking, and how they support learners to develop critical thinking skills while they solve technological problems.

This chapter starts with an introduction to and background of technology education in South Africa, and highlights the importance of developing critical thinking skills in the classroom. This is followed by the rationale of the study; problem statement; research questions; and an explanation of the key terms that are used in reporting this research. The chapter concludes with the outline and organisation of the dissertation.

1.2 Introduction and background

The South African Department of Basic Education (DBE) introduced technology into the Senior Phase (Grade 7-9) of the school curriculum due to the need to produce engineers, technicians, and artisans, which are in demand in modern society (DBE, 2011:8). Technology should, according to the DBE (2011:8), inspire learners to be creative and to develop the critical thinking skills required by a technology-driven world. One of the unique features and the scope of technology education specify that learners should be provided with opportunities to learn through applying various skills that are pertinent to real life situations in authentic contexts (DBE, 2011:9). These skills include the ability to think critically and innovatively; work in partnership; be able to identify needs; and solve problems using the design process (DBE, 2011:9-10).

The specific aims of technology education state that technology must contribute towards learners' technological literacy by providing them with opportunities to, *inter alia*, "develop and apply specific design skills to solve technological problems" (DBE, 2011:8). Atkinson (2000:255) highlights that design in technology provides suitable opportunities for learners to develop critical thinking and problem solving skills.

The fundamental goal of teaching the design process is to promote cognitive skills that are essential for solving technological problems (Mioduser & Dagan, 2007:137). The design process is considered by the DBE as the backbone for teaching technology and should, therefore, be used to structure the delivery of all learning aims (2011:12). The design process entails the ability to Investigate, Design, Make, Evaluate, and Communicate (DBE, 2011:12).

Duran and Sendaĝ (2012:241) assert that it is essential that learners are taught skills such as investigating, analysing information, and reflecting, which are vital for the development of critical thinking. Ku (2009:70) avows that it is important to teach critical thinking since learners should develop reasoning capacities that are essential in a rapidly changing world. Likewise, critical thinking skills enable learners to review information, evaluate alternative evidence, and demonstrate the ability to justify their arguments.

Yang and Chou (2008:661) note that teaching learners to think critically is important because critical thinking is fundamental in the workplace for decision making, leadership, scientific judgement, professional success and reflective participation in society. Abrami, Bernard, Borokhorski, Wade, Surkes, Timim, and Zhang (2008:1103) point out that critical thinking enables learners to contribute meaningfully to society. Jeevantham (2005:127) highlights that critical thinking enables people to solve the problems that society is confronted with. Halpern (1998:450) stresses that the rate at which knowledge develops has become more rapid - it is therefore imperative to develop individuals who are able to think critically and who will be able to solve future problems.

Dam and Volman (2004:366) add that the aim of critical thinking is to teach diverse citizens to make significant contributions, and emphasises that most instructional strategies for critical thinking should be aimed at this. Yang (2008:24) affirms that learners should be given the opportunity to think without obstruction, and should be able to justify their own thoughts to one another. The capacity to think critically and present arguments is a valuable skill that may help learners when confronted with technological problems. Therefore, educational institutions should support learners in the development of critical thinking skills.

Jakovljevic, Ankiewicz, De Swardt and Gross (2004:262) note that teachers seldom expose learners to technological problems that are appropriate to their level of knowledge and skills. Jonassen (2000:63) adds that technology learners hardly solve authentic (real-life) technological problems as envisaged by the curriculum. Consequently, these learners solve a few fragmented, isolated problems that are well-structured and therefore these learners might finish their studies without the ability to solve meaningful problems.

Although it is important to develop learners' critical thinking skills, teachers rarely teach critical thinking skills (Kuhn, 1999:16). Reed and Kromrey (2001:202) claim that most learners, after spending many years in the education system, lack critical thinking skills. The literature shows that the development of critical thinking is often not considered by technology teachers, and that they rather focus on the recall of facts and knowledge using repetitive strategies that are not stimulating (Viera, Tenreiro-Viera, & Martins, 2011:52).

A study conducted by Mok (2009:276) reveals that learners are not given enough opportunities to develop critical thinking skills in the classrooms. Teachers seem to dominate classroom interaction and learners are provided with little or no chance to share their experiences. As a result, learners are not exposed to solving problems that would enable them to develop critical thinking skills. Atkinson and Sandwith (2014:164) attest that research reveals that many technology teachers lack the necessary conceptual knowledge to solve technological problems. This negatively affects their confidence in teaching the design process and their ability to support learners efficiently through the design process.

Many teachers find it difficult to strike a balance between teaching the design process and teaching technology knowledge (William, 2008:282). Mawson (2003:120) reiterates that both teachers and learners fail to follow the design process as prescribed by policy; instead they adjust the finished product to suit the design process. The way in which the design process is used is different to how expert designers work. As a result, the design process is rather an administrative activity for teachers, particularly those who lack the expertise to teach the subject (Mawson, 2003:120).

Duran and Sendaĝ (2012:242) explain that teachers acknowledge the importance of developing critical thinking skills, but find it difficult to determine the instructional strategies that are suitable to actualise critical thinking skills in the classroom. Technology education involves the creation of artefacts that solve technological problems. Unfortunately, designing and making artefacts are often considered by critics of technology as activities that do not stimulate critical thinking (Mitcham, 1994:1). These critics believe that the making of artefacts merely involves assembling procedures (Jones, 1997:90).

Makina (2010:24) highlights that teachers are productive in presenting content knowledge, but not effective in actualising critical thinking skills. Pitchers and Soden (2000:239) add that teachers are not trained to instil critical thinking skills, and as a result teachers are not clear on what is expected of them in order to develop critical thinking skills. It is important for teachers to develop higher-order thinking capabilities so that they are able to actualise critical thinking skills in their learners (Lombard & Grosser, 2008:213).

Teachers spend too much time providing information to learners and ensuring that learners understand the subject rather than actualising critical thinking skills. Emphasis is placed on content knowledge (Haas & Keeley, 1998:63). Noor (2009:57) stresses that learners should be equipped to become future problem solvers and skilful decision makers with critical thinking capabilities. Furthermore, it is essential for learners to be critical thinkers, which they will require as citizens who could potentially and rapidly change the social order of society.

Van Gelder (2005:41) highlights that virtually every institution agrees that the development of critical thinking skills should be the main aim of education since it teaches learners to solve problems. Stapleton (2011:15) affirms that it is clear that there is a need to support learners to develop critical thinking skills, however, the undisputable comprehension of the concept and strategies to implement critical thinking continue to be blurred. Pienaar (2001:128) adds that the term critical thinking is widely used in educational policy documents, but the criteria to realise critical thinking in the classroom are rarely specified. Moore (2010:61) affirms that critical thinking is neither taught in schools nor universities, although its importance is highly emphasised.

1.3 Rationale of the study

The introduction and advancement of critical thinking skills in education are regarded as important, but there is limited research available that can be used to guide teachers on how to enhance critical thinking (Halpern & Marin, 2011:1). Recent publications have focused on assessing post-secondary learners' critical thinking and identified areas for curricular reforms. However, a few studies on critical thinking skills among high school technology learners are available (Miri, David, & Uri, 2007:356). Msila (2014:41) reports that most teachers merely teach learners to pass the examinations and fail to develop critical thinking skills. Further research is required to investigate how teachers can enhance critical thinking skills (Msila, 2014:41).

According to Dunn, Halonen, and Smith (2008: xivi), and Van Gelder (2005:41), most people acknowledge that one of the fundamental aims of education is to develop critical thinking, but it is difficult to support learners in achieving critical thinking. There are extensive initiatives and instructional strategies designed to develop critical thinking from various institutions, but little empirical research has been conducted to determine the attributes that support the development of critical thinking skills (Clifford, Boufal, & Kurtz, 2004:169).

Research conducted by Mathumbu, Rauscher and Braun (2014:7-8) reveals that teaching in the technology classroom is restricted to engage only lower-order thinking. The findings from this research are problematic and a reason for concern. Mathumbu et al. (2014:8) emphasise that if learners are not supported to develop higher-order thinking skills, the aims and the purpose of technology education are not accomplished and this may have implications for further studies and employment in key sectors such as engineering and other technological fields.

In the light of the above, it was deemed necessary to investigate how technology teachers actualise critical thinking skills in the classroom. Although the DBE (2011:11) states that learners' critical thinking skills must be developed, the Curriculum and Assessment Policy Statement (CAPS) provide little guidance as to how these critical thinking skills should be developed. The CAPS document stipulates that the design process is the mainstay of teaching technology, but it fails to inform technology teachers of how exactly critical thinking skills can be developed by using the design process.

1.4 Problem statement

From section 1.2 and 1.3 it is clear that learners should be taught critical thinking skills. It seems, however, that technology teachers are not equipped with the appropriate knowledge and skills to actualise critical thinking skills while supporting learners to solve technological problems. Also, Mathumbu et al. (2014:7-8) point out that higher-order thinking skills are not developed in the technology classroom. This is a problem that needs to be investigated; this study is an attempt to examine this issue.

1.5 Research questions

The following main research question was asked:

How do teachers actualise critical thinking skills in the technology classroom?

To address the main question, the following sub-questions were posed:

(i) What is technology teachers' understanding of critical thinking?
(ii) What opportunities does CAPS offer for fostering critical thinking skills in the technology classroom?
(iii) How do technology teachers connect a particular CAPS opportunity to critical thinking principles?

1.6 Explanation of key terms

1.6.1 Technology

The term technology is etymologically derived from the Greek word *techné* which is translated as 'art', 'craft' or 'skill' (Mitcham, 1994:128-129; Woodruff, 2011:9; Daker, 2005:73) and *logos* which, in this case, refers to the study of *techné* (Daker, 2005:73). Technology encompasses all artefacts used by people to advance their lives (Benenson & Piggott, 2002:68). Clarke (2005:143) views technology as the assortment of artefacts that are meant to work efficiently.

Technology encompasses the way humans develop, realise, and use (and evaluate) all sorts of artefacts, systems, and processes to improve the quality of life (Rossouw, Hacker, & De Vries, 2011:410). The DBE (2011:11) defines technology as:

> *The use of knowledge, skills, values, and resources to meet people's needs and wants by developing practical solutions to problems, taking social and environmental factors into consideration.*

The latter definition of technology has been used in this study.

1.6.2 Technological literacy

Technological literacy refers "to the ability to use, understand, manage and evaluate Technology" (DBE, 2011:72). The essence of technology literacy is the skill to analyse information and simplify multifaceted ideas in solving exceptional problems (Judson, 2010:272). Technology literacy is what people need to live in, and control, the technological environment that surround them (Rossouw et al., 2011:410).

1.6.3 Technology education

Technology education is a field of study that provides learners with an opportunity to develop technological literacy and acquire the essential knowledge to solve problems (Wicklein, Smith, & Kim, 2009:1). Benenson and Piggott (2002:3) highlight that technology education entails critical evaluation of the purpose and effects of artefacts and the environment while using design to enhance technology.

1.6.4 Artefact

An artefact "is a manufactured object" (DBE, 2003:66). Artefacts are frequently regarded to be key to what technology is (Stables, Benson, & De Vries, 2011:10). McRobbie, Ginns, and Stein (2000:81) highlights that technology leads to the manufacturing of artefacts. Frederik, Sonneveld and De Vries (2010:1) state that structures such as buildings, cars, computers, and televisions are some of the artefacts manufactured using technology. In this study, artefacts refer to the outcome or results of projects. Ball (1997:247) states that engineering is one of the fields that essentially produce artefacts that achieve certain requirements and the design process is used to develop artefacts.

1.6.5 Critical thinking

Critical thinking is the art of analysing and evaluating ideas with a view to improving them (Paul & Elder, 2008:2). Evans (1993:16) adds that critical thinking is thinking that is reasonable and reflective, and is focused on deciding what to believe or do. Paul, Binker, Martin and Adamson (1989:353) describe critical thinking as skilled thinking, characterised by empathy, into diverse opposing points of view and devotion to truth as against self-interest.

Facione (1990:6) describes critical thinking as:

> *Purposeful, self-regulatory judgement which results in interpretation, analysis, evaluation, and inference as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgement is based. Critical thinking is essential as a tool of inquiry. As such, critical thinking is a liberating force in education and a powerful resource in one's personal and civic life.*

The above definition of critical thinking was used as the working definition in this study. The skills of Interpretation, Analysis, Evaluation, Inference, Explanation, and Self-regulation are of particular importance as they are considered as essential critical thinking skills (Facione, 1990:15).

1.6.6 Design problem solving

Technology requires learners to design artefacts in order to solve technological problems or meet people's needs. The term "problem" means undesirable circumstances that need to be resolved. Problem solving involves finding solutions to people's needs by enhancing technological processes (Barak & Shachar, 2008:287). The design process is the fundamental technique used in technology to solve design problems. The design process embraces a cognitive approach in solving problems (Jones & De Vries, 2009:393).

Lewis (2006a:257) adds that design comprises different procedural tactics whereby learners are provided with open-ended problems that compel them to develop alternative solutions. In the South African context, the design process is used to solve problems while engaging the different steps of the prescribed process, namely to investigate, design, make, evaluate and communicate. Furthermore, the design process refers to "a creative and interactive approach used to develop solutions to identified problems or human needs" (DBE, 2011:67).

1.6.7 Constraints

Jonassen (1997:69) finds that various ill-structured problems possess constraints that are caused by situations or the artefacts' users. Taylor and Hauck (1991:82) affirms that constraints delineate the degree to which the problem is outlined, and constraints are dealt with during problem formulation. The DBE (2011:66) describes constraints as: "aspects that limit conditions within which the work or solution must be developed, e.g. time, materials, tools, human resources, cost, etc." Constraints in this study refer to the restrictions or limitations that a particular problem has, which the designer may experience when seeking solutions.

1.6.8 Conceptual knowledge

According to Krathwohl (2002:214), conceptual knowledge refers to the interrelationships among the basic elements within a larger structure that enable them to function together. Conceptual knowledge entails knowledge of classifications and categories, knowledge of theories, models, and structures (Krathwohl, 2002:214). Conceptual knowledge refers to teachers' ability to explore and understand what technology is all about, and involves the learning theories applicable to teaching technology (McCormick, 1997:148). McCormick (2004:24) asserts that conceptual knowledge relates to system concepts.

1.6.9 Procedural knowledge

Procedural knowledge refers to how to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods (Krathwohl, 2002:214). Moreover, procedural knowledge involves knowledge of subject-specific skills and algorithms, knowledge of subject-specific techniques and methods, and knowledge of criteria for determining when to use appropriate procedures.

1.7 Outline and organisation of the study

This study consists of five chapters. Table 1.1 presents the outline and organisation of the study.

Table 1.1: Outline and organisation of the study

Chapter	Chapter heading	Chapter description
1	Orientation of the study	Describes the background and rationale of the study, the statement of purpose, the problem statement, research questions, and explanation of key terms.
2	Literature review	Provides an overview of the literature regarding social cognition; social learning; thinking (foundation of critical thinking), the disposition of critical thinking, cognitive mechanisms; and the design process. Additionally, the chapter delineates the conceptual framework.
3	Research design and methodology	A detailed description of the methodology used in this study is described in this chapter. It firstly delineates the research design and the research paradigm. Furthermore, the chapter explains the population and sample, data collection instruments, and data analysis. Standards of rigour for research as well as the ethical considerations are also explained.
4	Discussion of the findings	This chapter discusses the findings and interprets the data. The interpretation of data stems from the question and observation protocols that have been written, including documents.
5	Summary of the findings, limitations, discussion, recommendations and conclusion	The final chapter provides a summary of the previous chapters and the corroboration of research questions. This chapter provides a discussion on the instructional strategies (inquiry-based learning and design-based learning, and play), recommendations and conclusions. The limitations of the study and future research are also presented.

Chapter 2: Literature review

2.1 Overview of this chapter

This chapter presents an overview of the literature regarding social cognition, social learning, and thinking, which form the foundation of critical thinking. This is followed by a discussion of critical thinking, the dispositions of critical thinking, and the skills required for critical thinking. The cognitive mechanisms are also described, as well as the design process, which should be used to solve technological problems in the technology classroom. The design process requires higher order thinking and ought to provide technology teachers with opportunities to actualise critical thinking skills in the classroom. The chapter concludes with the presentation and explanation of the conceptual framework that was used to guide the study.

2.2 Social cognition

Aronson, Wilson, and Akert (1997:99) describe the social cognition theory as the application of the mind to acquire knowledge by means of selecting, interpreting, and using information to make judgements and informed decisions. This description of social cognition theory echoes one of the general aims of the South African curriculum: the National Curriculum Statement (NCS) stipulates that learners should be able to "identify and solve problems and make decisions using critical and creative thinking" (DBE, 2011:5).

Aronson et al. (1997:99) state that people have schemas (cognitive framework or concepts) that assist them to organise information about a particular subject, and these schemas possess a forceful effect on the information people receive, think, and recall. People tend to respond to difficult situations and interpret these situations in accordance with their developed schemas (Aronson et al., 1997:99). Baron, Byrne and Branscombe (2006:41) view social cognition as the phenomenon that encompasses the behaviours that are exhibited when people interpret, analyse, recall, and utilise information in the social environment. In addition to this, social cognition involves the approach in which people perceive and relate to each other in the social world.

Fiske and Macrae (2012:1) regard social cognition as the means through which the world is interpreted and constructed. According to Hewston, Stroebe and Stephenson (1996:111), people reflect on their thoughts and also about how others think. Furthermore, social cognition is concerned with how people reach a particular interpretation of the social world. Baron et al.

(2006:41), and Fiske and Macrae (2012:1) support Aronson et al.'s (1997:99) view of social cognition theory, however, they add that the social cognition theory also involves the skill to analyse. Most importantly, these specified cognitive skills (interpreting, analysis, and reflecting) are practised in social settings whereby people perceive and relate to each other.

According to the Unique Features and Scope section of CAPS, technology should provide learners with the opportunity to learn, *inter alia*, to work collectively with other learners (DBE, 2011:9). One of the general aims of the NCS is to enable learners to "work effectively as individuals and with others as members of a team" (DBE, 2011:5). This emphasises the importance of team work, which can be used to instil social cognition theory.

Technology learners being exposed to ill-structured problems and social cognition theory create a productive classroom environment in which learners search and consider information beyond what is at their disposal. Learners are able to evaluate alternative solutions, and subsequently select the most suitable ideas to solve the technological problem. This could be achieved once learners are enabled to interpret, analyse, and use information to make well informed decisions as alluded to by Aronson et al. (1997:99). Learners in a group possess different mental structures and rely on each other's abilities to seek solutions to technological problems. The next section presents literature regarding social learning. Baron et al. (2006:41), and Fiske and Macrae (2012:1) explain that social cognition entails the way in which people think and relate to each other in a social environment.

2.3 Social learning

According to Bandura (1977:31), people tend to develop the skills to interpret what they have perceived to connected actions, and again convert ideas into structured series of actions. According to Bandura (1977:161), the social learning theory advocates that, to a certain degree, a person's behaviour is influenced and sustained over a certain period of time without being compelled by external stimulation in order to think. In all such instances, persuasion to act requires cognitive skills, and motivation seems to be the key element for people to perceive ideas that will be applicable in the future.

Bandura (1997) believes that, to a great extent, people are not challenged adequately to apply their minds. Bandura's (1997) views confirm what Jones (1997) alludes to in that learners consider the making of artefacts in technology classrooms as an activity that merely involves an assembling procedure, which does not require critical thinking skills. If learners are only exposed to well-structured problems instead of ill-structured problems, they will not develop cognitive skills. Bandura (1997) also suggests that motivation is the key determinant to anticipate ideas that might work in the future. Once learners are successful in solving ill-structured problems, they develop mental structures that enable them to anticipate future solutions.

Bandura (1977:164) finds that whenever people encounter discrepancies between facts and their conceived thoughts, they tend to interpret the facts instead of changing the way that they think. In the event that people have developed the intrinsic motivation or desire to know and acquire knowledge about their social world, this will enable them to progress to the more advanced levels of reasoning.

In light of the views expressed above, it seems that most people rather interpret contradictions between facts instead of examining the way that they think. Most people might find it difficult to develop critical thinking skills since one of the essential dispositions of critical thinking skills, as mentioned by both Facione and Ennis (see Section 2.3.1), is to be open-minded to different views and be flexible to consider alternative views. Being open-minded allows people to be willing to consider new suggestions as they seek solutions to problems, and also to consider different views on the interpretation of a design problem.

Carkett (2004:461) emphasises the views expressed by both Facione and Ennis (see Section 2.3.1) that, in most instances, problem solving in the technology classroom takes place in a collaborative setting. The researcher is of the opinion that learners who work in a collaborative environment with open-minded perspectives learn from others, and subsequently develop cognitive skills that teach them to reason and justify their arguments collectively.

Bandura (1977:171-173) points out that people who have developed cognitive skills are able to solve problems mentally before putting them into action. Subsequently, in order to develop cognitive skills and process information, people seek alternative solutions and evaluate the short and long term effects of the actions taken. In the technology context, the ability to solve problems mentally before putting them into action is relevant since learners should consider the impact of the solutions which they deem suitable for a particular technological problem. Most importantly, learners must choose the solution that best satisfies the specifications (DBE, 2011:68).

From the perspective of social learning, the consequences of an individual action do not constitute an exclusive source of knowledge (Bandura, 1977:181). Furthermore, people observe the results of an individual's actions to reflect on their own thoughts. However, it is not easy to determine the validity of personal thoughts since circumstances differ and depend on individual experience (Bandura, 1977:181). In some instances, people evaluate the rationale of their opinions by examining them against the views of others. In social learning, people either conform to established practices or challenge conventional practices and ways of thinking (Bandura, 1977:181).

Bandura (1977:181) further asserts that people gain some rules of inference as they develop and are able to identify errors by means of logical verification. Ideas are developed from information about occurrences in the social setting within which the available information serves as a proposition. In the event that these propositions are considered to be valid, they then generate logical implications that are used to determine the correctness of these propositions (Bandura, 1977:181). During this state, the rationale of ideas determines the validity of one's reasoning.

My viewpoint is that social learning teaches learners to develop cognitive skills as they examine their thoughts against those of their peers. Also, learners reflect on their own ideas while being mindful of how others reason and justify their actions. Carkett (2004:473) concurs with Bandura's views that ideas enable learners to develop reasoning skills, and adds that solving problems in a social setting supports learners to develop cross-fertilisation of ideas. This results in learners becoming successful at technology activities.

Furthermore, learners who are acquainted with social learning accordingly develop skills to evaluate information, reflect on their ideas, apply the rules of inference, eventually develop critical thinking skills, and succeed in solving technological problems. According to the CAPS document for technology, during the design process learners are required to investigate the situation in order to gain information (DBE, 2011:68). This obliges learners to recognise, anticipate, and interpret the information that has been gained. By implication, the capacity to investigate requires a variety of cognitive skills. Social learning teaches learners to debate different viewpoints that emanate from different backgrounds and experiences. Moreover, a robust exchange of divergent views emerges, and eventually these learners develop skills to reason and justify their viewpoints.

According to Resnick (1987:40-41), the social learning environment establishes opportunities for learners to develop cognitive skills. Thus, both teachers and learners that have developed cognitive skills exhibit the desirable methods of approaching technological problems while analysing the information and constructing a sensible discourse. The next section describes the foundation of critical thinking in order to understand the manner in which thinking is developed.

2.4 Thinking: the foundation of critical thinking

According to Dewey (1934:192), thinking is a skill that requires intellectual competency. Experience plays a vital role, as a lack of experience is frequently considered as sufficient grounds for the development of thinking. Experience enables people to respond generally to familiar situations. Dewey (1934:192) finds that learners should be exposed to genuine settings of experience that provide an opportunity to determine their interests in the learning activity that is provided.

In technology, an authentic problem should be developed by teachers within a prescribed context to provoke thinking. Learners are provided with ill-structured technological problems that provide a sense of incompleteness due to ill-structured design uncertainty. This challenges learners to apply their minds by seeking information and developing solutions to these technological problems.

One of the promoters of Dewey’s philosophy, Ratner (1939:837), describes thinking as “The maximum of reasonable certainty and the mind seizes upon the nearest or most convenient instrument of dismissing doubt and re-attaining security.” This description indicates that in solving ill-structured technological problems, the first positive ideas that learners conceptualise stimulate them to construct their thoughts with confidence. During investigation, once learners are able to gather the applicable information and determine the manner in which the gathered information connects to key concepts, then learners develop insight to seek the technological solution (DBE, 2011:68).

Ratner (1939:837) describes thinking as an occurrence of uncertainty being experienced that incites personal belief. The purpose of thinking is to develop knowledge and establish an unwavering state of equilibrium. In the event of doubt (uncertainty), the mind snatches the most suitable instrument that terminates uncertainty and retains assertion. Moreover, thinking is the comprehensive search for solutions and requires the thinker to develop a structured method of inquiry. The process of thinking pursues potentials by making reference to specific experiences (Ratner, 1939:844). Vygotsky (2006:157) defines thinking as:

> *Thinking constitutes, basically, only a combination of ordinary associative process, of the highest and most complex order, i.e., that it is a simple relation of verbal reactions. That aspect of thinking by virtue of which it comes to be viewed as part of behaviour, as an ensemble of the organism's motor reactions. Every thought associated with movement induces on its own a certain preliminary straining of a corresponding muscular system that tends to be expressed in movement. If it remains only a thought, then since this movement is not brought to fruition and is not fully disclosed, it remains concealed in an entirely tangible and effectual form.*

According to the CAPS document, the design process is considered as the backbone for teaching technology (DBE, 2011:12). The design process is an important cognitive activity that entails the mental structuring of ideas (Visser, 2009:192). Vygotsky's (2006) definition of thinking affirms the importance of connecting ideas in order to seek technological solutions. Vygotsky (2006) reveals that a single idea is not sufficient to activate thinking. This means that technology teachers should support learners to generate an idea and subsequently relate that idea to other ideas until a well-structured thought is constructed.

Rusk (1919:122-123) believes that thinking is a cognitive activity in which ideas are steered towards achieving a particular goal or solving a problem. Moreover, thinking provides human beings with greater freedom of choice and enables them to seek alternative solutions from various ideas that were mentally processed. French and Rhoder (1992:398) view thinking as a cognitive process that is generated by external stimuli, which results in gaining knowledge. Furthermore, thinking is a mental process wherein ideas are developed and manipulated to achieve a particular solution.

Duran and Sendaĝ (2012:242) define thinking as:

> *Thinking is based on relating and drawing conclusions on notion and events, and involves a variety of different cognitive process such as implicating, problem solving, examining, reflecting, and criticizing. Thinking begins with a physical or psychological inconvenience steaming from lacking the solution for a problem whose solution becomes the objective for an individual.*

In light of the above definition, the researcher submits that thinking is the culmination of both experience and knowledge that has been acquired, and a process that involves one testing his/her ideas against uncertainty. A person who is exposed to new uncertainty relies on personal conviction and experience in an attempt to steadily arrive at a state of certainty. In the process of thinking, as soon as certainty reappears, reasoning also re-emerges along with a sense of balance, which stimulates a person to pursue reasoning with confidence.

I am of the opinion that thinking starts from a sense of incompleteness and uncertainty, and this therefore awakens the determination to find a solution. The incompleteness is arrived at by an individual accepting that it is unquestionable assurance. Thinking emanates from doubting information at your disposal or being frustrated by a particular problem, or finding the most appropriate solution. It is a mental process wherein ideas are tested against each other with the intention to arrive at the most suitable conclusion.

According to Lewis (2006b:41), thinking in the technology classroom is an essential process that stimulates learners to be able to simplify technological problems. Once learners understand the problem, thinking enables learners to anticipate solutions to problems. As learners apply their minds, they analyse alternative solutions to the problems, and subsequently decide on a suitable solution to the problem. Technology teachers should provide learners with activities that provoke the learners to think (Lewis, 2006b:41).

In the next section, the concept of critical thinking is unpacked. It is essential that technology teachers be familiar with the aspects of critical thinking as this will enable them to actualise it in their classrooms in order to realise one of the primary aims of the NCS, namely, *"to produce learners that are able to identify and solve problems and make decisions using critical and creative thinking"* (DBE, 2011:5).

2.5 Critical thinking

Paul and Elder (2008:2) describe critical thinking as an art that analyses and evaluates thinking with the intention of developing it further. In essence, critical thinking is a self-examination activity that entails exceptional standards and appropriate use thereof. Critical thinking entails sound communication, and the ability to solve the problems encountered in society. Ennis (1998:16) views critical thinking as the capacity to reason and reflect with conviction.

Paul et al. (1989:353) see critical thinking as skilful thinking that fits into the nature of knowledge requirements, and is keen to seek authenticity. Critical thinking is considered as consistent thinking in the application of exceptional standards that seek a solution to a particular problem. Moreover, critical thinking is a skill used to constructively put to rest uncertainty, and to develop an open-minded approach (Paul et al., 1989:353). In technology, an open-minded approach enables learners to seek alternative solutions to technological problems (DBE, 2011:68). Furthermore, an open-minded approach allows learners to share ideas and perhaps change their viewpoints when persuasive arguments emerge.

Following the foregoing views on critical thinking, the researcher has noticed that both Paul and Elder (2008:2), and Paul et al. (1989:353) share similar views on what constitutes critical thinking skills. They agree that critical thinking involves the aptitude to analyse, evaluate, reason, reflect, judge, interpret, and manipulate information. These features of critical thinking are fundamental and thus justify the selection of the framework adopted for this study (see Section 2.4), which includes: analysing, evaluating, and interpreting critical thinking skills.

Being able to observe, interpret, analyse, and manipulate information to solve problems exhibits competence in critical thinking. Critical thinking involves problem solving, looking for alternatives, and being able to analyse findings (Adams & Hamm, 2005:17). Moore (2010:61) asserts that critical thinking provides a structure for problem solving. Critical thinkers are able to reflect on their own ideas and justify their decisions, intentionally focusing on a particular goal (Crawford, Saul, Matthews, & Makinster, 2005:4).

Critical thinking is a collaborative process that calls for active involvement and interaction between learners and teachers (Hooks, 2010:9). Dunn et al. (2008:1) augment that critical thinking is a far-reaching process. One of the characteristics of critical thinking is the capability to analyse information. Furthermore, critical thinkers ask vital questions and solve complex problems by applying open-mindedness, and using the ability to communicate effectively with others (Duron, Limbach, & Waugh, 2006:160).

Cross (1999:35) notes that when designers solve technological problems, they come across enormous amounts of information that might be useful to any solution, but they should be critical and consider the most suitable solution to the problem they are faced with since not all possible solutions might be relevant. McCade (1990:2) affirms that technology teachers ought to actualise these skills to critically analyse the effect of the solutions they have considered suitable, and to predict the effectiveness of the product. Subsequent to examining the definition of critical thinking, the researcher acknowledges that critical thinking seems to emanate from the quest to seek the authenticity of the problem. Authenticity encompasses facts, reality, certainty, and confidence. People extract authenticity in order to ascertain certainty. In pursuit of authenticity, individuals examine the information presented to them by questioning its validity. Based on this, it is evident that the aspiration to seek authenticity leads to critical thinking.

In technology education, learners ought to be encouraged to investigate technological problems with the quest to pursue authentic technology based solutions. The next section discusses the disposition of critical thinking. Dispositions are fundamental characters that learners demonstrate as an indication that they are developing critical thinking skills.

2.6 The dispositions of critical thinking

The list on the next page outlines the dispositions of critical thinking that technology teachers ought to be familiar with in order to actualise critical thinking skills while supporting learners to solve technological problems.

Dispositions of critical thinking

- Inquisitiveness on a broad range of matters
- Keen to be well-informed
- Cautious for likelihood to apply critical thinking
- Belief in the procedures that stem from rational investigation
- Confident in personal aptitude to reason
- Open-mindedness to different views, and flexible to consider alternative views
- Perceptive to others' standpoint
- Reasoning fairly without prejudices
- Forethought before taking a decision
- Keen to review personal stance where new evidence emerges (Facione, 1990:25).

This list outlines the disposition of critical thinking that Facione (1990:25) considers as fundamental to develop critical thinking skills. Inquisitiveness as an essential character of critical thinking skills emanates from the desire to seek dependable and valid information (Facione, 1990:23). In addition to being inquisitive, learners should be well informed about the manner in which technological problems are solved using the design process and, in particular, how to conduct an in-depth investigation. Teachers should be alert to seize opportunities to actualise critical thinking skills in the technology classroom. According to the CAPS document, technology should provide learners with the opportunities to, *inter alia,* "combine thinking and doing in a way that links abstract concepts to concrete understanding"(DBE, 2011:9). Teachers should be able to connect abstract concepts to concrete understanding when supporting learners to solve technological problems.

In accordance with the disposition of critical thinking, teachers should consider the procedures that emanate from a well-considered inquiry. It is rather important that learners engage different views that are expressed by their fellow learners with an open-minded attitude. The latter will enable learners to be flexible and reason fairly without being biased (Facione, 1990:28). Being flexible means that if a particular learner has a pre-conceived standpoint, once new, sound information emerges, he or she should be able to reflect on the information and perhaps change his or her standpoint. This is essential since the design process require learners to consider alternative solutions (DBE, 2011:68).

The list below outlines the alternative dispositions of critical thinking proposed by Ennis (1998:17). This list serves as an alternate criterion for technology teachers to recognise characters that may actualise critical thinking skills in the classroom.

Alternative dispositions of critical thinking

- Seek alternatives on assumptions, explanations, conclusions with an open mind
- Prudence in supporting standpoint and the presented information
- Being well informed
- Clarity on information presented while remaining attentive
- Considerate to others' viewpoints and reasons
- Demonstrate sympathy while reasoning (Ennis, 1998:17).

Ennis (1998:17) believes that critical thinkers seek alternatives based on claims and conclusions while being mindful of their standpoints. In addition to being mindful, teachers should be well informed about the design process. According to CAPS, there are three important issues that technology teachers should consider when teaching technology, for example, how to solve technological problems applying the design process; practical skills; and knowledge that should be acquired and applied (DBE, 2011:9).

The above alternative dispositions of critical thinking indicate that critical thinkers seek clarity on information that is presented to them. The ability to seek clarity enables teachers to interpret the information at their disposal. To seek clarity affirms one of the opportunities that technology provides learners with, for example, to apply an authentic context that is ingrained in real experience (DBE, 2011:9). The researcher suggests that when a learner seeks clarity, he or she attempts to connect the new information with reality.

In the light of the above-mentioned disposition of critical thinking, both Facione (1990) and Ennis (1998) share their findings regarding specific features of critical thinking. The two authors emphasise that it is essential to seek alternatives, evaluate information presented, and possess a willingness to change one's personal views when new evidence comes into sight. However, the dispositions of critical thinking that Ennis (1998) writes about do not stress inquisitiveness, which Facione (1990) has emphasised as a fundamental springboard to critical thinking. Additionally, Ennis (1998) makes reference to the presence of personal conviction while one is reasoning. Conviction enables people to develop confidence in justifying their arguments.

According to Paul and Elder (2008:2), an ideal critical thinker is a person who asks important questions and explicitly formulates problems; collects and examines information in order to interpret it systematically; reaches reasonable solutions and conclusions; uses an open-minded approach within alternative ideas; and thoroughly scrutinises his or her assumptions and implications; and successfully communicates with others to determine the possible solutions to challenging problems.

Ennis (1998:18) asserts that an ideal critical thinker has the capability to provide clarification, inference, supposition and integration, and auxiliary critical thinking abilities. Clarification refers to the ability to recognise the focal point of the matter, analyse arguments, provide clarity on questions being asked and answered, and pass judgement on the trustworthiness of the source of information. Inference means the ability to recognise unspecified assumptions and figure out what led to a particular conclusion.

Before learners engage with the design process, the technology teacher is required to set the scenario within which the need or problem that needs to be solved is located (DBE, 2011:30-37). For instance, when teaching about electrical systems and control, the technology teacher should describe the context in which an electronic circuit could be used to meet a need, solve problems or create possible opportunities. This enables learners to seek clarification and subsequently draw their own conclusions (inference) about the problem to be solved. Most importantly, learners are able to structure their thoughts in an attempt to seek the most suitable technological solution.

Supposition implies the ability to reason from a particular stance or proposition, being mindful of the assumptions and different point of views of others, but not allowing those positions to impede one's thinking. Integration refers to the capability to put together other skills and dispositions in making a decision, and being able to justify that decision. Auxiliary critical thinking entails the capacity to systematically solve a problem while reflecting on it at the same time. In addition to this, auxiliary refers to being considerate towards others' feelings and their scope of knowledge (Ennis, 1998:18). The next section discusses the essential critical thinking skills that technology teachers require in order to actualise critical thinking skills in their classrooms.

2.7 The skills required for critical thinking

This study utilises the essential critical thinking skills and sub-skills as identified by Facione (1990:15). These skills are used to investigate how technology teachers actualise critical thinking skills in the technology classroom. Table 2.1 provides a summary of these critical thinking skills and sub-skills.

Table 2.1: Essential critical thinking skills, adapted from Facione (1990:15)

Skills	Sub-skills
Interpretation	Categorisation Decoding significance Clarifying meaning
Analysis	Examining ideas Identifying arguments Analysing arguments
Evaluation	Assessing claims Assessing arguments
Inference	Querying evidence Conjuring alternatives Drawing conclusions
Explanation	Stating results Justifying the procedure Presenting arguments
Self-regulation	Self-examination Self-corrections

‘Interpretation’ in Table 2.1 encompasses *categorisation, decoding, and clarification of meaning*. Interpretation means the competency to understand and effectively articulate the meaning and the implications of experiences, circumstances, information, beliefs, criteria, and processes over a broad scope (Facione, 1990:16-17). In essence, teachers should be able to identify a technological problem and classify its course without a predetermined method of inquiry. Teachers should demonstrate the skills to spell out ideas and concepts including any presented information. Simpson and Courtney (2002:91) add that interpretation is vital to critical thinking in the sense that critical thinking is not acquired instantly, but is relatively an extensive process that encompasses cognitive aptitude. In terms of what the term ‘interpretation’ represents, the researcher considers interpretation as an opportunity to make sense of the technological problem that must be solved. According to the CAPS document for technology, learners are required to investigate a technological problem, which involves conducting the relevant research (DBE, 2011:68).

While conducting research, learners are supposed to collect data, demonstrate an understanding of key technological concepts, and develop insight. The ability to interpret information is imperative during investigation as this enables learners to contextualise the technological problem at hand. Once learners are able to make sense of what the problem is, they should be capable of applying their minds in pursuit of a solution. In order to develop interpretation skills, technology teachers should be knowledgeable with regard to the design process, and should effectively support their learners.

‘Analysis’ (Table 2.1) involves “Examining ideas, Identifying arguments, and subsequently Analys[ing] the arguments” (Facione, 1990:17-18). Analysis refers to the ability to compare and distinguish ideas. In an analysis, teachers should be able to determine the elements of the technological problem and establish the relationship between each element and the whole problem. When teachers analyse the information, they should display the ability to detect arguments in the presented statements or information, and determine whether the arguments are intended to articulate reasons for a particular point of view. As a result, teachers should develop a systematic representation that thoroughly illustrates the flow of reasoning that led to a particular conclusion (Facione, 1990:17-18).

Facione's (1990: 17-18) analysis technique has influenced other authors (Jin & Chusilp, 2006; Ho, 2001; Killen, 2010) to describe analytical skills. Analysing a problem essentially involves an understanding of the problem provided, and explores its requirements and restrictions in accordance with the design process (Jin & Chusilp, 2006:30). Ho (2001:28) refers to 'analysis' as the ability to break down the problem into sub-problems. Killen (2010:271) adds that once information has been collected and classified, it is important to place it within the specific framework. This indicates that learners should be able to recognise key components in a technological problem, as well as the relationship between a range of pieces of collected information.

In light of the above, 'analysis' means the ability to disintegrate a technological problem and determine how each part of the problem fits into the problem as a whole. In essence, an approach to solving a problem begins with the capability to isolate each piece of the problem from the whole and distinguish how each piece connects with another in order to develop a whole.

'Evaluation' (Table 2.1) entails the assessment of claims and arguments. Evaluation involves the skills to assess the trustworthiness of information that represents an individual's perspective, experience, circumstances, and conviction (Facione, 1990:18). This includes the teachers' ability to identify the pertinent factors that are applicable to determine the extent of credibility of the source of information. In assessing an argument, teachers develop the skills to judge whether the argument leads to an acceptable conclusion. Furthermore, assessing arguments depends on the ability to determine if the argument is based on false assumptions (Facione, 1990:18).

The skill of 'evaluation' depends on learners' understanding of the relationship between the problem and the solutions that they attempt to find (McCormick, Murphy & Hennessy, 1994:7). Also, for learners to develop the skills to evaluate, the technology teacher ought to assist them in determining the connection between intentions, actions, and the effect of both intentions and actions while finding the solution to a problem. Learners should develop a thorough understanding of the process of solving technological problems.

In order to enable learners to develop evaluation skills, technology teachers should ask learners critical questions regarding the methods they would use to seek solutions. Moreover, it is imperative for learners to understand how to evaluate the problem by taking the problem's context into consideration (McCormick et al., 1994:7). The CAPS document for technology states that the design process is cyclic and frequently determined by evaluation. Also, each step of the design process should be evaluated, and the next step of the design process should be influenced by what transpired in the previous step (DBE, 2011:74).

In light of the above, it is clear that 'evaluation' is a fundamental skill required to solve technological problems. Ideas that are exchanged throughout all steps of the design process ought to be evaluated until a final decision is made. The final decision should also be evaluated. Evaluation involves the ability to examine whether the developed artefact serves the intended purpose. Adjustments could then be made if the artefact has some defects. Various arguments should be presented to justify the effectiveness of the artefact.

'Inference' (Table 2.1) involves "Querying evidence, Conjuring alternatives, and Draw [sic] conclusions" (Facione, 1990:19). Inference means the competency to recognise and preserve the required elements in order to draw a well-founded conclusion. The skills to query entail the ability to consider the relevant information to be used in order to manipulate that information and arrive at a particular response. Possible alternatives refer to teachers putting together several solutions to a particular technological problem.

It is acknowledged that 'inference' refers to the skills required to substantiate an argument at one's disposal and to determine its credibility. This approach enables teachers to support learners in verifying the information presented to them by their teachers instead of readily accepting it. Learners ought to be supported to determine the merit of whatever information is presented to them and to probe its validity. It is important to understand all of the possible factors that led to a particular conclusion. In this way the South African educational system could develop a generation of critical thinkers.

Facione (1990:18) views 'explanation' (Table 2.1) as "Stating results, Justify [sic] the procedures, and Present [sic] the arguments". Explanation refers to the capacity to present results precisely and defend those results using predetermined criteria. In stating results, teachers should be able to demonstrate coherent reasoning skills and provide the context that the explanation is based on. Learners should be provided with an opportunity to explain how they have followed the design process while making an artefact.

Based on the description of 'explanation' above, the researcher assumes that 'explanation' refers to the competency to articulate a technological solution and the ability to justify the design choices made. Explanation is one of the key skills for critical thinking that could be used by teachers to challenge learners to confidently present their arguments in a systematic manner. This skill is fundamental for learners to develop reasoning skills, and be able to share their perspective with self-reliance.

'Self-regulation' (Table 2.1) encompasses the capability of teachers to exercise "Self-examination and Self-correction" (Facione, 1990:22). Self-regulation implies the skills to observe one's cognitive conduct. *Self-examination* refers to personal reflection on the way one reasons and determines the limitations. *Self-correction* indicates the extent to which one corrects a personal deficiency.

Jonassen and Strobel (2006:499) assert that solving technological problems effectively depends on the established self-regulation skills that enable teachers to be successful in dealing with cognitive processes. Also, self-regulation entails evaluating solutions and making necessary corrections while readily being prepared to respond to unforeseen obstructions. Doornekamp and Streumer (1996:63) add that self-regulation enables teachers to reflect on a particular order in which technological problems are solved, and to encourage learners to ask themselves critical questions while seeking solutions to problems.

Barak (2010:398) states that technology provides an appropriate platform that promotes learners' self-regulation. This subject stimulates learners' interests, provokes their imaginations, and relates their experiences to daily life and to those of others in society. It fosters the concept of 'learning by doing', which is an important ingredient that stimulates learners' cognitive and social skills. Additionally, technology learners receive feedback from both teachers and classmates in their attempt to solve technological problems.

In light of the discussion on self-regulation, the researcher acknowledges that self-regulation emphasises reflection. In order to develop critical thinking skills, learners ought to monitor their reasoning capabilities and improve their cognitive skills. Self-regulation is essential to personal cognitive development. In addition to this, Barak (2010) explicitly articulates the important aspects of technology education in relation to self-regulation.

It is essential that technology learners embrace self-regulation since the artefacts that they manufacture should be produced in accordance with the design process and feedback from both the teacher and classmates. The ensuing section presents a discussion of cognitive mechanisms: an understanding of cognitive skills may help teachers to exploit the cognitive processes involved in solving technological problems.

2.8 Cognitive mechanisms

A cognitive mechanism is a fundamental competence that emanates from the skills utilised to construct logical and consistent links between events (McDonnel, Lloyd & Valkenburg, 2004:509). Hence, a designer is able to make sense of the world by articulating credible descriptions of events or experiences that are understandable in a social setting.

Sirois, Spratling, Thomas, Wester-mann, Mareschal and Johnson (2008:323) declare that the mind obtains and develops multiple, disconnected representations that are enough to inspire spontaneous action. Cognitive functions are considered to be extremely complex occurrences that work and relate naturally with any circumstances that emerge. The next section presents two different views of cognitive mechanisms from both Evans (1998) and Arbor (1989). The latter provides different perspectives that technology teachers could learn from and use to support learners to actualise critical thinking skills.

2.8.1 Evans' view of cognitive mechanism

The mind, according to Evans (1993:2), works in three basic stages: firstly, the designer scrutinises the statements within an argument and subsequently builds a mental structure in order to establish the grounds on which an argument is valid; secondly, the designer arrives at a general acceptable conclusion by indicating the statements that are true within an argument; and finally, the designer evaluates the acceptable proposition against alternatives to determine the validity of the acceptable proposition. The next section presents the different cognitive mechanisms described by Arbor (1989).

2.8.2 Arbor's view of cognitive mechanism

Arbor (1989:292-293) asserts that the intentions and constraints of the design process are reserved and regained in the personal memory, and are consequences of certain stimuli that generate reaction. These stimuli strategically activate memory to solve the problem encountered. Arbor (1989:292-293) uses schemata, a generator-and-test, a goal plan, and a perceptual-test to substantiate the development of cognitive mechanisms. Each of these mental processes will now be discussed. According to Arbor (1989:293), the schemata in the sphere of design problems are the branch of knowledge that is represented by a systematic frame network. Design elements that are controlled during the design process are vital to information processing.

Nodes (a point in a network) are represented in the frame network by means of design elements that are clustered in accordance with discipline functional correlations. It is, however, assumed that the components of schemata, which are reserved in immense design information, are connected with the semantic net. In the established network, components of the schemata produce procedural knowledge about the restrictions of the problem. Knowledge reserved in the schemata generates the solution to a problem (Arbor, 1989:292).

Arbor (1989:293) explains that a generator and a tester are mechanisms that constitute the design problem. A generator provides the input that creates a solution to a problem. The input has three sources, namely: an evocation of schemata, a series of schemata, and retrieval. An evocation of schemata reserved in the memory triggers information that is reserved in the short-term memory and successively uses it. The generator utilises a series of schemata to develop a solution to the problem. Subsequently, the developed solution is either considered or adjusted as a result of retrieval from the memory. Once the generator develops a solution to the problem, the tester evaluates the problem against perceived constraints (Arbor, 1989:292).

Arbor (1989:293) further states that the goal plan is a systematic procedure that manipulates a series of operations. A goal plan is regarded as the fundamental mechanism that simplifies the ill-structured problems. In the design context, those who design have acquired wide procedures that are reserved in their long-term memory, which support them in seeking a solution (Arbor, 1989:293).

According to Arbor (1989:293), in relation to the perceptual-test, a person who designs should continuously collect information about the problem. The so-called production system that has been developed by means of perception outlines the mechanisms that are considered to be a perceptual-test. The perceptual-test recognises the context of the problem and determines a suitable solution. In the design process, a perceptual-test is regarded as an essential control mechanism (Arbor, 1989:293).

Subsequent to examining the cognitive mechanisms that both Evans (1993) and Arbor (1989) conceptualise, the researcher suggests that is it imperative for technology teachers to understand how learners develop cognitive skills. Evans (1993) outlines the fundamental attributes of thinking. Evans' (1993) framework emphasises the aspects of reasoning in the sense that a person determines the credibility of inferences in an argument. However, Evans (1993) provides a limited explanation of cognitive mechanisms and does not allude to the context of reasoning in a social setting.

In order to develop critical thinking skills, learners should be enabled to analyse the validity of the information that is provided to them and be able to justify their standpoint within the shared cognition. Arbor's (1989) framework encourages teachers to enhance learners' development of schemata. For learners to be effective in using cognitive skills, they should be supported to develop a desire to reserve vast amounts of information in their memories such that they improve the representation of ideas without difficulty. Vast information should be readily available to confront technological problems aggressively. The next section discusses the design process since it is the prescribed procedure to solve technological problems in South African schools (DBE, 2011:12).

2.9 The design process

According to Mitcham (2001:29), the concept 'design' stems from the Latin word "*designare',* which means 'to mark out', 'trace', 'denote', or 'devise'. Design has the same linguistic derivation in Italian, '*disegno'*, and in French it is called "*dessein"* which implies the 'plan or purpose', and '*dessein'*, which means 'drawing' or 'write'. Furthermore, design in English means a plan or drawing that represents how a particular object functions before it is manufactured (Mitcham, 2001:29). In practical terms, design refers to a plan of action (Stewart, 2011:516). Visser (2009:192) states that design is a cognitive act that involves the solving of ill-structured problems.

Halpern (1998:451) asserts that critical thinking skills are required in order to deal with difficult and ill-structured problems. Mitcham (2001:29) explains that design as a concept has been developed in relation to contemporary engineering and technology since the late 16th Century. In addition to this, engineers design authentic structures using sophisticated systems and procedures. However, design in technology involves the process that must be followed to construct an artefact while considering scientific information and applying technical skills. In fact, design requires cognitive aptitude for developing an artefact (Mitcham, 2001:29). Design is an essential cognitive activity of technology and involves mental representations of thoughts (Visser, 2009:192; Goel & Piroll, 1992:3). In technology, design is the strategy used to solve technological problems by considering the following series of steps, namely: intensive analysis of the problem; identifying the link between the elements of the problem; seeking a solution; and combining the components of the problem (Mioduser, 2009:4).

Mioduser (2009:3) further declares that technological problems are solved in various processes, namely, from a total flexible to a strictly structured design process. However, in most instances, the design process encompasses comprehensive cognitive skills. The design process is a highly innovative and complex procedure that emphasises the construction and evaluation of artefacts. Kim, Kim, Lee and Park (2007:587) acknowledge that understanding the aspects of a technological problem provides insight into the design process.

Van Dooren, Boshuize, Van Merriënbvoer, Asselbergs, and Van Drost (2014:54-59) assert that the ability to design is a complex, innovative and flexible skill. The design process is consequently a cognitive procedure that involves intensive thinking while constructing an artefact, and also involves reflection on different and converging developments. Furthermore, design is a process that strives to enable the likelihood of future technology developments, analysing and seeking alternatives while solving socio-technological problems.

Hill (1997:35) describes design as a process that envisions production, invention, manufacture, or planning a reasonable product that will benefit society. Design is a continual process that requires perpetual refinement. Asunda and Hill (2007:26) find that design refers to a continuous unlimited procedure of developing a product in a creative manner.Design is a suitable procedure for use in technology education (William, 2000:52). Potter (2013:69) acknowledges that design and problem solving are fundamental aspects of both technology and technology education. Design is a fundamental process used to solve problems in technology that provides an opportunity for learners to think critically while going through the specific steps of the design process (Lunt & Helps, 2001:1).

After examining various sources on what design is, it is concluded that the design process remains a significant pillar for teaching technology in schools. An appropriate design exhibits complete details of an artefact before is it manufactured, and allows the designer(s) to make necessary modifications. In essence, designers should be convinced of the feasibility of the artefact through its design. For learners to be able to determine the feasibility of an artefact, critical thinking skills are required. Moreover, technological problems tend to be ill-structured and, by implication, cognitive skills are thus mandatory. Table 2.2 presents the CAPS IDMEC design process in order to list the sub-skills required to solve given design problems in the mini-PAT (DBE, 2011).

Table 2.2: The design process adapted from CAPS (DBE, 2011:63)

The process	**Activities**
Investigation	Seek information Conduct relevant investigation Grasp concepts and gain insight Determine new techniques
Design	Design brief Generate possible solutions Draw ideas Graphics (2/3D) Make decision Choose best solution and justify
Make	Use tools and equipment Building, testing, and modifying product Safety and health atmosphere
Evaluate	Evaluate actions, decisions, and results Evaluate solutions and process followed Suggest necessary improvements Evaluate constraints
Communicate	Presentation Record of process

'Investigation' in Table 2.2 requires learners to seek information, conduct the relevant research, grasp the concepts and gain insight, and determine new techniques. Before learners can engage in this activity, the teacher should set the scenario to describe the context in which the specific technological problem could meet a need (DBE, 2011). This enables learners to investigate the context in which the technological problem is situated. According to the Unique Features and Scope section of CAPS, technology provides learners with the opportunity to learn, *inter alia*, to "use the authentic contexts rooted in real situations outside the classroom" (DBE, 2011:9).

'Design' (Table 2.2) requires learners to write the design brief as soon as they completely understand the technological problem. Learners should also generate alternative solutions, and put their ideas on paper. Design requires learners to be familiar with graphics representation such as two-dimensional (2D) and three-dimensional (3D) object representation. Afterwards, learners should select the solution that best fits the set specifications, and justify their choice.

During the 'make' stage of the process (Table 2.2), learners are obliged to use tools and equipment, build the artefact, and adhere to the safety precautions as set out by their teacher. 'Make' provides learners with the opportunities to learn to use specific tools and equipment to solve a technological problem. Learners are also required to evaluate the artefact and if possible modify it.

'Evaluation' (Table 2.2) requires learners to evaluate their action, decisions, and the results that they obtained through the design process. Learners evaluate the technological solutions and the process that they followed to reach a consensus. During 'evaluation', learners are required to make necessary improvements. Learners may experience unexpected constraints that they either cause themselves, or which are given to them. Evaluation is a design step that uses inquisitive questions, unbiased testing, and analysis.

Lastly, 'Communication' (Table 2.2) involves representation and recording of the process followed. Communication encompasses all of the steps of the design process. Learners are required to provide evidence of the process followed to arrive at the solution. This includes the capability to analyse, investigate, design, evaluate, and communicate using different modes of representations. Most importantly, learners should develop a record of the processes that were followed from the formation of the problem to arriving at the solution, which should be in a portfolio format.

In following an investigation into fifteen different design processes, Mehalik and Schunn (2006:519-532) identified eleven (11) activities that they believe a good design process should include. These activities indicate whether the design process is linear, cyclic or iterative. Mehalik and Schunn (2006:521) assert that every step of their design process represents a separate feature of a design activity. These activities are listed in Figure 2.1 on the next page.

The design process		
Explore problem representation Explore graphic representation Use functional decomposition Explore engineering facts Explore issues of measurement Build normative model	Explore scope of constraints Redefine constraints Conduct failure analysis Validate assumptions and constraints Search the space (evaluate design alternatives)	Examine existing designs/artefacts Follow interactive/recursive/iterative design methodology Explore user perspective Encourage reflection on design process

Figure 2.1: The design process according to Mehalik and Schunn (2006:519-532)

Each of the activities of the design process as listed in Figure 2.1 will now be discussed. According to Mehalik and Schunn (2006:521), explore problem representation refers to the basis on which a problem is framed or structured. This criterion involves exploring a problem that should be investigated and analysed. The manner in which a designer interprets the problem determines the technique used to seek the solution, including the constraints that esigners encounter as they seek the solution to a problem. This activity in design takes place in the initial stages of the design process whereby designers think about the formation of the problem in a group (Mehalik & Schunn, 2006:521).

Based on Mehalik and Schunn's (2006) design process, the researcher has noticed a few differences after comparing this model with others. The said model emphasises aspects of design constraints, a feature that the prescribed design process for technology does not allude to (DBE, 2011:68). The researcher is of the opinion that considering the constraints in design allows both technology teachers and learners to develop the scope or frame of the problem. In the event that there are limited resources, teachers and learners might improvise and still achieve the desired outcomes. The constraints encountered provide opportunity for future technology prospects since the limitations are outlined and designers will be determined to enhance their artefacts by dealing with those constraints.

Mehalik and Schunn (2006:521) state that, during the interactive design methodology in the design process, the designer purposely deliberates on the problem to be solved without adhering to the structured model of the design process. This criterion involves the designers exchanging ideas with other teams of designers and examining other design processes (Mehalik & Schunn, 2006:521).

The design process prescribed for technology should consider incorporating an interactive design methodology (flow of information between the technology teacher and the learner) (DBE, 2001:68). This is an aspect that the researcher suggests will encourage learners to develop social cognition and will expose them to various design processes. The goals to be achieved should be set and expressed in the initial stages of the design process. Learners should be enabled to break down (analyse) a problem and consider how the solution functions within the context of technology.

Building a normative model is an activity that demonstrates that a model is developed and presented using multiple representations. "The term 'model' refers to multiple forms of representations – verbal, visual, tactual, physical, etc." (Mehalik & Schunn, 2006:522). Designers patiently articulate how the perfect design could have been created if they did not encounter certain constraints that are found in the design process (Mehalik & Schunn, 2006:522). This affirms what the prescribed design process stipulates, that some evaluation should be conducted against the constraints that are created or experienced during the design process (DBE, 2011:68). Designers analyse and evaluate the model before presenting it to a particular audience (Mehalik & Schunn, 2006:522).

Mehalik and Schunn (2006:523) indicate that searching the space as an activity in the design process outlines the goals and constraints of the problem and inspires designers to examine and evaluate the possible solutions to a problem. Also, designers apply different plans of action and approaches to lead this process. Designers seek alternatives that are suitable to meet the goals and constraints that are outlined (Mehalik & Schunn, 2006:523).

Using functional criterion decomposition during the design process requires the designer to analyse the problem and structure the problem in such a way that it could be investigated effortlessly and contribute towards general functionality (Mehalik & Schunn, 2006:522). Essentially, this activity in the design process is about making a complex problem simple.

Explore graphic representation refers to graphic or visual media such as Computer-Aided Drawing (CAD), which are used by designers as strategies to prevent a design problem. Graphics enable designers to scrutinize the comprehensive layout of the design and examine particular features of the design while providing thorough details (Mehalik & Schunn, 2006:522). According to CAPS (DBE, 2011:68), learners are required to be aware of the knowledge and skills of graphics representations such as two-dimensional (2D) and three-dimensional (3D) object representation. This essentially will teach learners to plan, write, calculate, and build a model of the technological solution. By implication, teachers should teach technical drawing in technology so that learners are able to provide graphic representations.

According to Mehalik and Schunn (2006:521), 'Redefine constraints' in the design process describes the activities that are investigated further to determine the manner in which certain constraints were set or considered important. Alternatively, the designer redefines the constraints to attain a predetermined goal instead of exploring the effect of the constraints on the design (Mehalik & Schunn, 2006:523). The activity to 'Explore scope of constraints' means that designers collectively develop a strategy to deal with the conceptual or physical constraints that might make it difficult to achieve the goal within the problem context. Frequently designers might redefine the constraints in the design process. This activity necessitates designers studying how constraints impact the design (Mehalik & Schunn, 2006:523).

To 'validate assumptions and constraints' demonstrates that designers evaluate their design to verify whether it falls within the anticipated constraints, and that their predetermined assumptions are true (Mehalik & Schunn, 2006:523). Validation entails the process carried out to ensure that users' expectations are taken into consideration at the various stages in the design process.

Most importantly, technology teachers are required to teach learners to construct artefacts that "reflect originality; aesthetics [appreciate beautify]; value for money; fit-for-purpose; ease of manufacture; safety and ergonomics; environmental factors; and prejudice" (DBE, 2011:12). The latter will certainly motivate learners to construct authentic solutions that are ingrained in a real-life context. The importance of outlining the design constraints cannot be over-emphasised. The design process prescribed for technology ought to bring in the aspect of validity assumptions, which will teach learners to reason and justify their arguments and subsequently develop critical thinking skills in a social setting (DBE, 2011:68).

'Examine existing designs' means that designers occasionally learn from existing solutions that are relevant to their design problem, which enables them to enhance their designs (Mehalik & Schunn, 2006:523). Various alternatives related to designers' problems are studied. Another aspect that the prescribed design process does not articulate is social cognition within the design process (DBE, 2011:68). Mehalik and Schunn's (2006) design model encourages learners to share their experiences and interpretations without systematically following the structured process. This is an aspect where the researcher suggests that critical thinking skills could be developed since learners are given an opportunity to share ideas through an open-minded approach. An open-minded approach is an essential skill, as articulated by Facione (see Section 2.4).

'Explore users' perspectives' implies that the users are consulted during the various stages of the design process to consider their expectations of and needs for the particular artefact (Mehalik & Schunn, 2006:524). Additionally, previous users' experiences are considered and data is collected by means of interviews, simulations, and questionnaires.

Mehalik and Schunn's (2006) design process emphasises the essence of users' expectations, an aspect that is not considered in the prescribed design process (DBE, 2011:68). However, CAPS stipulates that technology in South Africa provides learners with the opportunity to learn to solve problems using authentic contexts firmly established in real-life experience (DBE, 2011:9). Be that as it may, artefacts that the researcher has seen so far lack functionality and educational value. In addition to this, the prescribed design process does not provide an opportunity for the user's input or experiences (DBE, 2011:9) as indicated in Melik and Schunn's (2006:532) design process.

According to Mehalik and Schunn (2006:523), self-reflection encourages reflection during the design process. It is important that designers spend some time reflecting on the design process that they have followed in order to determine whether they (designers) were able to reach their intended goals. Also, self-reflection should be conducted during the construction of the artefact and after completing the artefact.

The design process as prescribed for technology (DBE, 2011) does not emphasise the importance of setting goals, as alluded to by Mehalik and Schunn (2006). The researcher is of the opinion that set goals guide both teachers and learners to focus on attaining the desired outcomes and necessary adjustments could then be done to steer all resources to achieve a set goal. Furthermore, every stage of Mehalik and Schunn's (2006) design process challenges designers to analyse the problem. In this aspect, the DBE's (2011:68) design process concurs with that of Mehalik and Schunn (2006).

Oxman (2004:66) affirms that teaching learners how to obtain, systematically arrange, and apply both conceptual and procedural knowledge relies greatly on teachers' cognitive skills and the instructional strategies that teachers actualise. However, Rauscher (2011:295) points out that the current technology teachers lack conceptual and procedural knowledge. The latter means that technology teachers experience challenges in effectively teaching the subject. Cross (1982:224) adds that technology teachers should be as eloquent as possible when teaching design otherwise they might not have the basis for selecting content and instructional strategies. The next section presents the conceptual framework that was used to guide the study.

2.10 Conceptual framework

The purpose of this study is to investigate how technology teachers actualise critical thinking skills while supporting learners to solve technological problems. The conceptual framework of this study was adopted from Facione (1990:13-19) and the CAPS IDMEC design process (DBE, 2011:68-69). Facione (1990:13-19) believes that critical thinking skills could be developed through Interpretation, Analysis, Evaluation, Inference, Explanation, and Self-regulations. Facione's (1990) framework was used in this study as the researcher considered it detailed and, most importantly, this framework allows for the cognitive skills suggested in the CAPS IDMEC model, unlike the other critical thinking frameworks that were scrutinised.

The frameworks of Siegel (2010); Bailin, Case, Coombs, and Daniel (1999); Halpern (1998) will be discussed below to compare the differences and similarities of these frameworks with that of Facione (1990). Siegel (2010:141) highlights that critical thinking involves two divergent elements: "skills of reason assessment and the dispositions to engage in and guided by such assessment".

Siegel (2010:142) explains that critical thinking encompasses the ability to reason in a good manner, develop and evaluate several arguments, and establish inferences, which certain premises emanate from. The researcher views Siegel's (2010) framework as limited in assessing reasoning. However, Siegel (2010) mentions that critical thinking involves the ability to evaluate and analyse. These are some of the essential skills required for critical thinking that constitute Facione's (1990) framework.

Bailin, et al. (1999:286) assert that critical thinking should be aimed at achieving skills such as responding to a question, decision making, problem solving, resolving a matter, planning, or carrying out a project. Bailin et al.'s (1999) framework highlights the features of critical thinking instead of rich concepts that define critical thinking. Ennis (1993:179) describes critical thinking using Bloom's taxonomy (analysis, synthesis, and evaluation) and emphasises that critical thinking is the correct way to assess statements. Moreover, Ennis (1993:180) affirms the dispositions for critical thinking that Facione (1990) alludes to.

Halpern (1998:451) states that critical thinking involves solving problems, developing inferences, determining possibilities, and making decisions. Critical thinking also includes evaluating the reasons that lead to a particular conclusion. Halpern (1998:451) explains that critical thinking is frequently referred to as higher order cognitive skills that involve making judgements, analysis, synthesis, reflecting, and self-monitoring. To make a judgement is the same as making inferences and self-monitoring is comparable to self-regulation. This is one of the essentials of critical thinking that Facione (1990) specifies. Halpern developed a framework that teachers can use to actualise critical thinking skills. This framework comprises four parts: "a dispositional or attitudinal component; instruction in and practice with critical thinking skills; structure-training activities designed to facilitate transfer across contexts; and a metacognitive component used to direct and assess thinking" (1998:451). The researcher considers Halpern's (1998) framework too complex to use as compared to Facione's (1990) framework.

According to Siegel (2010), Bailin et al. (1999), Ennis (1993), and Halpern (1998), critical thinking involves reasoning, evaluation, analysis, inference, synthesis, and self-monitoring. However, emphasis was placed on evaluation, analysis, and inference. These are some of the essential critical thinking skills that Facione's (1990) framework incorporates. Thus, the reason why the researcher decided to use Facione's (1990) framework and this framework can also be attributed to the inclusion of interpretation and self-regulation, which were not specified above.

The researcher used Facione's (1990) framework to construct the interview questions and develop the observation schedule. The interview questions were structured using critical thinking skills (interpretation, analysis, evaluation, inference, explanation, and self-regulations) and sub-skills. The sub-skills were used to allow the participants to verify their ability to actualise critical thinking skills. This framework was also used to analyse and interpret the data.

The design process forms the backbone of teaching technology in South Africa (DBE, 2011:12). The design process was therefore also adopted into the conceptual framework. The design process involved investigation, designing, making, evaluating, and communicating. The conceptual framework is delineated in Figure 2.2 below.

Critical thinking skills (Facione, 1990)					
Interpretation	Analysis	Evaluation	Inference	Explanation	Self-regulation
Categorisation Decoding significance Clarifying meaning	Examining ideas Identifying arguments Analysing arguments	Assessing claims Assessing arguments	Querying evidence Conjuring alternatives Drawing conclusions	Stating results Justifying procedures Presenting arguments	Self-examination Self-correction

Design process (IDMEC) (DBE, 2011)				
Investigation	Design	Make	Evaluate	Communicate
Seek information Conduct relevant research Grasp concepts and gain insight Determine new techniques	Design brief Generate possible solutions Draw ideas Graphics (2/3D) Take decion Choose best solution and justify	Use tools and equipment Building, testing, and modifying product Safety and healthy atmosphere	Evaluate actions, decisions, and results Evaluate solutions and process followed Suggest necessary improvements Evaluate constraints	Presentation Record of process

Figure 2.2: Conceptual framework for this study

Figure 2.2 shows the conceptual framework of this study, which is based on Facione's (1990) critical thinking skills and incorporates the sub-skills included in the IDMEC design process as prescribed by the DBE (2011). In order to determine which critical thinking skills and sub-skills may be engaged in each step of the design process, a content analysis of the design process activities in CAPS was conducted. Table 2.3 summarises the findings of the content analysis, showing the sub-skills that could potentially be involved in each step of the design process. The sub-skills are used to clarify the extent of each critical thinking skill (Facione, 1990:16).

Table 2.3: Critical thinking skills within the IDMEC design process

<table>
<tr><th>Investigation</th><th>Design</th><th>Make</th><th>Evaluate</th><th>Communication</th></tr>
<tr><td>Seek information
• Clarifying meaning
• Stating results
• Categorisation
• Decoding significance</td><td>Design brief
• Categorisation
• Examining ideas</td><td>Use of tools and equipment
• Categorisation
• Examining ideas</td><td>Evaluate actions, decisions, and results
• Decoding significance
• Examining ideas
• Clarifying meaning
• Querying evidence</td><td>Presentation
• Categorisation
• Stating results</td></tr>
<tr><td>Conduct relevant research
• Categorisation
• Draw conclusions</td><td>Generate possible solution
• Examining ideas
• Categorisation
• Conjuring alternatives</td><td>Building, testing, and modifying product
• Examining ideas
• Self-corrections</td><td>Evaluate solutions and process followed
• Decoding significance
• Examining ideas
• Analysing arguments
• Assessing claims</td><td>Record of process
• Justifying procedure</td></tr>
<tr><td>Grasp concepts and gain insight
• Clarifying meaning
• Categorisation
• Examining ideas</td><td>Draw ideas
• Examining ideas
• Identifying arguments
• Assessing claims</td><td>Safety and healthy atmosphere
• Categorisation
• Self-examination</td><td>Suggest necessary improvements
• Analysing arguments
• Assess arguments</td><td></td></tr>
<tr><td>Determine new techniques
• Categorisation
• Examining ideas
• Decoding significance</td><td>Graphics (2/3 dimensions)
• Stating results</td><td></td><td>Evaluate constraints
• Assessing claims</td><td></td></tr>
<tr><td></td><td>Make decision
• Querying evidence
• Examining ideas
• Analysing arguments</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Chose best solution and justify
• Categorisation
• Examining ideas
• Assessing claims
• Assess arguments</td><td></td><td></td><td></td></tr>
</table>

Table 2.3 shows which of Facione's (1990) sub-skills can be utilised in each step of the design process (DBE, 2011). The table presents the design process steps in the top row, and outlines the sub-skills that support each step in the columns below each step. The manner in which the content analysis is structured could assist technology teachers to plan how to support learners in developing critical thinking skills. Importantly, Table 2.3 addresses the sub-question (ii) that was raised in Chapter 1 (see Section 1.5): what opportunities does CAPS offer for fostering critical thinking skills in the technology classroom? The table shows how technology teachers could connect a particular CAPS opportunity to critical thinking principles.

'Investigation' (Table 2.3) is the initial step of the design process wherein learners seek information (DBE, 2011:68). The relevant sub-skills for critical thinking for this step are *categorisation, decoding significance, clarifying meaning,* and *stating results*. *Categorisation* means the ability to classify information and establish a framework for understanding. *Decoding significance* implies the ability to recognise the purpose of information and its social significance. *Clarifying meaning* denotes the ability to simplify a particular idea or concept. Basically, *Clarifying meaning* implies the capacity to dispel confusion or ambiguity in a given statement. *Stating results* is a sub-skill that would enable learners to present a reliable report (Facione's, 1990:13-19).

According to social learning (see Section 2.3), people tend to develop the skills to interpret what they have perceived to be connecting actions, and again convert these perceived ideas into a structured series of actions. Table 2.3 shows the link between investigation and the sub-skills required for critical thinking. During the investigation stage, learners should be supported to develop the skills to interpret the information and translate how these ideas could be fit into the design process. In essence, the outlined sub-skills could enable learners to develop the skill of interpretation, which is a primary critical thinking skill in this framework.

Furthermore, investigation involves *conducting relevant research* (DBE, 2011:68).The relevant sub-skills required are the ability to *draw conclusions using inductive reasoning*, and *categorisation*. To *draw conclusions using inductive reasoning* means the capacity to reach a conclusion that is supported by the information at hand, and the capacity to persuade others to consider the conclusion. *Categorisation* denotes the ability to describe a situation or event in order to establish an understandable meaning in relation to that situation or event (Facione's, 1990: 13-19).

It is thus important that technology teachers support learners to *conduct relevant research* (DBE, 2011: 68) and consequently *draw conclusions using inductive reasoning* (Facione's, 1990:13-19). This teaches learners to develop the skill of drawing an 'inference'. Basically, the ability to *draw conclusions using inductive reasoning* stimulates learners to develop 'inference' skills. Moreover, 'inference' is one of the essential critical thinking skills. When learners *conduct relevant research*, they seek evidence that substantiates a particular conclusion

During 'investigation', learners are also required to grasp concepts and gain insight (DBE, 2011: 68). The suitable sub-skills that could support learners in grasping concepts and gaining insight are *categorisation, clarifying meaning,* and *examining ideas*. *Categorisation* denotes the ability to classify information and establish a framework for understanding. *Clarifying meaning* is a sub-skill that implies the ability to clear up particular concepts and allay the unintentional vagueness. *Examining ideas* is a sub-skill that requires the capacity to describe concepts and compare statements (Facione's, 1990: 13-19).

In light of the above, it shows that the specified sub-skills could be used to teach learners to grasp concepts and gain insight. In order to grasp concepts, learners should be supported in classifying information and establishing a framework for understanding. Classifying information could enable learners to organise information such that it is easier to describe experiences or events. Once a framework for understanding is established, learners will be able to conduct an investigation with confidence and consequently gain insight. Furthermore, to grasp concepts and gain insight, learners need to *examine ideas* as they investigate the solution. Examining ideas is an essential sub-skill for analysis, which is one of the primary critical thinking skills. In essence, the ability to *examine ideas* will teach learners to develop critical thinking skills.

Furthermore, 'investigation' entails the aptitude to determine new techniques (DBE, 2011: 68), the relevant sub-skills for this are *categorisation, decoding significance* and *examining ideas*. *Categorisation* and *decoding significance* are suitable sub-skills that could enable learners to develop the skills required for interpretation, which is a primary critical thinking skill. In order to determine new techniques, learners should be supported by technology teachers to formulate suitable categories and recognise the purpose of a particular expression (Facione's, 1990:13-19).

According to social learning (Bandura, 1977:52), people who support the advancement of new technologies and beliefs create opportunities for improved solutions that are better than well-established solutions. During the investigation stage (see Table 2.3), subsequent to conducting the relevant research and grasping the concepts and gained insight, learners are required to determine new techniques. Social learning advocates that new techniques should be developed to improve existing solutions.

The next step of the design process, namely 'design' (Table 2.3), obliges learners to write a design brief (DBE, 2011: 68). Writing a design brief entails the ability to outline preliminary ideas on paper, draw a realistic drawing with sufficient details, and specify the required skills to realise a solution. The appropriate sub-skills needed to write the design brief are *categorisation*, *examining ideas*, and *assessing claims*. *Categorisation* is a relevant sub-skill that requires learners to establish an appropriate framework for understanding (Facione's, 1990:13-19).

Once the framework for understanding is established, learners will be able to *examine ideas* and possibly anticipate a suitable solution. The preliminary ideas should be examined, and consequently *assessing claims* that are made should be carried out. The ability to *examine ideas* and *assess claims* teaches learners to develop the skills required for analysis, which is an important critical thinking skill (Facione's, 1990:13-19).

During the 'design' step, learners are required to generate possible solutions (DBE, 2011: 68). This necessitates sub-skills such as *categorisation*, *examining ideas*, and *conjuring alternatives*. *Categorisation* means, *inter alia*, the ability to describe experiences, situations and events. Since different ideas are discussed until a possible solution is reached, it is important for learners to be supported to *examine ideas* and subsequently generate possible solutions.

Being able to *categorise* and *examine ideas* teaches learners to develop critical thinking skills such as interpretation and analysis. Additionally, while learners generate possible solutions, they should draw inferences at the end. This emanates from the ability to *conjure alternatives*. *Conjuring alternatives* is a sub-skill that requires learners to create various alternatives that enable them to solve a particular technological problem (Facione, 1990:13-19).

During the ‘design’ step, learners are obliged to draw ideas (DBE, 2011:68) and the relevant critical thinking sub-skills for this are *examining ideas, identifying arguments*, and *assessing claims*. As learners draw ideas, the initial ideas might not be the most suitable ones and it is therefore important to suggest a variety of solutions. This requires learners to *examine ideas* that are suggested and to *identify the arguments*. To *identify the arguments* enables learners to recognise statements or reasons that support a particular claim. While learners are *identifying arguments*, they should be supported by technology teachers to *assess claims*. In this regard, learners should be able to evaluate the contextual relevance of the information. *Examining ideas* and being able to *identify the arguments* supports learners to develop critical thinking skills such as analysis and evaluation. Also, the ability to *assess the claims* teaches learners to develop critical thinking skills to evaluate information (Facione’s, 1990:13-19).

Furthermore, ‘design’ requires learners to *make decisions* once possible solutions are presented (DBE, 2011:68) and the suitable sub-skills in this regard are *examining ideas, analysing arguments*, and *querying evidence*. All available possible solutions should be examined. While possible solutions are examined, arguments should be substantiated. This involves the ability to *query evidence*. Consequently, the ability to *examine ideas* and *analyse arguments* will result in learners developing the skills of analysis. Thus, analysis is one of the essential critical thinking skills. To *query evidence* teaches learners to develop the skills required to draw inferences (Facione’s, 1990:13-19).

Social learning (see Section 2.3) advocates that people who have developed higher-order thinking skills tend to solve problems in thought before implementing them. Once people have developed these higher-order thinking skills, they are able to generate alternative solutions and instantly evaluate the long term effect of various courses of action. The IDMEC design process provides learners with the opportunity to generate alternative solutions. However, technology teachers are required to support learners to develop higher-order thinking skills in order to generate alternative technological solutions that are authentic.

‘Design’ obliges learners to choose the best solution and justify their choice (DBE, 2011: 68). The chosen solution should be the one that certainly fits the specifications; the relevant sub-skills for this are *examining ideas* and *assessing claims*. The final idea that is deemed to fit the specifications should still be examined to ascertain whether it is the best solution. The best solution should be evaluated in order to assess its credibility. Learners are still required to assess the contextual relevance of the information provided (Facione, 1990:14-15).

The next step of the design process, 'Make' (Table 2.3), requires learners to use tools and equipment (DBE, 2011:68). The right tools and equipment should be used for the specific task. Learners are required to identify the correct tools and adhere to safety precautions. In addition to this, learners should select the appropriate material to be used. This requires sub-skills such as *categorisation* and *examining ideas.* Specific tools should be classified, learners could then describe past experiences of using those tools. To select or identify appropriate materials involves *examining ideas*. Learners could argue about the effectiveness of a particular material (Facione, 1990:13-19).

The 'make' stage requires learners to build, test and modify the product (DBE, 2011:68). The appropriate sub-skills in this regard are *examining ideas* and *self-correction*. When an artefact is constructed, or built, cognitive skills are mandatory since learners apply a particular technique, and ensure that the artefact is realistic. Testing the artefact requires evaluation skills. Hence learners *examine ideas* that are presented while ensuring that the artefact is realistic. When learners test a product, they may realise that it needs some modification. This obliges learners to conduct *self-correction. Self-correction* is an important sub-skill that enables learners to rectify unforeseen errors or deficiencies (Facione, 1990:13-19).

'Make' also requires learners to adhere to safety precautions, and to ensure a healthy atmosphere (DBE, 2011:68). The latter is important since the environment in which learners construct artefacts should be conducive to working. Working under a safe and healthy atmosphere minimises injuries. The relevant sub-skills in this regard are *categorisation* and *self-examination. Categorisation* enables learners to classify and describe safety precautions. Learners should reflect on their own reasoning and be able to substantiate the results obtained in order to arrive at a particular solution (Facione, 1990:13-19).

The next step of the design process, 'Evaluation' (Table 2.3) requires learners to evaluate their actions, decisions, and the result (DBE, 2011:68). This requires sub-skills, namely, *decoding significance, clarifying meaning,* and *examining ideas. Decoding significance* entails the ability to identify and describe the purpose of particular information. Learners are enabled to assess the intentions of their actions and decisions while evaluating an artefact. This is a critical step of the design process since learners have developed an artefact, which they are required to ensure serves the intended purpose. Any decision that is taken here should be clarified. 'Evaluation' enables learners to *query evidence* presented in relation to how a developed artefact functions. The projected functions of a developed artefact should be *queried* and if needs be, modified (Facione, 1990:13-19). ‘Evaluation’ requires learners to evaluate solutions and the process followed (DBE, 2011:68). This necessitates sub-skills such as *examining ideas, assessing claims,* and *analysing arguments*. Various expressions should be examined when evaluating the solution. Learners should develop skills to differentiate ideas that support a particular claim and its premises.

‘Evaluation’ as an aspect of the design process provides learners with the opportunity to ascertain whether the solution is authentic and meets the specified need. Arguments presented should be assessed to determine whether they are true statements. *Analysing arguments* teaches learners to realise whether a presented argument is based on false assumptions or substantive assumptions (Facione, 1990:13-19). ‘Evaluation’ requires learners to suggest improvements where necessary (DBE, 2011:68); the required sub-skills for this are *analysing arguments* and *assessing arguments*. When suggestions for necessary improvements are presented, learners should be able to identify reasons that support a particular improvement and analyse it against the intended solution. Additionally, learners should be supported to judge the validity of the arguments being made. *Assessing arguments* provides learners with the ability to determine the strength of an argument and decide whether additional information is needed to augment a weak argument (Facione, 1990:13-19).

‘Evaluation’ further obliges learners to evaluate constraints (DBE, 2011:68). This step of the design process requires learners to raise questions and conduct fair tests, the sub-skills for which are *examining ideas* and *assessing claims*. Sometimes learners encounter constraints that make it difficult to achieve the desired solution. Arguments and claims will be generated once learners face constraints and it is important to *examine ideas* during the arguments and *assess the claims*. Learners should compare and contrast ideas in order to achieve the desired solution with minimal constraints (Facione, 1990: 13-19). Basically, once learners identify constraints in solving a particular technological problem, they (learners) are able to determine the limitations that they have experienced and decide on how to solve the problem with the identified constraints. Moreover, if the constraints are clearly identified, learners are somewhat enabled to anticipate future solutions with specific improvements.

The final step of the design process, ‘Communication’ (Table 2.3), requires learners to provide an assessment of the evidence of the process that was followed in a presentation form. This includes learners providing evidence on their ability to analyse, investigate, plan, design, evaluate and communicate (DBE, 2011:68). In this step of the design process, learners need to substantiate the process followed that led them to arrive at a particular solution. This requires the following sub-skills: *categorisation*, *clarifying meaning*, *examining ideas*, *querying evidence*, *analysing arguments*, *assessing claims*, and *stating results*. First and foremost, during a presentation, learners should explain the framework for their understanding in relation to *categorisation*. Also, learners should describe their experiences during their initial process and again as they go through the entire design process (Facione, 1990:13-19).

Learners should indicate the concepts that they were not familiar with and explain how these concepts were clarified. *Clarifying meaning* includes how any confusion was dealt with. In addition to this, learners should explain how they were arrived at the conclusion to consider a particular idea. Again, presentation involves *querying evidence*. Learners should state how they addressed evidence that was presented to substantiate the views that were expressed. Also, learners should provide reasons in explaining what led them to consider a particular solution and outline how arguments were analysed.

'Communication' also requires learners to provide a record of process and to *justify procedure*, which is regarded as a suitable sub-skill that provides a record of process (DBE, 2011:68). Justifying procedure means that learners must systematically describe the process that was followed from beginning to end. The researcher has noted that communication is an essential part of the design process because it provides learners with the opportunity to substantiate a solution that has been developed. It also allows learners to contextualise the ideas that influenced them (learners) to interpret, analyse, evaluate, and infer to the extent that they were able to provide an accurate record of events.

2.11 Conclusion

This chapter provided an overview of the literature on social cognition theory, the theory in which this study is located. It pointed out that social cognition theory embraces social learning that establishes a suitable environment for learners to initiate debates on how to solve an encountered technological problem, and to justify their arguments. Social cognition theory is considered appropriate in teaching technology since the design process forms the backbone for teaching technology. Also, the design process is a cognitive process used to solve technological problems. However, the prescribed design process does not emphasise the essence of social learning. Technological problems are solved in a co-operative manner whereby learners collectively examine each idea, which makes social learning imperative.

Thinking (foundation of critical thinking) enabled the researcher to understand the development and dynamics of thinking. It is seems that experience and knowledge play an important part as far as thinking is concerned. Technology teachers are continuously confronted with new technological problems and, in order to respond to these problems, it is expected that teachers draw insight from both experience and knowledge. Personal conviction plays an important role in stimulating thinking when learners are exposed to uncertainty.

This chapter also referred to various authors who define critical thinking, after which the researcher concluded that the emphasis is often placed on skills such as analysing, evaluating reasoning, reflecting, judging, interpreting, and manipulating information. These skills are essential in enabling technology teachers to encourage their learners to seek the authenticity in solving technological problems. Critical thinking emanates from a quest to search for authenticity. Without knowing what the real problem is, it is difficult to develop a solution. Therefore, authenticity serves as a vital instrument in determining the root cause of a technological problem.

This chapter also outlined the dispositions of critical thinking. It is important that technology teachers be familiar with the dispositions of critical thinking, as it would enable them to understand the nature of critical thinking and incorporate this in planning their teaching. It seems that the South African education system has the intention to instil critical thinking skills as stipulated in CAPS, but achieving this depends on technology teachers' competence in enhancing the dispositions of critical thinking skills.

The design process is considered as the backbone for teaching technology, but critical thinking skills are not sufficiently emphasised and this might lead to technology teachers not fostering these skills. The outlined conceptual framework that guided the study was also presented and discussed in this chapter. Most importantly, the prescribed design process was analysed in order to show how critical thinking can be incorporated in the design process. The next chapter addresses the research methodology utilised in this study.

Chapter 3: Research design and methodology

3.1 Overview of the chapter

This chapter presents the research design, research paradigm, and population and sampling used in this study. The data collection strategy is described as well as the instruments that were used to collect the data. Subsequently, the data analysis and standards of rigour for the research are explicated. The ethical considerations are then also delineated.

3.2 Research design

This study engaged qualitative research using a multiple case study approach. Qualitative research is typically used to answer questions about the complex nature of a phenomenon, often with the purpose of describing and understanding the phenomenon from the participants' views (Leedy & Ormord, 2002:97). Merriam and Associates (2002:9) note that a case study provides an intensive description of a phenomenon or social unit such as an individual, a group, an institution, or a community.

According to Ary, Jacobs, and Sovensen (2010:455-456) a multiple case study uses several cases selected to further understand and investigate a phenomenon, population, or general condition. A single case may not provide a thorough understanding of the phenomenon being investigated, and it is believed that using multiple cases can provide a better explanation of how teachers actualise critical thinking skills in the technology classroom.

3.3 Research paradigm

A constructivist paradigm was selected for this study. Constructivism is a theory that supports a relativist perspective, which presupposes multiple, understandable, and comparable dependable realities (Schwandt, 1994). According to Ponterotto (2005:129), a constructivist paradigm enables the researcher to uncover deeper meaning and allows both the researcher and the participants to collectively co-construct the findings from their interaction and interpretations. For this reason, a constructivist paradigm was followed to understand how technology teachers actualise critical thinking skills while supporting learners to solve technological problems. The ontological, epistemological and methodological implication of selecting a constructivist paradigm will now be discussed.

3.3.1 Ontology

According to Ponterotto (2005:130), ontology entails the nature of reality and existence. In accordance with a constructivist paradigm, reality is subjective and is influenced by experience and perspectives (Ponterotto, 2005:130). The implication is that people provide multiple explanations and interpret multiple realities differently. Dills and Romiszwiski (1997:271) explain that the constructivist paradigm advocates that there are multiple realities. The researcher, therefore, either endeavours to disclose a particular "reality" as described by the participants or tries to confirm certain preconceived assumptions (Ponterotto, 2005:130). As a result, it is insignificant that another researcher might arrive at a different conclusion while using the same data (Ponterotto, 2005:130).

Eastman, McCraven and Newteller (2001:30) emphasise that ontologically, technological problems are not solved using any modest form of unity, but are solved in the space of a social and physical environment wherein learners with diverse knowledge and skills are grouped. The study investigated how technology teachers actualise critical thinking skills in solving technological problems. The multiple settings and experiences of technology teachers are essential. For this reason, technology teachers were interviewed and observed in different settings (schools) in order to also understand their environment.

3.3.2 Epistemology

Epistemology addresses the relationship between the knower and would be knower (Ponterotto, 2005:131). Ponterotto (2005:131) highlights that the constructivist paradigm supports a transactional and biased standpoint which emphasises that reality is socially constructed. The interaction between the researcher and the participant is therefore significant when recording and describing the 'lived experience' of the participant (Ponterotto, 2005:131).

The participants were interviewed to provide them with an opportunity to describe their experiences and to explain how they actualise critical thinking skills in the classroom. Their subjective experiences were recorded and subsequently described. Also, observations were conducted to confirm what was said during the interviews. However, the researcher has noted that participants somewhat struggled to actualise critical thinking skills in their classrooms.

3.3.3 Methodology

Methodology denotes the process and procedures involved in conducting research (Ponterotto, 2005:132). Constructivists embrace a naturalistic research design in order to promote an intense co-operation among the researcher and the participant. Naturalistic inquiry often calls for qualitative researchers to use exhaustive direct contact interviews and observation of the participants, which was the case in this study. When analysing the data, in-depth knowledge was acquired of the research that was conducted.

The literature provided Facione's (1990) conceptual framework, which was used deductively to formulate the interview questions and the observation schedule, and then used to analyse the data. The selected technology teachers expressed their experiences verbally and were also observed in their classrooms individually while teaching the topic of electrical systems and control. Substantial data was collected in order to understand and successively interpret the multiple realities of these technology teachers.

3.4 Population and sample

Purposive sampling was used in this study. According to Ary et al. (2010:428-429), qualitative researchers purposefully select samples believing these to be sufficient to provide maximum insight and understanding of what they are studying. Researchers also use their experience and knowledge to select a sample in a particular environment. Denscombe (2007:17) asserts that with purposive sampling, the sample is 'hand-picked' for the research. Sarantakos (2005:164) adds that in this technique, the researcher purposely choose a subject who, in their opinion, is relevant to the project.

To achieve the purpose of this study, it was important to select the participants that had appropriate qualifications and experience in teaching technology. The participants' qualifications and experiences were essential since teachers with suitable qualifications and experience in teaching technology could provide a better understanding of how critical thinking skills are actualised in the technology classroom. Technology teachers who had obtained a Higher Diploma in Education (HDE) or Bachelor of Education (BEd) with technology as a major subject and had been teaching the subject for at least four years were considered as experienced teachers for the sake of this study.

Technology teachers in the Limpopo Province of South Africa were considered as the population of this study. Four technology teachers who taught Grade 9 in Polokwane City in the Mankweng District were selected as the sample of the study. Grade 9 teachers were chosen since technology is taught only up to Grade 9, and it is assumed that these teachers should be able to implement CAPS properly and be capable of assisting learners to develop critical thinking skills as required by CAPS (DBE, 2011:5).

Critical thinking skills include interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 1990:15). These are the skills that Grade 9 teachers should support learners to develop. Grade 4-6 teachers, on the other hand, are only required to introduce critical thinking skills such as "identifying problems and issues, predicting, hypothesizing, planning investigation, interpreting information, designing, and evaluating products" (DBE, 2011:11).

The study was conducted with limited resources and time constraints. For this reason, the Mankweng District was used since it is in proximity to the researcher's place of work and residence. The intention was to start with three technology teachers and continue until a point of saturation had been reached. Four participants were interviewed, and after the third participant it was noticed that there was no new information presented. Also, during the observations, the third participant did not provide new information.

Powers and Knapp (2011:116) state that in qualitative research, saturation is a sense of closure that transpires during data collection once new information is no longer forthcoming. A minimum of three schools around the City of Polokwane in the Mankweng District were visited to identify Grade 9 technology teacher participants and these teachers were interviewed to determine their experience in teaching technology.

3.5 Data collection

Data was collected by means of structured interviews and classroom observations in an electrical systems and control context. Creswell (2007:38) highlights that qualitative researchers typically gather multiple forms of data such as interviews and observations rather than rely on a single data source. Both the interview questions and observation schedule were developed from the conceptual framework, as discussed in Section 2.9 and shown in Figure 2.1.

3.5.1 Interviews

A qualitative interview is an interaction in which the interviewer leads the conversation and follows specific issues that are raised by the respondent (Babbie & Mouton, 2001:289). In this study, structured face-to-face interviews with the sampled technology teachers were conducted in order to understand the teachers' knowledge and understanding of critical thinking. Sarantakos (2005:268) states that structured interviews use structured questions that are orally presented to the participants and the interviewer strictly stick to the questions. The questions in this study were organised in such a way that all the essential critical thinking skills, as discussed in the conceptual framework (see Section 2.9), were addressed.

The critical thinking sub-skills (see Section 2.9) were then used as follow-up questions to further probe the teachers' knowledge and understanding of each critical thinking skill. Wisker (2001:168) acknowledges that structured, open-ended interviews manage to address the need for comparable responses whereby the same questions are asked to each participant and conversations which are rich and rewarding are developed between the participants and the researcher.

Structured interviews with twenty-two (22) open-ended questions (see Appendix A), were used to allow participants to share their experiences and express their opinion of critical thinking and how they actualise critical thinking skills in their classrooms. The interviews were conducted during normal school hours when these participants were free. To ensure that there were no disruptions, the participants arranged suitable rooms for privacy in the visited schools.

The interviews were audio recorded in order to document the responses to questions and to describe the views of the technology teachers. Participants were allowed to express themselves without interruption. Furthermore, the interview questions were clarified to ensure that the participants understood the questions before responding, and follow-up questions were made in instances where the participants did not understand a question.

3.5.2 Observations

A structured observation schedule (see Appendix B) was used during the classroom observations to observe the sampled teachers. Sarantakos (2005:222-223) highlights that structured observations actualise a formal and organised procedure with a set of well-defined observation categories, and are subjected to high levels of control and standardisation. The observation categories were, as noted earlier, directly derived from the conceptual framework. Observation was selected to collect data during lesson presentations to examine the manner in which the technology teachers actualised critical thinking skills in the classroom. Observations were done towards the end of Term 3 when the topic of electrical systems and control was addressed. In accordance with both CAPS (DBE, 2011) and the textbook that the participants used, Term 3 is scheduled for teaching electrical systems and control. Without disrupting the school timetable, the researcher observed lessons that were presented for 45-60 minutes.

The observation schedule was structured in such a way that the relevant aspect of critical thinking could be ticked off, but only when it was observed during the lesson. In addition to the observation schedule, the researcher took field notes to supplement the observation schedule and to fill possible gaps in the observation schedule. The researcher took notes as the participants presented the lessons to capture the relevant aspects of both critical thinking and the design process.

Observations enabled the researcher to verify the aspects of critical thinking that were raised during the interviews. During the observations, the manner in which technology teachers encouraged learners to interpret, analyse new information, make inferences, and explain was observed (Facione, 1990:15). The observations were useful in determining the dispositions that are essential to developing critical thinking.

3.6 Data analysis

As indicated in the research design, this study engaged a multiple case study approach and data collected from the observations and interviews were analysed using the conceptual framework and presented in a narrative manner. The data from the audio recording about technology teachers' perceptions and views were transcribed in order to make sense of the explanations, and additionally, to identify statements that relate to actualising critical thinking. The set of questions was used to structure the narrative and the participants' utterances.

Observations were carried out in order to verify the findings obtained from the interviews. Firstly, the context of each observation was provided and followed by a summary in table form. Subsequently, the findings were discussed in detail. To compare the findings, triangulation was used. Maree and Van der Westhuizen (2007:274) affirm that triangulation is the most suitable method when a researcher wants to collect data from multiple sources at the same time regarding a single phenomenon. This allows the researcher to compare and contrast the different findings to produce a well-validated conclusion. The conceptual framework was used deductively to develop the observation schedule and data was analysed accordingly.

Triangulation enabled this researcher to substantiate what participants mentioned during the interviews and to verify it against observations. The participants were asked how they actualise critical thinking skills when teaching technology and their responses were verified during the observations. The final report was drafted to present a detailed description of the cases and their contexts.

Ary et al. (2010:499) highlight that a combination of data sources, such as interviews and observations, increases the likelihood that the phenomenon under study is being understood from various points of view. The ability of technology teachers to encourage learners to develop their own reasoning skills in a cooperative manner, that is, to interpret, analyse arguments, and make inferences as they solve a problem, enabled the researcher to analyse the emerging data with reference to the principles of social cognitive theory.

3.7 Standards of rigor for research

The four standards of rigour for qualitative research are: credibility, transferability, dependability (or trustworthiness), and confirmability (Ary et al., 2010:498). The next section describes how the four standards of rigour were enhanced in this study.

3.7.1 Credibility

In order to enhance the credibility of the research findings, as suggested by Ary et al. (2010:498), the study engaged structural corroboration, which entails using multiple sources of data. Four interviews and three observations were conducted. Triangulation was used to confirm data collected from the interviews by means of observations. In order to enhance the credibility of the finding, data was interpreted with reference to the conceptual framework (see Section 2.9). The participants were constantly asked the structured questions and the researcher acted neutrally without showing personal interest. This was done to minimise the aspect of bias and enhance the degree of objectivity. Sarantakos (2005:268) highlights that the interviewer who acts neutrally and interview the respondents in the same manner, lessen the degree of bias.

Additionally, the raw data, along with interpretation, were forwarded to a colleague of the researcher who lectures technology at the University of Limpopo for peer reviewing. This colleague advised the researcher to focus on the main themes when reporting, instead of providing the entire transcript; this advice was taken into consideration. Before drafting the final report, interview transcripts were presented to the participants so that they could confirm the accuracy of the transcriptions. The participants indicated that they were fairly represented and acknowledged that they had discovered their limitations in actualising critical thinking skills in the classroom. Moreover, the participants stressed that they would use the transcripts to correct their limitations.

3.7.2 Transferability

In accordance with the principles of transferability, the study provided, as suggested by Ary et al. (2010:499), adequate, rich, and detailed descriptions of both interview and observation details so that the reader is able to compare and make judgements about the similarity and the differences of the cases studied. To enable readers to decide on the extent of transferability, an accurate and comprehensive description of the study context was provided from both the observation and the interview records. Also, field notes are attached in Appendix D for scrutiny.

3.7.3 Dependability

In order to enhance the dependability of the findings, this study provides an audit trail which will enable readers to evaluate the context of the study, as suggested by Ary et al. (2010:499). The latter will enable the reader to understand the context in which the research influenced the conclusions that were drawn. Raw data (audio recordings and field notes) that were obtained from both the interviews and observations will be stored for verification. The study provided a complete presentation of the research results in order to assist the reader to decide on the trustworthiness of the research. Since the study used multiple case studies, data collected from both the observations and the interviews was verified by means of triangulation, which establishes dependability, particularly if similar findings are identified.

3.7.4 Confirmability

The study applied member checking in order to confirm the findings of the study (Ary et al., 2010:499). Participants were asked to verify the accuracy of the verbatim quotations that were recorded during interviews. All of the participants acknowledged that the transcripts were a true reflection of what they mentioned.

3.8 Ethical considerations

First and foremost, the researcher acknowledged the social responsibility that research should adhere to. To conform to the appropriate ethical considerations, the postgraduate research policy from the University of Pretoria (Faculty of Education) was consulted. The postgraduate research policy clearly outlined specific procedures and regulations, and included an application form that provides guidance for ethical considerations.

The researcher then applied for ethical clearance at the Faculty of Education (see Appendix C). Permission was granted to collect data for this study (see Appendix CC), but it was emphasised that upon completion of research, an Integrated Declaration Form should be submitted to confirm that the conditions were adhered to, as stipulated. The ethical clearance certificate (see page iv) shows that the research was approved by the Faculty of Education's ethics committee. The principles of moral code as described in the application were adhered to. The participants were, for example, treated fairly, permission to conduct the research was requested from all the relevant authorities; and all the principles of confidentiality were conformed to. The study was conducted in a professional manner and the participants were treated with respect.

Potter (2002:154-156) explains that academic research is about creating a community of scholars that is sustained by both trust and scepticism. In addition to this, it is worth emphasising that there is a strong moral duty to have due consideration for confidentiality and privacy in any subject of research that the researcher may carry out.

Permission was requested (see Appendix D) from the Department of Education (Limpopo) and, once permission had been granted (see Appendix DD), further permission was sought from the Circuit Manager (see Appendix E) and Appendix EE confirms the permission that was granted. The school principals were consulted and the purpose of the study was explained, after which permission was again requested (see Appendix F) to approach the technology teachers before commencing with the research. Furthermore, informed consent was also obtained from the parents (see Appendix HH) since learners were present in the classroom observations. Letters of informed consent for permission from the principal, technology teachers (see Appendix G) and parents (see Appendix H) are attached. The participants were provided with a consent form that outlined the purpose of the study. Participation was on a voluntary basis and participants had the right to discontinue participation at any stage of the study without penalties. Moreover, the participants' right to privacy was respected.

The study did not expose the research participants (technology teachers) to undue physical or psychological harm. No individual was forced to participate and the participants received letters of informed consent as attached in Appendix F, which clearly emphasises that they participated on a voluntarily basis and that they were free to stop participating at any point. The purpose and procedure of the study was explained thoroughly to the participants.

The parents of learners at the participating schools were sent an informed consent form since learners were present in the classroom during observations. The letters to the parents were written in a vernacular in order to accommodate parents who were not conversant in English. Appendix HH confirms the latter. It was considered ethical to obtain permission from the parents since the teachers were observed in the presence of the learners and it was anticipated that there would be interaction between the teacher and the learners during the observations. In essence, learners were indirectly affected by the research. The parents were informed about the purpose of the research and were assured that the learners would not be interviewed or observed.

The focus of the study was on the technology teacher. It was emphasised that the researcher would not interfere with the teacher while he/she presented a lesson and information obtained from this research would be used for the purpose of this research only. In addition to this, the information obtained was treated in the strictest confidentiality possible and no child's name is mentioned.

Pseudonyms were used to protect the names of schools in both the interview and observation schedule attached in Appendix A and B. The study strived for academic rigour in analysing the data and reporting on it. Leedy and Ormord (2005:101) emphasise that researchers should report their findings in a complete and honest fashion, without misrepresenting what they have done or intentionally misleading others about the nature of their findings. This has been adhered to in this study.

3.9 Summary of the chapter

This chapter presented a detailed qualitative investigation that comprised the research design, research paradigm, and population and sampling procedure. Qualitative enquiry was used to understand and describe the experiences and perceptions of the participating technology teachers when actualising critical thinking skills while supporting learners to solve technological problems. Additionally, this chapter described the data collection strategy, data analysis, standards of rigour for research, and the ethical considerations adhered to in carrying out this research. The next chapter presents the findings of the study.

Chapter 4: Discussion of the findings

4.1 Overview of the Chapter

This chapter reports on the analysis of the data that was collected by means of both the interviews and observations. It starts with an outline of the biographical information of the participants in order to show their academic qualifications and experience in teaching technology. This is followed by a discussion on the participants' responses that were obtained from the structured interviews. The participants' responses are presented in a narrative manner and conclusions are drawn in accordance with the participants' responses. A discussion of the observations will then be presented whereby the context will be provided and followed by a summary of each observation.

4.2 Biographical information of participants

Four Grade 9 teachers were initially selected as participants for this study (see Chapter 3, Section 3.4), and pseudonyms were used to ensure the confidentiality of the participants. Table 4.1 summarises the participants' biographical information in terms of their gender, age, qualifications and experience in teaching technology.

Table 4.1: Summary of participants' biographical information

Name	Gender	Age	Qualifications	Teaching Experience
John	**Male**	46 - 50	Std: Life Sciences And Biblical Studies. ACE: School Management ACE: Technology Education	5 - 10
Matthew	**Male**	46 - 50	B Ed: Technology Education B Ed (Hons): Technology Education	More Than 15 Years (Including Teaching Technical Subjects)
Mark	**Male**	31 - 35	B Ed: Technology Education	5 - 10
Luke	**Female**	36 - 40	B Ed: Technology Education B Ed (Hons): Curriculum Studies	5 - 10

Table 4.1 shows that three participants met the requirements stipulated in the sampling in Chapter 3 (see Section 3.4). Teachers who held an advanced certificate in Education (ACE) as their highest qualification in education were initially not considered. In one of the schools where permission was obtained to conduct research, it was discovered that one of the participants (John) held an ACE in technology education. Since this research was conducted towards the end of Term 3, there was too much of a limitation on time to find another qualified Grade 9 teacher elsewhere. Thus, John was included in the sample since he had more than five years of experience in teaching technology and it would take too long to obtain permission to carry out research in another school.

Data was collected by means of structured, face to face interviews and classroom observations. The interviews were conducted first; the next section provides a discussion of the interview process.

4.3 The interviews

Twenty two (22) questions were derived from the conceptual framework, focusing specifically on critical thinking and Facione's critical thinking skills framework (see Section 2.4). These questions (see Appendix A) were used to conduct the interviews. The first two questions probed the teachers' understanding of critical thinking and how they actualised critical thinking in their classrooms. The third question focused on the dispositions of critical thinking. The rest of the questions (from Questions 4) used Facione's critical thinking skills as a basis to formulate questions related to each of the critical thinking skills. Each question for each critical thinking skill was directly followed by questions pertaining to each critical thinking sub-skill (see Figure 2.1).

Since the researcher personally conducted the interviews, it was possible to simplify the questions and clarify concepts that the participants may not have understood. This ensured that the participants fully comprehended the questions before they responded. The findings will be presented as follows: the question that was asked will be stated followed by a critical discussion of the participants' responses. The critical discussion is then related to the theory and conceptual framework, and presented in a narrative manner. Examples of the participants' utterances will be provided to support the discussion. Thereafter, conclusions are drawn based on the participants' responses.

Question 1: What is your definition of critical thinking?

According to Facione (1990:6), critical thinking is a dedicated self-regulatory ability to make rational conclusions emanating from skills, i.e. to interpret, analyse, evaluate, infer, and provide explanation. For the purpose of this study, these critical thinking skills were used as criteria that provided guidance in the interpretation of the participants' definitions of critical thinking. The research participants described critical thinking as an aptitude to discussing the merits and faults of the information provided. To them, critical thinking meant thinking in a creative manner and learners learning to apply their minds. Utterances of participants on the definition of critical thinking include the following:

> *Critical thinking is defined as the ability to criticise, to compare and contrast. It means that you go into deeper analysis. (John)*
>
> *Questions given to learners enable them to understand. (Matthew)*
>
> *Critical thinking means that when leaners are given chance to think. (Mark)*
>
> *It means learners are able to think out of the box. (Luke)*

It appears that the participants had a very basic understanding of what critical thinking entails. The ability to compare and contrast means the potential to examine ideas, which is a sub-skill of 'Analysis'. This is one of the essential critical thinking skills in Facione's (1990) framework (see Section 2.7). The questions asked by the teachers in their classrooms encouraged learners to think and subsequently clarify meaning and develop the skills to interpret. Also, 'interpretation' is a primary critical thinking skill that is developed through sub-skills such as *categorisation, decoding significance, and clarifying meaning* (Facione, 1990:15). Teachers could use questioning as a teaching method to develop learners' critical thinking skills.

Question 2: How do you actualise critical thinking skills in teaching technology?

The design process is a fundamental technique used in technology to solve design problems. The design process embraces a cognitive approach in solving problems (Jones & De Vries, 2009:393). Thus, the design process can be used to actualise critical thinking in the classroom. Also, Facione (1990:6) stresses that critical thinking is, in essence, an instrument used to conduct inquiry.

The participants reported that learners should be able to solve technological problems using the design process independently. Learners were provided with tasks that encouraged them to seek information, identify, and solve problems as well. The learners modified existing products by coming up with new ideas. Utterances of participants on how they actualise critical thinking skills include:

> *Learners should be independent, be able to identify problems, state the problem in accordance with the technological process. (John)*
>
> *By giving learners assignments and home works [sic] that learners should refer to and find more information. (Matthew)*
>
> *Ensuring that learners are aware that the purpose of technology is to solve problems. (Mark)*
>
> *Introducing learners to things that they normally see daily and come up with new ideas. (Luke)*

Question 2 was asked in order to provide the participants with an opportunity to explain how they actualise critical thinking skills in the technology classroom. While the design process offers the opportunity to foster critical thinking skills, the participants' explanations indirectly made reference to identifying and solving problems. Identifying and solving problems are key to the design process, however, the participants did not emphasise the use of the design process to provide an opportunity to actualise critical thinking skills. Seeking information and identifying a problem are activities that are limited to 'investigation' (see Section 2.9, Table 2.2).

Question 3: What are your personal characteristics that enable you to teach critical thinking skills?

Facione (1990:28) emphasises that an ideal critical thinker habitually demonstrates characteristics such as inquisitiveness, being well-informed, trustful of reason, open minded, flexible, fair-minded in appropriate reasoning, honest in facing personal biases, prudent and willing to revise views where honest reflection suggests that change is warranted. These characteristics were mostly deficient in the participants' answers to Question 3. The participants claimed that they were able to teach the design process. The researcher is, however, not convinced that this statement is true since this statement contradicts participants' answers to Questions 17 and 18. A possible reason for the discrepancy in their answers may be attributed to their lack of knowledge of how to teach the design process in accordance with CAPS.

The participants encouraged learners to search information using the internet. The participants also reported that they facilitated learning in the classroom in order to stimulate critical thinking. The teachers assisted their learners by solving a particular technological problem and thereafter providing learners with an opportunity to think about other solutions. The participants indicated that they used experience gained while studying at university to teach critical thinking skills. This is another contradiction. Utterances of participants on personal characteristics that enabled them to teach critical thinking skills include:

> *I am able to unfold the technological processes to learners except I still have challenges. (John)*
>
> *Allow learners to explore and use internet to extend their knowledge. (Matthew)*
>
> *Plays the facilitating role and identify one solution and thereafter allow learners to think about the other solutions. (Mark)*
>
> *Use what I have learned when studying at the university. (Luke)*

The participants' answers disclosed limited dispositions typical of a critical thinker. In the researcher's opinion, it is important that teachers be positively disposed towards using critical thinking in order to actualise critical thinking skills. For instance, technology teachers should be inquisitive and instill that degree of inquisitiveness in their learners. Facione (1990:23) states that inquisitiveness generates a mind that is keen, motivated to reason, and seeks reliable information. Once learners have developed inquisitiveness, they will be taught to explore (as reported by participants) willingly with eagerness to seek information. Open-mindedness is another important characteristic that the participants did not refer to. Divergent views need to be treated with an open mind (see Section 2.6).

Question 4: What kind of approach do you use to encourage learners to interpret information?

This question was intended to determine the methods that the participants employed in order to support learners in interpreting information that they (learners) accessed or information that the teacher presented. According to Facione (1990:16-17), 'interpretation', a critical thinking skill, enables teachers to grasp and articulate the meaning of a particular concept. Interpretation includes sub-skills such as *categorisation*, *decoding significance*, and *clarifying meaning*.

The participants reported that learners in Grade 9 are expected to be able to interpret information. A figure of speech was used to interpret technological concepts. The participants also indicated that learners considered whatever information the teachers presented to them without interpretation. Utterances of participants on how they encouraged learners to interpret information include:

> *Learners who have good knowledge of technology and having passed Grade 8 should be able to interpret. (John)*
>
> *When you want learners to understand something better like colours of the resistor. You give them this, say: "bad boys' rape of young girls but violet grab wine" [sic]. (Matthew)*
>
> *Learners take whatever information presented to them [sic]. (Mark)*
>
> *Put learners in a group and give them an activity to solve a problem. (Luke)*

It appears that the participants found it difficult to encourage learners to interpret information. None of the participants mentioned how they taught learners to grasp and express the meaning of a particular technological concept. In accordance with Facione's (1990:16-17) framework, 'interpretation' involves the ability to describe experiences, situations, or events. Learners should be taught to recognise and describe the context of a technological problem, and to identify possible constraints. The participants were unable to clearly articulate, and could therefore not explicitly explain how they encouraged learners to interpret information.

Question 5: Do you allow learners to describe their experiences, situations, beliefs, and events in order to understand the meaning of a particular context?

Question 4 was an open question used to determine if the participants had a particular approach to encouraging learners to interpret information. Question 5 was a follow-up question intended to examine whether the participants could substantiate their ability to encourage learners to interpret information. Facione (1990:16) emphasises that during *categorisation*, a sub-skill for 'interpretation' (see Figure 2.1), learners describe their experiences, situations, beliefs, and events in order to grasp the context of the appropriate framework.

The participants reported that the learners had the tendency to waste time disputing beliefs and experiences without identifying reasonable experiences. For instance, when teaching about electric circuits, learners were encouraged to share their experiences. Also, learners were asked if they had ever used a particular electronic component and what their experiences with it were. Utterances of the participants on how they allowed learners to describe their experiences and beliefs include:

> *In most cases we differ in terms and take a long time arguing amongst ourselves. (John)*
>
> *I don't just teach them, I also want them to tell me what they understand about a particular content. (Matthew)*
>
> *Learners are able to criticise one another's method (Mark)*
>
> *We normally refer them back to what they do in their daily lives. (Luke)*

It appears that the research participants did not exploit or create sufficient opportunities for leaners to share their experiences and or beliefs. The researcher believes that learners will develop the skills to reason and justify their arguments if they are supported in explaining their experiences and relating these to the context of the technological problem at hand.

Question 6: How do you support learners to recognise the significance of interpreting the learning experience?

Recognising (decoding) significance is another sub-skill of 'interpretation' (see Figure 2.1). Thus, Question 6 served as a follow-up to Question 5 and was intended to determine whether the participants were able to support their learners in recognising the significance of interpreting the learning activity at hand. Facione (1990:17) highlights that *decoding significance* enables learners to recognise the purpose and motives of specific information. The participants reported that the learners were instructed to put a particular theory into practice and to determine whether the theory was appropriate.

The learners were encouraged to randomly search for technological problems at home and attempt to solve them. Utterances of participants on how they supported learners to recognise the significance of interpreting the learning experience include:

> *Do it in practice to see as to whether it is wrong or right, we were given some steps to follow and practically test given theory. (John)*
>
> *I give them projects to interpret what they have learned. (Matthew)*
>
> *I tell them to identify the problems in their various communities and come up with solutions to solve that problem. (Luke)*

Recognising (decoding) the significance of the learning activity enables learners to identify, consider, and describe the purposes and motives of the particular information that was acquired during the learning experience (Facione, 1990:17). Developing the skill to recognise this significance emanates from the ability to contextualise information, and to understand social significances and the values of particular information. The participants did not allude to such concepts and this supports the finding in Question 4 that the participants found it difficult to encourage learners to interpret information. It appears that the participants somewhat deprived their learners of the opportunity to develop interpretation skills.

Question 7: Do you provide learners with the opportunity to clarify meaning?

Clarifying meaning is a sub-skill of ‘interpretation’ (see Figure 2.1) and it denotes the ability to express the meaning of something using different words, seeking clarity, and using figurative utterances to eliminate confusion and unplanned ambiguity (Facione, 1990:17). The participants disclosed that they usually determined learners’ understanding of a particular concept before explaining the concept to the learners. The learners were grouped and instructed to discuss a particular concept. Once the learners understood the concept, they were supposed to determine how the concept could assist them in solving a technological problem. Thereafter, the learners asked questions.

The participants also disclosed that the learners were given an opportunity to explore and share their experiences. To provide learners with the opportunity to clarify meaning depends on the content of the subject and learners' level of understanding. Utterances of participants on how they provided learners with the opportunity to clarify meaning include:

> *Normally what I do before I can even explain certain concepts to them I need to have their view first to know their general understanding. (John)*
>
> *I give them opportunity to explore, we share experience especially with the acronyms [sic]. (Matthew)*

Once teachers present a particular concept, learners should be given an opportunity to clarify that concept. In clarifying concepts, learners attempt to understand and contextualise the concept. However, it seems that the participants did not understand what *clarifying meaning* entailed. The learners spontaneously expressed their views on particular concepts without proper guidance. Teachers should teach learners to seek clarity and grasp the intended meaning of particular ideas (Facione, 1990:17).

Question 8: How do you motivate learners to analyse statements?

Before presenting Question 8 to the participants, the researcher explained to each participant (see Appendix A) that analysis is a critical thinking skill that enables learners to identify the intended and actual inferential relationship between statements. This was done to clarify the question and avoid ambiguity. According to Facione (1990:17), 'analysis' involves *examining ideas*, *detecting arguments*, and *analysing the arguments*. Analysis refers to the ability to compare and distinguish ideas. The participants divulged that the learners were encouraged to investigate the development of specific information and not to consider the information as is. Learners should be inquisitive. Learners are advised to identify the main idea within a sentence and perceive the intended meaning.

The learners should firstly discuss their analysis with their teacher to determine the rationale of their analysis. Learners are often given case studies to explain the meaning of particular statements. Utterances of the participants on how they motivated learners to analyse statements include:

> *Whenever you have information, try to find out how the information came into existence, don't take things raw as they are. (John)*
>
> *We look at the critical point in the sentence, the facts, underline those facts and combine the understanding. (Matthew)*
>
> *Learners must tell me what they know so that I know where to start and end. (Mark)*
>
> *By giving them case studies and ask them to tell me what those statements meant. (Luke)*

Amongst others, 'analysis' is an essential critical thinking skill that technology teachers should consider seriously if they want to be successful in actualising critical thinking skills. Learners should be supported in examining ideas, identifying the arguments within statements that are made, and being able to analyse arguments (Facione, 1990: 17). However, it appears that the participants had limited knowledge of how to motivate learners to analyse statements. Giving learners an opportunity to look at some words from a dictionary and glossary does not provide leaners with an opportunity to develop analysis skills. In essence, the participants deprived their learners of the ability to recognise the relationship between statements made, such that these learners are able to compare similarities or divergent views in order to arrive at a realistic conclusion.

Question 9: How do you support learners to examine ideas during the learning experience?

To *examine ideas* is a sub-skill of 'analysis' (see Figure 2.1). Question 9 serves as a follow-up to Question 8 to further probe how the participants analysed statements. Facione (1990:17) states that *examining ideas* means the ability to define the meaning of a particular concept, compare statements, and recognise the conceptual links of various parts to each component and to the whole. The participants reported that the learners were advised to scrutinise whatever ideas they had with their fellow leaners.

The learners were also encouraged to work in groups and consult and share their ideas. Group discussion teaches learners to determine whether they share the same understanding. The participants revealed that they regularly provided clues only if the learners struggled to solve a technological problems. Utterances of participants on how they supported learners to examine ideas include:

> *I group them to share ideas among themselves. (Matthew)*
>
> *I don't know if I support learners to examine ideas during the learning experience. (Mark)*
>
> *When I see that learners are struggling in identifying a problem, I always give them a hint. (Luke)*

Technology teachers should teach learners to compare ideas instead of spontaneously sharing ideas. *Examining ideas* implies the ability to detect a technological problem and be able to ascertain the elements of this problem. Furthermore, learners should be guided to recognise the conceptual links between various parts and each component, and the problem as a whole (Facione, 1990:17). However, the participants did not allude to this. It seems that the participants battled to support learners in examining ideas, otherwise the participants would have explicitly substantiated how their learners compared statements and drew conclusions.

Question 10: How do you assist learners to recognise arguments within claims or opinions?

Identifying the arguments is another sub-skill of 'analysis' (see Figure 2.1). Learners should be able to identify the arguments within statements that are made, and determine the rationale of these arguments. Statements or graphic representations are used to determine whether they intend to support or reject certain claims or opinions (Facione, 1990:18). The participants disclosed that once the learners were told that their answers were incorrect, they tended to be discouraged and stopped participating. However, the teachers motivated learners to give reasons for their answers. For assessment purposes, the learners were advised to consider what the prescribed textbook recommended.

The participants also disclosed that it was difficult to assist learners to recognise (detect) arguments within claims or opinions. However, the participants used questions in order to motivate learners to express their views. Utterances of participants on how they assisted learners to recognise arguments include:

> *Give me reasons why, how you arrived at this solution. Let's follow this route because this is the one that is going to be examined through the same content. (John)*
>
> *It is when you ask them questions, we give their point of view from there we share them. (Matthew)*
>
> *We have never come to a point where learners contest some claims. (Mark)*

The ability to detect arguments teaches learners to substantiate their opinions with reasons. Once a claim is presented, learners should be able to determine whether it is correct or not. It appears that the participants had not established even one opportunity for claims to be expressed and subsequently contested. The opportunity to recognise arguments within a particular claim teaches learners to develop critical thinking skills and have the prospects to justify their arguments. The participants did not assist their learners to recognise arguments within claims that are expressed.

Question 11: How do you encourage learners to analyse arguments?

Once learners are able to identify an argument within a statement that is made, they should be supported to analyse those arguments: analysing arguments is a sub-skill of 'analysis' (see Figure 2.1). Question 11 served as a follow-up to Question 10 to further determine if the participants taught learners how to analyse statements that are made. Facione (1990:18) states that *analysing arguments* means the ability to identify and differentiate reasons that support a particular expression. The participants reported that during an argument, they recognised the idea and subsequently modified that idea accordingly.

The learners tended to suggest ideas that were irrelevant; however, the participants eventually corrected learners with ideas that were closer to the mark. Some learners were shy to analyse arguments during group discussions, but privately expressed their views. The participants also reported that learners were encouraged to reason systematically. Utterances of participants on how they encouraged learners to analyse arguments include:

> *When learners argue I recognise the idea irrespective of whether is correct or wrong, the fact is that it is only the answer that I am going to modify. (John)*
>
> *When learners analyse, they start looking at each other as if they don't know, but privately we share so that they understand. (Matthew)*
>
> *I tell them whatever decision they come across, they must reason like scientists. (Luke)*

According to Facione (1990), learners are supposed to recognise and distinguish reasons that substantiate a given expression. However, it seems that the participants had a limited understanding of how to encourage learners to analyse arguments. In addition to this, the participants acknowledged that they did not know how to encourage learners to analyse arguments. To recognise an idea and modify the answer does not reflect the ability to analyse arguments. Learners should be encouraged to identify and differentiate between the reasons given for an idea that led to a particular conclusion (Facione, 1990:18).

Question 12: How do you persuade learners to evaluate the credibility of given statements?

Before asking participants Question 12, the researcher explained to each participant (see Appendix A), that 'evaluation' is a critical thinking skill that enables learners to assess the credibility of statements that are made. Facione (1990: 18) highlights that *evaluation* means ascertaining the reliability of statements presented, and determining the rationale of the reasons as to why a particular conclusion was reached. The participants divulged that the learners were evaluated for assessment purposes. The learners were encouraged to study given statements until these statements were thoroughly understood and consequently, learners considered important information in the statements made and discussed the given information.

Furthermore, a dictionary was used for reference in cases where a particular concept in a statement was not understood. The participants also reported that learners usually evaluated the projects that they made, and not statements. Utterances of participants on how the participants persuaded learners to evaluate the credibility of given statements include:

> *There is a need to evaluate learners formally and informally and give learners activity to do which I can control [sic]. (John)*
>
> *Learners take critical points or areas of the importance in each statement, from there we talk about that. (Matthew)*
>
> *Learners evaluate their own projects, not the statements. (Luke)*

According to the CAPS document for technology, learners are required to evaluate their learning activities, conclusions, and results obtained while following the design process (DBE, 2011:68). The learners evaluated technological problems, but when the researcher compares the manner in which both Facione (1990) and the DBE (2011) describe *evaluation*, it is clear that evaluation involves the ability to establish the reliability of the statements. Learners should assess their actions while solving technological problems. It seems that the participants did not support learners in ascertaining the credibility of the statements presented.

The participants did not explicitly explain how they persuaded learners to assess their own activities and conclusions. CAPS stipulate that *evaluation* in the design process is not merely a series of steps that are arranged in sequence, but is a "*cyclical*" process (DBE, 2011:74). The participants did not specify that their learners evaluated each and every step of the design process and simultaneously re-assessed each design step to show that the design process was cyclic. It seems that the participants did not engage the design process as prescribed by CAPS, let alone teach learners to develop evaluation skills.

Question 13: Do you think learners are able to recognise the factors relevant to assessing the degree of credibility of a given statement?

One of the sub-skills of evaluation is the ability to assess claims that are made (see Figure 2.1). This question serves as a follow-up to Question 12 as a means of allowing participants to substantiate the manner in which they supported their learners to evaluate the credibility of given statements. Facione (1990:18-19) states that recognising the factors relevant to evaluating the degree of credibility means endorsing the source of information. The context of the information should be evaluated and ascertained as to whether it is acceptable or not. The participants disclosed that the learners were encouraged to work in groups and rectify their mistakes. The participants acknowledged that they assisted the learners, but that it was not easy to identify factors that are relevant to assessing the degree of credibility. For instance, when the teacher presented a lesson on Ohm's law, the learners should have understood the definition of Ohm's law before being able to calculate resistance, current, and voltage. Utterances of participants on the learners' ability to recognise the factors relevant to assessing the degree of credibility include:

> *In most cases, like project, I encourage learners to do it in groups and correct their mistakes. (John)*
>
> *No, I don't think so. (Luke)*

It should be noted that some participants found this question difficult to understand. Only after the researcher attempted to simplify it by giving examples were they able to respond. The participants admitted that it was difficult to notice whether learners were able to identify the factors relevant to assessing the degree of credibility. This implies that these learners were not enabled to endorse the source of information and establish whether claims or opinions made are acceptable or not.

Question 14: Do you think learners are able to judge the strength of an argument's premises and assumptions with a view towards determining the acceptability of the arguments?

Assessing arguments is a sub-skill of 'evaluation' (Figure 2.1). Similar to Question 13, this question was intended to probe whether the participants were able to support learners to develop evaluation skills. This question was asked to determine whether the teachers were able to assist learners in examining the strength of an argument and accepting the argument as reliable. Facione (1990:19) highlights that *assessing arguments* encompasses the ability to establish whether the argument is based on unfounded assumptions, and therefore determine how essentially these assumptions impact on the strength of the argument's premises. The participants reported that it depended on the learners' ability since learners differ in terms of their level of understanding. All ideas suggested by learners should be considered important as these ideas represent learners' level of understanding. However, the participants indicated that the time allocated to teaching technology was insufficient given the kind of activities that they were expected to do.

The teachers were hesitant to explore additional activities since this could delay them from finishing the syllabus in the specific time allocated. The learners did not argue with intention to reach agreement, and it was difficult to monitor how they argued since the classes were overcrowded. Utterances of participants on how they motivated learners to analyse statements include:

> *Every idea of every person is as much important as the others. (John)*
>
> *Sometimes due to time factor some activities, items we don't do. (Matthew)*
>
> *Our learners do not engage themselves in arguments. (Mark)*
>
> *With many learners that we have, sometimes it is not easy to do that. (Luke)*

The participants acknowledged that they did not allow learners to judge the strength of an argument's premises and assumptions. This implies that the learners were not given the opportunity to assess arguments. Assessing arguments enables learners to ascertain and conclude the strength of an argument (Facione, 1990:19).

Question 15: How do you support learners in drawing their own conclusions when solving technological problems?

Before asking Question 15, the researcher explained to each participant (see Appendix A), that 'inference' is a critical thinking skill that enables learners to identify and secure elements needed to draw reasonable conclusions. According to Facione (1990:16), 'inference' involves the ability to recognise and secure the components required to draw a realistic conclusion. Inference allows learners to think critically about the applicable information that is drawn from statements, evidence, and any other forms of representation.

The participants revealed that they assessed learners' activities by examining each activity step by step to establish how the learners systematically arrived at their solutions. This helped the participants to know how to assist their learners. The learners were allowed to argue until they reached a consensus. In addition to this, the learners were provided with an opportunity to explore technological solutions on their own and thereafter submit their results.

The participants also indicated that the learners' results were examined, after which they provided feedback to the learners to enable them improve their submissions. The learners were required to present their ideas or solutions that enabled them to solve a technological problem and subsequently choose and justify the best solution. Utterances of participants on how they supported learners to draw conclusion include:

> *Knowing very well that their understandings are not the same, that's where they must argue up until they come to a certain conclusion. (John)*
>
> *I give them chance to explore by doing on their own and when they submit, I improve their results. (Matthew)*
>
> *You guide them, you might not tell them what you want to achieve because they can't do it on their own. (Mark)*
>
> *Learners should come up with ideas or solutions to solve problem [sic] and choose the one that they think is best for the problem based on the reasons put forward. (Luke)*

It seems that the participants had limited knowledge and understanding of how to enable learners to draw conclusions. Learners should be allowed and encouraged to verify statements or evidence presented to them in order to draw an applicable conclusion. The participants reported that in their opinion, learners should argue until they reach consensus. This suggests that learners' discussions were not guided with the intension of achieving a desired goal.

Question 16: Do you think learners are able to query evidence in an attempt to develop credible arguments?

Querying evidence is a sub-skill of 'inference' (see Figure 2.1). This question was asked to verify whether the participants were able to support learners in examining the evidence presented and using the evidence to support a particular argument. Facione (1990:20) explains that *Querying evidence* involves the ability to identify statements that need support and develop a plan to pursue information relevant to supporting the identified statements. The participants reported that some learners tended to insist that their solution was appropriate, even though others disagreed. Learners should be able to provide facts to settle a disagreement.

The participants also indicated that it depended on the learners' intelligence as to whether they were able to efficiently query evidence. Also, some learners were too shy to express themselves, but when the teacher asked them questions, they gave correct responses. The participants perceived that some learners tended to disagree with the evidence provided, but they (participants) could not substantiate that. Utterances of participants regarding the ability to query evidence include:

> *Other learners are able to query solutions based on facts. (John)*
>
> *It depends on the learners' intelligence, but most learners have got inferiority complex. (Matthew)*

It is noteworthy that some learners were able to query the solutions developed by their fellow learners. This indicates that there was at least a foundation from which the technology teachers could actualise critical thinking skills, especially when the learners queried evidence based on facts. However, there is still a lot to be done given that some participants acknowledged that the learners were able to disagree with the evidence presented in an attempt to develop credible arguments.

Question 17: Are learners able to formulate multiple alternative solutions while solving technological problems?

Conjuring alternatives is a sub-skill of 'inference' (see Figure 2.1). CAPS stipulates that during the design process, learners are required to generate possible solutions (DBE, 2011:68) and as soon as possible solutions are generated, learners are also required to consider the most suitable solution that fits the specifications. Facione (1990:20) states that conjecturing alternatives means the ability to develop various plans to accomplish a particular objective.

The participants reported that the learners seldom developed multiple alternatives in solving technological problems. However, if the lesson presented was based on communal experiences, then the learners were able to suggest alternative solutions. Utterances of participants on the ability of learners to formulate multiple alternatives include:

> *Not always, but they also have alternatives. (John)*
>
> *Not that regular because of the time factor, but in groups they are able to explore. (Matthew)*
>
> *Sometimes, it depends on what you are doing in class, if it is around people they can come with solutions. (Mark)*

They have a variety of solutions; they basically come up with different kinds of solutions and pick or choose the best solution. (Luke)

The learners were able to formulate alternatives in solving technological problems, but this is a rare practice. In some instances, the ability of learners to formulate alternative solutions depended on whether they were taught to reflect on what they had experienced in their communities. This reflects the degree of exposure and implies that learners rely on common sense instead of applying their minds. The participants reported that due to time constraints, the learners seldom formulated alternatives.

Question 18: How do you support learners in justifying their reasoning?

Justifying the procedure is a sub-skill of 'explanation' (Figure 2.1). Before asking Question 18, the researcher explained to each participant (see Appendix A) that explanation is a critical thinking skill that encourages learners to justify their reasoning. This was done in order to ensure that the participants understood the question before responding. According to CAPS, learners are expected to provide reasons for considering a particular solution (DBE, 2011:68). Learners are also expected to justify their decisions. Facione (1990:6) affirms that reasoning is also one of the dispositions of critical thinking. The participants divulged that the learners were instructed that as long as they did not justify their solutions, those solutions remained incorrect.

The learners were encouraged to explain how they reached a particular solution. An incorrect explanation requires teachers to consider the solution as incorrect. The learners were encouraged to define concepts and compare their definitions, which were discussed collectively. Thereafter the teacher provided learners with the answer that is documented in the prescribed textbook.

Learners were encouraged to explain their answers comprehensively. Utterances of participants on how they supported learners in justifying their reasoning were:

I told learners that as long as you don't have reasons for your answer, it is not correct. (John)

After giving them some work to defy, we compare definitions from the group. Thereafter, I give the one that is from the book or the one I think is correct. (Matthew)

Some of them appear to be ambiguous, so they be must explained thoroughly to others. (Mark)

The learners seemed to be encouraged to justify their reasoning. The manner in which learners were encouraged to justify their actions was not in accordance with the prescribed design process (DBE, 2011:68), and Facione's (1990) critical thinking skills. CAPS stipulates that learners are required to generate possible solutions and select the best solution that meets a set specification, and justify their decisions (DBE, 2011:68).

The participants did not mention any specifications or specify the design brief. Facione (1990:21) states that to justify involves the ability to present evidence, concepts, methods, criterion, and the context that were considered to form learners' interpretations, analysis, evaluation or inference in order to provide reliable recordings and descriptions of the process followed. This implies that justifying procedures is rather complex and comprehensive. Technology teachers should be familiar with this process and should exploit it.

Question 19: Do learners produce clear descriptions of their results?

Stating results is a sub-skill of 'explanation' (Figure 2.1). CAPS stipulates' that during the design process, *communication* requires learners to provide a record of the processes that unfolded from conception to achievement of the solution (DBE, 2011:68–69). Facione (1990:21) adds that to *state results* denotes the ability to produce reliable statements and explanations of the results. Moreover, the person who presents the results should state his/her reasons for holding the particular perception that led to him/her analysing, evaluating, and drawing inferences from those results. The participants disclosed that not all learners could present a clear descriptions of the results produced when solving technological problems. Not all learners were actively participating in the classroom.

However, when the learners were individually addressed outside the classroom environment, they tended to provide clear explanations. The participants also disclosed that they developed a portfolio wherein learners only filled in the required information. The learners conducted research, investigated and came up with suitable solutions. Utterances of participants on the ability of learners to produce clear descriptions of their results include:

> *Not all learners, other learners are not active when in class, but they write correct things. (John)*
>
> *I designed a portfolio were they only fill in. (Matthew)*
>
> *They do research, investigate, and then come up with the suitable solution. (Luke)*

To produce clear descriptions of results means the ability to *state results* (Facione, 1990:21). CAPS stipulate that *communication* in the design process involves the ability to analyse, investigate, and evaluate the process followed while learners develop an artefact (DBE, 2011:68-69). It appears that the participants did not make an effort to teach what communication in the design process entails. The participants limited communication to participation, whereas communication in the design process also involves making presentations. Learners are required to present the artefact and articulate the process followed. In addition to this, learners are required to provide a detailed explanation that reflects the process followed from the beginning to the final product. This includes how divergent opinions were analysed, evaluated and what led to learners considering a particular conclusion. In essence, *stating results* and *communication* provides teachers with a fruitful opportunity to actualise critical thinking skills.

Question 20: How effective are learners when presenting the procedures that they have followed while solving technological problems?

Present argument is a sub-skill of 'explanation' (Figure 2.1). CAPS stipulates that technology provides learners with an opportunity to solve problems creatively using authentic contexts ingrained in real life situations outside of the classroom (DBE, 2011:9). CAPS also affirms that the criteria to teach and assess design features are, *inter alia*, "originality and aesthetics; value for money; and fit-for-purpose and suitability of materials" (DBE, 2011:12). The participants divulged that learners' participations in the classroom depended on the topic being taught. Topics such as structures and processing received the maximum participation. Some learners still could not read with confidence despite being in Grade 9, which has a bearing on participation.

The participants also revealed that learners were able to present the procedures that were followed in solving technological problems. They also hinted that they lacked the suitable technological equipment to make authentic (genuine) technological solutions. Utterances of participants on how they regarded learners' effectiveness when presenting procedures include:

> *For you to be able to explain something, you should have read. (John)*
>
> *They do very well, but it is difficult to them because we use waste material. (Matthew)*
>
> *They are not well oriented with the design process. (Mark)*

> *They are preventing a particular project, other learners also question how they came up with that particular solutions. (Luke)*

It appears that the learners found it difficult to make authentic technological solutions, and that they often used inappropriate materials. Failing to make practical solutions to technological problems hinders the criterion for teaching and assessing design features (DBE, 2011:12).

The participants acknowledged that the learners were not well acquainted with the design process. This seems to suggest that some technology teachers are unable to teach learners to engage with the design process, or perhaps these teachers do not understand the design process themselves. CAPS emphasises that the design process forms the backbone of technology (DBE, 2011:12). CAPS also stipulates that a "record of the process from the beginning to achievement of the technological solution should be in a portfolio form" (DBE, 2011:70). The participants did not mention that their learners developed a portfolio. This may imply that the participants did not support learners to engage in the design process as prescribed by the DBE.

Question 21: Do you encourage learners to reflect on their own reasoning and verify the results produced?

Before asking Question 21, the researcher explained to each participant (see Appendix A), that self-regulation is a critical thinking skill that enable learners to monitor their cognitive activities. This was done in order to ascertain that participants understood the question. Facione (1990:22) states that *self-examination*, a sub-skill of self-regulation (Figure 2.1), denotes an ability to review one's own reasoning and substantiate the produced results and correct the application. *Self-examination* involves the ability to review one's motives in establishing whether the attempt was fair-minded, reasonable and sensible from one's analysis, interpretation, and inferences. The participants reported that sometimes they instructed learners to evaluate themselves before the teacher evaluated them. The learners allocated themselves marks and motivated the allocated marks. The reasons that the learners provided had to be convincing. Additionally, projects were displayed for learners to select the project that is deemed best. The learners were encouraged to draw up a checklist to assess their own projects.

Utterances of participants on how they encouraged learners to reflect on their own reasoning and verify the results produced include:

> *Sometimes to let learners evaluate themselves first before my evaluation. (John)*
>
> *After making a product, we display that in class and then learners choose the one they think is more relevant. (Matthew)*
>
> *I always encourage them to draw maybe a checklist to evaluate their own project. (Luke)*

It seems that the participants did attempt to encourage learners to reflect on their own projects. Their limited attempts were, however, inadequate since *self-regulation* also involves the ability to reflect on personal reasoning and being able to verify the results produced, including the application (Facione, 1990:22). Being able to verify results also emphasises the critical thinking skills that the participants were unable to actualise. Learners should be taught to reflect on their cognitive activities and determine whether what they intended to achieve represents the dispositions of critical thinking (see Section 2.6). It is the researcher's opinion that displaying a project and instructing learners to select the best project does not support learners in reflecting their cognitive skills.

Question 22: How do you encourage learners to correct their errors?

Self-correction is a sub-skill of 'self-regulation' (Figure 2.1). Facione (1990:22) highlights that *self-correction* entails identifying errors or deficiencies in order to provide a remedy and possibly determine what prompted the errors or deficiencies. The participants reported that they conducted corrections with the intention of providing constructive feedback and enhancing learning. A learner might copy corrections and still have no understanding of his or her deficiencies.

Learners were also encouraged to correct each other. Furthermore, the learners were required to develop functioning artefacts, and if the artefact did not work, learners had to rectify it. The learners rectified artefacts without the teachers' assistance. Utterances of participants on how they encouraged learners to correct their errors include:

> *I taught my learners that when one learner is writing on the chalkboard, don't disrupt him, wait until he is finished and then correct it. (John)*
>
> *After each and every reflection, we do corrections. (Matthew)*

Learners must go on their own and rectify the mistake. (Mark)

Sometimes I do question them on how they arrived at that particular solution. (Luke)

Learners should be helped to identify errors or deficiencies and develop remedial strategies (Facione, 1990:22). The participants disclosed that they encouraged learners to correct their own mistakes. This practice was limited to correcting mistakes as there was no remedy or attempt to determine what instigated the errors or deficiencies.

Effective remedial actions could provide a fruitful opportunity to actualise critical thinking skills. In essence, there are numerous opportunities for technology teachers to exploit cognitive skills, but those opportunities tend to be futile. Technology teachers should be familiar with the dispositions of critical thinking and strive to actualise critical thinking skills in their classrooms (see Section 2.6).

The next section presents a discussion of the classroom observations that enabled the researcher to confirm the interview data. The participants were asked how they actualised critical thinking in teaching technology. The participants mentioned that they encouraged learners to be independent when identifying technological problems while using the prescribed design process. The classroom observations enabled a confirmation of whether the participants were able to encourage learners to identify technological problems independently. However, it was observed that participants did not engage the prescribed design process.

The participants were also asked to specify the characteristics that enabled them to teach critical thinking skills. They mentioned that they allowed learners to explore and play a facilitating role so that the learners could identify technological problems. During the classroom observations, the researcher expected the participants to demonstrate these characteristics, but they did not. An observation schedule (see Appendix B) was used to record the critical thinking skills when they were observed during the lessons.

When the lesson plans presented by both John and Matthew were examined, it was noticed that they still focused on investigation in terms of the design process, while these observations were done towards the end of Term 3. It was expected for them to focus on making or evaluating in accordance with the way in which CAPS stipulates the design process should be used.

The activity that John taught is part of the revision for simple circuit and conventional current. This is supposed to be dealt with at the beginning of Term 3 because this is the information that learners will use to make artefacts. Matthew also focused on calculating values using Ohm's law, which should be done after revision at the beginning of Term 3. This demonstrated the participants' lack of understanding of the design process.

4.4 The observations

The researcher observed three participants (John, Matthew and Mark). However, Luke (the fourth participant) could not be observed due to cultural activities that took place at her school, despite numerous attempts to reschedule. The observation schedule (Appendix B) was derived from the conceptual framework and focused specifically on Facione's (1990:15) critical thinking skills and the design process as prescribed by the DBE (2011:68).

The observation schedule was structured in such a way that critical thinking skills, including the sub-skills, were linked to the steps of the design process. This enabled the researcher to observe how the participants used the design process to develop critical thinking. During the lesson, the appropriate block was ticked when the link between the design process and critical thinking was observed. Field notes were also taken during the observations (see Appendix BB) to enhance the rigour of this study. Each case will be discussed separately.

This section will be structured as follows: the context will first be provided, followed by a summary in table form of the findings of each observation. These findings will then be discussed in detail. The observations were conducted during the school's third term and the focus was on electrical systems and control. However, only two participants were observed for electrical systems and control as the third participant presented the topic of processing. The reasons as to why the third participant (Mark) presented processing will be discussed in Section 4.4.3.

According to CAPS (DBE, 2011:34-35), and the textbook that the participants used, at the end of the section on electrical systems and control, learners should be able to, *inter alia*, test Ohm's law by means of both the voltage and current strength in the electric circuit; plot a graph that reflects their readings; interpret the resistor's colours codes; calculate the strength while using the formula for Ohm's law; draw and make the electronic circuits; and set the scenario (describe a situation in which an electric circuit can solve a particular problem or meet a need).

At the end of the section on electrical systems and control, learners should be able to write a design brief for the device; draw the circuit diagram and represent the device in three dimension (3D); collectively decide on a final solution; build the device; and compile a record. Teachers are expected to conduct revision on the components symbols and simple circuits. This involves revising the topic of series and parallel connections. After conducting revision, learners should be taught the resistor colour codes; how to calculate the values; about switches; diodes and Light Emitting Diode (LED); about transistors; sensors; and simple electronic circuits.

4.4.1 First observation: John

John's lesson focused on simple electrical circuits and conventional current. He began his lesson by asking learners to define or explain electricity. While his question elicited one response, he did not react to the answer nor did he give other learners the opportunity to give their own views. He merely proceeded to the next section.

Learners were given the following activity from the textbook:

> *Draw a circuit diagram with the following components, using the correct electronic components symbols:*
>
> (i) *A cell, closed switch, and two lamps in series;*
> (ii) *Two cells in series, open switch, a lamp and a resistor in series;*
> (iii) *Three cells in series, a push switch and a bell.*

Learners were instructed to present their answers on the chalkboard. John asked if the answers were correct and the learners provided inconsistent responses. However, John did not comment on any of the answers and indicated that he would respond later. Afterwards, John indicated that the circuit diagrams were correct and asked learners another question: what is the use of a resistor or a conductor in a circuit? Although the learners provided answers, John did not encourage them to justify their answers. John explained the use of a resistor to minimise the flow of electricity.

John then asked what would happen if another lamp in the first circuit diagram were to be removed. However, this time John asked the learner to explain his answer. Without giving the correct answer, John asked what would happen if another lamp were added to the circuit diagram. John proceeded to the next question: what is the advantage of connecting a lamp in series? When the learners responded, John insisted to know the cause of what they had observed in the circuit diagram. The lesson ended and the researcher noticed that no equipment was used to demonstrate or enhance John's teaching. In order to verify whether John planned to actualise critical thinking skills during the lesson, the researcher examined his lesson plan (see Appendix K). Jensen (2005:403) alludes to the fact that the lesson plan is an exceptionally valuable instrument that functions as a guide, outlines necessary resources, reflects teaching philosophy, and essentially specifies the goals to be achieved. Additionally, the lesson plan enabled the researcher to address the sub-question raised in Chapter 1 (see Section 1.5): How do technology teachers connect a particular CAPS opportunity to critical thinking principles?

The specific aim of John's lesson plan was to enable learners to investigate technological challenges on their own and also to come up with alternative solutions to these challenges. John did not specify the challenges and left learners to investigate those unspecified challenges on their own. As a qualified, experienced teacher, John should have identified these challenges and developed a strategy to support learners in addressing those challenges. John's lesson plan specified that learners must be able to investigate, design, make, communicate, and evaluate.

However, John did not follow the prescribed design process when planning his lesson. The CAPS document for technology highlights that appropriate design process skills must be achieved (DBE, 2011:33). For instance, for learners to develop investigation skills, they (learners) are advised to investigate the situation and the nature of the need so that an appropriate circuit can be chosen to solve the problem, need or want given in the scenario. Unfortunately, the lesson plan did not mention setting the scenario.

In order to develop the design brief, learners are advised to write suggestions for designs with specifications and constraints, and ultimately produce a 3Dimension (3D) representation of the device that will use the electronic circuit. John noted teacher's activities without specifying those activities. It is this study's viewpoint that a lesson plan is a road map or blue print for teaching and learning that should be structured in such a way that it provides an explicit indication of the learning experience that is expected during the lesson.

In the event that a particular technology teacher is absent from class, any qualified experienced technology teacher should be able to follow the prepared lesson plan and present an effective lesson. Basically, a lesson plan should explicitly specify the learning objectives and activities. John's lesson plan did not provide explicit learning objectives with specific teaching and learning activities.

Table 4.2 shows a summary of what transpired in John's classroom in terms of the critical thinking skills in relation to the steps of the design process. This table shows the critical thinking sub-skills (and by implication the critical thinking skills) that were observed from the observation schedule (see Appendix B). The table was adapted to display only what was captured from the observation schedule.

John's lesson was restricted to the 'investigation' step of the design process, with its associated activities, and did not make any reference to designing, making, evaluating, and communicating. This indicates that John lacked the understanding to use the design process. It is rather strange that John focused on investigations at the end of the Term 3 while this is expected to be covered at the beginning of the term.

Table 4.2: Observation of John's lesson

Critical Thinking Skills / **Design Process**	**Interpretation**	Categorise	Translate significance	Clarify meaning	**Analysis**	Examine ideas	Identify arguments	Analyse arguments	**Evaluate**	Assess credibility	Assess quality	**Inference**	Query evidence	Conjure alternatives	Draw conclusions	**Explanation**	State results	Justify the procedure	Present argument	**Self-regulation**	Self-examination	Self-correction
Investigation																						
Investigate solutions	√																√					√
Investigate the nature of the problem																						
Incorporate electronic circuits into design																						

According to Table 4.2, John addressed only three critical thinking skills: clarifying meaning; stating the results while investigating the solution; and self-correction. While John's lesson provided three opportunities to actualise critical thinking skills, more opportunities were potentially available that he could have utilised to encourage learners to think critically, but he failed to do so. For instance, during the introduction of the lesson, John asked learners to define electricity, a learner responded but John did not ask this learner to justify his answer.

In the interview session, John was asked how he actualised critical thinking skills in teaching technology. He mentioned that "learners are able to identify problems and state the problem in accordance with the technological problem". In accordance with the design process, the teacher should set the scenario and describe where electric circuits can be used to meet a need (DBE, 2011:35). Setting the scenario enables learners to investigate the appropriate electric circuit that can be used to solve a technological problem. John did not allow learners to identify any technological problems. This confirms what John alluded to when answering Question 3 as he indicated that he still had challenges in teaching the design process.

During the interview session, John was also asked how he supported learners in justifying their reasoning. John responded *"as long as you don't have reasons for your answers, it is not correct unless a learner prove then the answer is correct"*. This implies that John did not encourage learners to justify their answers. Facione (1990:21) states that the ability to justify teaches learners to present evidence and contextual considerations that will enable them to interpret, analyse, evaluate or make inferences in order to present reliable information.

John asked learners what the use of a resistor is. The learners provided answers and instead of John encouraging them to explain or justify their answers, he gave the learners the correct answer. This was another opportunity to actualise critical thinking skills, but John missed the opportunity. Learners drew different circuit diagrams in response to the activity given. John asked learners to state what would happen if another lamp in one of the circuit diagrams was removed. Instantly, a learner responded, but the learner realised that the answer he had given was incorrect and subsequently acknowledged that he misunderstood the question. This learner's attempt shows the appropriate character to develop critical thinking skills since the learner was able to conduct self-correction. *Self-correction* is an element of 'self-regulation' (see Section 2.4). At the end of the lesson, John expressed his challenges to the researcher in that it was difficult to teach learners about electrical systems and control without the necessary equipment.

4.4.2 Second observation: Matthew

During the second observation, Matthew presented a lesson on Ohm's law and conducted revision on how to calculate resistance using Ohm's law. He went further to explain the formula that was derived from Ohm's law without encouraging learners to seek clarity or at least ask questions. He then gave the learners an activity to do and instructed learners to calculate the unknown values in the circuit while reminding the learners to include correct units in their answers.

Learners were given the following activity from the textbook:

> *Mabu sets up a circuit consisting of a battery of three cells and a 3,5Ω lamp. The voltmeter measures 4,2V over the lamp. Calculate the current strength in the circuit.*

In calculating the current values, Matthew advised learners to underline the values that were given first in order to determine the current values. Afterwards, learners presented their answers on the chalkboard. Matthew then asked the learners some questions regarding the resistor colour codes, but the learners were silent and he ended up providing the answers. He changed the values in the initial question and asked learners to determine the unknown values. The answer was written on the chalkboard, but Matthew did not notice that the answer was incorrect and the lesson ended.

According to CAPS, technology teachers are required to set the scenario in order to describe a situation where a circuit could be used to meet a need or solve a technological problem (DBE, 2011:35). Like John, Matthew gave learners an activity without setting the scenario. As a result, learners calculated the unknown values in the circuit without knowing the context of the activity.

In developing a lesson plan, Matthew was supposed to implement what the South African education system intends to achieve, particularly in Grade 9. The CAPS document for technology stipulates clearly what technology teachers should do in order to achieve the specific aims of the subject. Unlike John (the first participant), Matthew attempted to adhere to CAPS when preparing his lesson.

However, he did not specify the learning outcomes and his lesson plan was shallow since it provided little and insufficient depth regarding what he intended to achieve. Subsequent to examining Matthew's lesson plan, as far as the design process is concerned, like John, Matthew focused on the 'investigation' step of the design process towards the end of Term 3 when this is expected to be done at the beginning of the term. This indicates John's lack of understanding of how to use the design process.

Matthew stated that values would be calculated using Ohm's law, this means an attempt to investigate the solution. In investigating the nature of the problem, Matthew used the Ohm's law triangle and intended to teach learners about the colours of resistors. Moreover, Matthew made reference to the textbook that he used, which seems to be an effort to illustrate how Ohm derived the formula, R = V/I and a triangle was used to simplify Ohm's law.

Matthew's lesson plan did not represent the other design process steps such as designing, making, evaluating, and communicating. It is clear that both John and Matthew prepared their lesson plans without adhering to the CAPS document for technology that stipulates precisely what technology teachers must teach in order to achieve the purpose of this subject in South Africa (DBE, 2011:34-35). Technology as a subject is intended to encourage learners to be innovative and acquire creative and critical thinking skills (DBE, 2011:8).

Table 4.3 shows a summary of what transpired in Matthew's classroom - in terms of the critical thinking skills in relation to the steps of the design process. This table only represents the critical thinking sub-skills that were observed from the observation schedule (see Appendix B). The table had been adapted to display only what was captured from the observation schedule. Like John, Matthew's lesson was limited to investigation and did not make any reference to design, make, evaluate, and communicate.

Table 4.3: Observation of Matthew's lesson

Critical Thinking Skills / **Design Process**	**Interpretation**	Categorise	Translate significance	Clarify meaning	**Analysis**	Examine ideas	Identify arguments	Analyse arguments	**Evaluate**	Assess credibility	Assess quality	**Inference**	Query evidence	Conjure alternatives	Draw conclusions	**Explanation**	State results	Justify the procedure	Present argument	**Self-regulation**	Self-examination	Self-correction
Investigation																						
Investigate solutions		√															√					
Investigate the nature of the problem																						
Incorporate electronic circuits into design																						

Table 4.3 demonstrates Matthew's poor attempt to actualise critical thinking skills during the lesson. Matthew presented learners with an activity that focused on investigating a solution. The full observation schedule is attached in Appendix B. As a result, learners were able to categorize and state the results. During the observation, no other critical thinking skills could be recognised.

Just like John (first participant), Matthew missed opportunities to encourage learners to develop critical thinking skills. In the first instance, Matthew taught learners how the formula calculates either the voltage or resistor without providing learners with the opportunity to seek clarity or to interpret Ohm's law. Matthew's learners had a tendency to be silent when asked questions and he did not make attempts to encourage the learners to ask questions. It is the viewpoint of the researcher that teaching should instil enthusiasm and curiosity in learners.

Enthusiasms involve eagerness, keenness, passion, zeal, excitement, which should be fostered in learners. Additionally, curiosity stimulates learners to develop questioning skills, which gradually enables learners to develop inquiry-based skills. Matthew missed another opportunity to actualise critical thinking skills because, according to the textbook, Matthew was supposed to use a resistor colour code table to support learners to interpret the different colour codes of the resistor. Table 4.4 presents the resistor colour codes.

Table 4.4: Resistor's colour codes

Colour	**1st band**	**2nd band**	**3rd band zeroes**								
Black	0	0									
Brown	1	1	0								
Red	2	2	0	0							
Orange	3	3	0	0	0						
Yellow	4	4	0	0	0	0					
Green	5	5	0	0	0	0	0				
Blue	6	6	0	0	0	0	0	0			
Violet	7	7	0	0	0	0	0	0	0		
Grey	8	8	0	0	0	0	0	0	0	0	
White	9	9	0	0	0	0	0	0	0	0	0

Table 4.4 shows the colours of the bands and their positions, which are essential when the resistance value of a resistor must be determined. The first band provides the first digit, the second band provides the second digit, and the third band indicates the number of zeros that are added to the end of each number.

In essence, Matthew should have used a table like Table 4.4 to encourage learners to interpret the colour codes of the resistors instead of the phrase: "bad boys rape of young girl but violet grab wine", which makes little sense in English, and is also inappropriate. In the interview, Matthew indicated that this is the phrase he used to interpret the resistor colour codes while teaching. This shows that, to some extent, Matthew practiced in the observation exactly what he said he did in the interview.

During the interview session, Matthew was asked how he actualised critical thinking skills in teaching technology. Matthew's responded that "by giving learners assignments and home works that learners should refer to and find information". Firstly, Matthew did not give leaners any homework and again he did not encourage learners to find information. Instead, Matthew provided learners with the answers.

Matthew did little to support learners in developing critical thinking skills. For instance, the CAPS document stipulates that technology teachers are required to set the scenario in order to describe a situation where a circuit could be used to meet a need or solve a technological problem (DBE, 2011:35). However, Matthew, just like John, gave learners an activity without setting the scenario. As a result, learners calculated the current in the circuit without knowing the context of the activity.

In the course of the interview session, Matthew was asked about his personal characteristics that enabled him to actualise critical thinking skills. Matthew said: “I allow learners to explore and use internet to extend their knowledge”. However, while Matthew was teaching he did not encourage learners to explore or refer them to the internet. Matthew provided learners with answers without giving them opportunities to explore the problem in a critical manner.

4.4.3 Third observation: Mark

Mark indicated that he had already completed all the activities for Term 3 on electrical systems and control, however, his decision to start Term 4 work on processing was not in accordance with CAPS (DBE, 2011) and the textbook that he used. Mark taught on the topic of food preservation.

As explained earlier, Mark was included due to the fact that it was too long of a process to persuade the authorities involved to use another Grade 9 technology teacher, particularly because the data was collected towards the end of Term 3. Also, some provinces do not allow researchers to collect data in Term 4 since schools are preparing for examinations. Since Mark had already been interviewed, it was important to observe how Mark actualised critical thinking skills in his teaching.

According to CAPS, processing requires learners to be able to, *inter alia*, know the methods used to preserve metals (painting, galvanising, and electroplating); explain how grain is preserved in storage; explain how the pickling method (preserving food by soaking it in a brine mixture of salt and water) is used to preserve food; show how food is dried and salted to be preserved; explain the manner in which plastic is manufactured into pellets for re-use; and conduct a case study (DBE, 2011:36). Galvanisation is a process in which a piece of metal is dipped into hot zinc to prevent corrosion. Electroplating is a process used to improve appearance, electrical conductivity and corrosion (Marchant, Pretorius, Smith, & Smith, 2013:83-89).

Mark began his lesson by asking learners what the reasons for preserving food are. The learners replied, but Mark did not encourage them to analyse and evaluate their answers. Mark merely proceeded to the next question without addressing the learners' responses. The learners answered by mentioning different types of methods. Instead of verifying the learners' responses or allowing then to substantiate their answers, Mark went on to mention another method of preserving food.

Afterwards, Mark instructed the learners to sit in groups and identify the advantages and disadvantages of each food preservation method. During the interview session, Mark was asked whether he allowed learners to describe their experiences, situation, beliefs, and events in order to understand the meaning of a particular context, he replied: "learners are able to criticise one another's method". However, this behaviour was not observed while he was teaching. Later, the learners collectively reported their ideas without being encouraged to justify their statements.

Table 4.5 presents a summary of what transpired in Mark's classroom in terms of the critical thinking skills required for the different steps of the design process. This table only represents the critical thinking skills that were observed from the observation schedule (see Appendix B). The table has been adapted to display only what was captured from the observation schedule. Like John and Matthew, Mark's lesson was also limited to 'investigation' and did not make any reference to designing, making, evaluating, and communicating.

Table 4.5: Observation of Mark's lesson

Critical Thinking Skills / **Design Process**	**Interpretation**	Categorise	Translate significance	Clarify meaning	**Analysis**	Examine ideas	Identify arguments	Analyse arguments	**Evaluate**	Assess credibility	Assess quality	**Inference**	Query evidence	Conjure alternatives	Draw conclusions	**Explanation**	State results	Justify the procedure	Present argument	**Self-regulation**	Self-examination	Self-correction
Investigation																						
Investigate solutions		√																				
Investigate the nature of the problem																						
Incorporate electronic circuits into design																						

According to Table 4.5, Mark addressed only one critical thinking skill, namely categorising. CAPS stipulates that food preservation methods that are discussed include storing grain in a grain hut, storing grain in a bag, in a clay pot, a grass basket, and in a grain well, which are all indigenous methods (DBE, 2011:36). Mark did not specify this while teaching. This implies that Mark did not adhere to the CAPS requirements. During the interview, Mark was asked how he actualised critical thinking skills in teaching technology. He indicated that the learners came with different ideas when the learning activity was based on what they experienced at home.

Food processing is one of the things that learners see daily. It is posited that if Mark specified the food processing methods that learners see daily as well as various methods of preserving food, a lot of ideas would have emerged, which would provide an opportunity to examine ideas, identify arguments, analyse arguments, and assess the arguments since learners are familiar with indigenous foods. As a result, Marks missed the opportunity to support learners in developing critical thinking skills.

The textbook that Mark used recommends that one of the disadvantages of processing food is that some nutrients are lost, particularly water-soluble vitamins. This could provide an opportunity for learners to investigate the nutrients that are lost during food processing, and most importantly, learners could then share their experiences and beliefs, which would enable them to develop inference skills and the ability to provide a sound explanation. Inference is one of the essential critical thinking skills. In conclusion, Mark withheld important knowledge that he was supposed to share with learners, even though CAPS provides guidelines to teach processing.

Mark did not adhere to the CAPS schedule, which emphasises that it is compulsory to cover the given scope in the term indicated, and that the sequence of the work within the term must be adhered to (DBE, 2011:36). During the interview session, when Mark was asked how he actualised critical thinking skills in teaching technology, he added that: “by ensuring that learners are aware that the purpose of Technology is to solve problems”. However, the textbook that Mark used to supplement CAPS clearly specified the kind of activities that learners are required to do (DBE, 2011). Mark did not expose learners to solving problems as specified in the textbook. As a result, learners are deprived of the opportunity to develop critical thinking skills.

4.5 Conclusion

This chapter presented a detailed analysis of data that was collected by means of interviews and observations. Firstly, the chapter outlined the biographical information of the participants. This was followed by the findings and discussions on the interviews and observations. The findings revealed that the sampled technology teachers had a limited understanding of critical thinking. This is concerning since the CAPS document for technology requires learners to be inventive and to develop critical thinking skills (DBE, 2011).

It is therefore important that technology teachers have a sound understanding of critical thinking in order to align their teaching strategies towards developing critical thinking skills. The definition of critical thinking encompasses interpretation, analysis, evaluation, inference, explanation, and self-regulation (see Section 2.7). The participants were able to define critical thinking to a limited extent. For instance, one participant defined critical thinking as the ability to criticise, compare, and contrast information. This definition shows that the sampled technology teachers had at least a partial idea of what critical thinking entails.

Technology teachers should be conversant with critical thinking in order to actualise it in their classrooms. While critical thinking is emphasised in CAPS, the findings suggest that the sampled technology teachers seem to neglect the actualisation of critical thinking skills in the classroom. By implication, the aim of the NCS namely, "to identify and solve problems and make decisions using critical and creative thinking" (DBE, 2011:5) may not be completely realised.

This chapter also revealed that the respondents were not able to explain how they supported their learners to engage with critical thinking skills such as interpretation, analysis, evaluation, inference, explanation, and self-regulation. This was not surprising since these selected participants provided a rather shallow definition of critical thinking. The way in which their lesson plans were prepared confirmed that actualising critical thinking skills was not even considered.

The CAPS document for technology emphasises that before the teacher supports learners in solving a technological problem, while using the Mini-PAT, a scenario should be set (DBE, 2011). In setting a scenario, the technology teacher can help learners to understand how artefacts can be used to solve technological problems, and meet human needs. However, none of the participants set a scenario, which is a platform to strengthen the purpose of the NCS.

Basically, these participants deprived their learners of the latitude to understand how technology activities are used to solve technological problems by using the design process. According to the Unique Features and Scope section, technology should provide learners with the opportunity to learn, *inter alia*, “to work effectively with others” (DBE, 2011:9). The aim of the NCS is to produce learners that are able to “work effectively as individuals and with others as members of a team” (DBE, 2011:5). Also, CAPS stipulates that the design process “forms the backbone” of teaching technology (DBE, 2011:12). This indicates that technology in South Africa advocates team effort in solving technological problems, and the design process is used to solve those problems.

Team effort is an essential social setting that this study advocates. This study embraced social cognitive theory. By implication, team effort, which is considered to constitute shared cognition, creates a fertile classroom environment in which leaners search and consider information beyond what is at their disposal (see Section 2.2). Evaluation is an essential step in the design process: it provides an opportunity for learners to determine whether the artefact is able to satisfy human needs. The next chapter will present, discuss, conclude, and provide the recommendations of this study for future research.

Chapter 5: Summary, conclusion, and recommendations

5.1 Overview of the chapter

This chapter commences with a summary of the previous chapters, highlighting the key aspects relevant to each chapter. The research questions are revised with the intention to answer each sub-question, and consequently the main research question. This is followed by the limitations of the study, recommendations for future research and conclusions.

5.2 Chapter summary

In Chapter 1, the purpose of technology was explained, i.e. to support learners to be creative and develop critical thinking skills. The importance of developing critical thinking was addressed, as well as the concern that teachers seem to find it difficult to teach at higher cognitive levels. Attention was also drawn to the fact that CAPS provides little guidance as to how exactly critical thinking should be developed in the technology classroom. The foregoing concerns and the lack of support from CAPS with regard to the fostering of critical thinking, inspired the main research questions for this study: how do teachers actualise critical thinking skills in the technology classroom? Three sub-questions were formulated to address the main question. Chapter 1 concluded with an explanation of the key terms pertinent to this study.

Chapter 2 presented a review of the literature regarding social cognition, social learning and thinking, which forms the foundation of critical thinking. Critical thinking was discussed as well as the disposition of critical thinking. The cognitive mechanisms and the design process that are used to solve technological problems were also addressed. It was pointed out that the prescribed design process provides ample opportunities to develop critical thinking skills; technology teachers should identify and use these opportunities to actualise critical thinking skills in their classrooms. The chapter ended with a presentation and explanation of the conceptual framework that was used to guide this study.

The research design, research paradigm, and population and sampling used in this study were explained in Chapter 3. In addition to this, the strategies as well as the instruments that were used to collect data were described. This was followed by a description of how the data was analysed and how the standards of rigour for research were enhanced. The chapter also addressed ethical considerations.

Chapter 4 reported on the findings of the study. The chapter commenced by outlining the biographical information of the participants to show their academic qualifications and experience in teaching technology. The participants' responses, obtained from structured interviews, were then discussed. This was followed by a discussion of the data obtained from the classroom observations.

5.3 Reflecting on the research questions

This section reflects the research questions that were formulated (see Section 1.6) in Chapter 1. The main research questions are:

Main question: How do teachers actualise critical thinking in the technology classroom?

Three sub-questions were formulated to elucidate the main question:

(i) What is technology teachers' understanding of critical thinking?
(ii) What opportunities does CAPS offer for fostering critical thinking skills?
(iii) How do technology teachers connect a particular CAPS opportunity to critical thinking principles?

The first sub-question sought to determine Technology teachers' understanding of critical thinking.

This study adopted Facione's (1990) set of critical thinking skills which are: interpretation, analysis, evaluation, inference, and self-regulation. The results of the study indicate that all the participants had some, albeit limited, understanding of the concepts that define critical thinking. John (first participant) mentioned that critical thinking means the ability to "criticise, compare, and contrast". Matthew (second participant) defined critical thinking as "when you give learners a question or ask them something back that they can develop". Mark (third participant) alluded to the fact that critical thinking "is about giving learners a chance to think". Luke (forth participant) mentioned that critical thinking "meant that learner are able to think out of the box".

The manner in which the participants understood critical thinking was different to how the literature defines critical thinking. Critical thinking, according to the literature, involves the ability to analyse, evaluate, reason and reflect with conviction, a desire to seek authenticity, and find faults (see Section 2.4).

The second sub-question asked: what opportunities does CAPS offer for fostering critical thinking skills. The DBE (2011:10) stipulates that the design process should be used as the backbone for structuring the teaching of technology. In CAPS, learners are provided with opportunities "to solve problems in a creative way using authentic contexts rooted in real situations outside the classroom. In addition, to combine thinking and doing in a way that links abstract concepts to concrete understanding" (DBE, 2011:9). This indicates that CAPS advocates teaching that actualise critical thinking skills.

During the 'investigation' step of the design process, learners are encouraged to "seek information, conduct relevant research, grasp concepts and gain insight, and determine new techniques" (DBE, 2011). These activities are opportunities for fostering critical thinking skills and should be utilised by teachers when learners are required to investigate solutions to authentic technological problems. Table 2.3 in Section 2.10 shows which critical thinking sub-skills could be actualised through 'investigation'.

During the 'design' step of the design process, learners are required to "write the design brief, generate alternative solutions, draw ideas, take decision, and choose the best solution and justify the choice" (DBE, 2011:68). These are all design related opportunities that are offered in CAPS for fostering critical thinking skills. For instance, in order to write a design brief, a learner should think critically because the design brief determines a technological solution. Generating alternative solutions reflects the ability to suggest more than one idea. In order to make a decision, learners should be able to anticipate the consequences of that decision. This means that learners should think critically before making a particular decision. Lastly, during the 'design' step, the learners are required to choose the best solution and justify that choice. Justifying is the ability to reason such that other learners are convinced that the choice is correct. Table 2.3 in Section 2.10 shows which critical thinking sub-skills could be actualised through 'design'.

'Make' as another step of the design process requires learners to "use tools and equipment; build, test, and modify the product; and adhere to safety and healthy atmosphere" (DBE, 2011:68). It is important to use the correct tools and equipment for a particular activity. This indicates the ability to search for suitable tools and equipment. Once the artefact has been constructed, it should be tested to determine whether it is efficient or has faults. This requires critical thinking skills because learners must evaluate the artefact and determine if it serve the intended purpose and possibly make necessary changes. While building the artefact, learners should consider the safety of others and obey safety precautions. Table 2.3 in Section 2.10 shows which critical thinking sub-skills could be actualised through the 'make' step.

'Evaluation' is central to the design process when solving technological problems. Learners are required to "evaluate actions, decisions, and results; evaluate solutions and process followed; suggest necessary improvement; and evaluate constraints" (DBE, 2011:68). 'Evaluation' is one of the essential critical thinking skills identified by Facione (1990) (see Figure 2.4). 'Evaluation' as a design step requires learners to evaluate each process they engage with while seeking a solution. CAPS stipulates that all the steps of the design process should be evaluated and 'evaluation' determines the next step of the design process (DBE, 2011:74). Table 2.3 in Section 2.10 shows which critical thinking sub-skills could be actualised through 'evaluation'.

'Communication' as the final step of the design process requires learners to provide "the record of the process from conception to realisation of the solution" (DBE, 2011:68-69). Learners are required to provide evidence on how they analysed, conducted an investigation, and planned and evaluated the solutions during the design process. The process followed can be presented verbally, transcribed, presented graphically, or in electronic means. The final step of the design process shows that *communication* encompasses all the steps of the design process. The ability to analyse, investigate, plan, and evaluate the solution brings about cognitive skills. Thus, *communication* offers opportunities for fostering critical thinking skills as shown in Table 2.3 in Section 2.10.

The third sub-question asked how technology teachers connect a particular CAPS opportunity to critical thinking principles. The results of the study revealed that the participants were less than successful in connecting the opportunities offered by CAPS in critical thinking principles. The conceptual framework shows the connection between the design process and critical thinking skills (see Section 2.8.2).

During 'investigation', learners are required to acquire information and, in relation to critical thinking, learners should *clarify meaning* and *state results*. None of the participants were able to explicitly articulate how they provided learners with opportunities to clarify meaning. *Clarifying meaning* means the ability to contextualise a particular concept in order to make sense of it. The results revealed that the participants did not support their learners during the 'investigation' step of the design process according to expectation. Inadequate investigation leads to poor solutions that do not properly address needs or solve technological problems.

The 'investigation' step of the design process provides many opportunities for technology teachers to connect with investigative activities, which are stipulated in CAPS, to critical thinking. Learners are required to conduct research and this is in line with the ability to "draw conclusions using inductive reasoning" (Facione, 1990:17). This requires 'inference' which is a critical thinking skill (see Section 2.4). The results disclosed that the participants supported their learners poorly when they (the learners) conducted research - to the extent that the learners did not develop the necessary skills to draw conclusions using inductive reasoning.

John indicated that for him to assist learners to arrive at a reasonable conclusion, he "goes through learners work step by step". By implication, John did not support learners to either conduct the relevant research or draw conclusions using inductive reasoning, but merely checked if learners followed the design process. During the interview, John indicated that he experienced challenges implementing the design process, which incapacitated him in examining the learners work effectively.

Matthew mentioned that he "give[s] learners a chance to explore by allowing them to do things on their own". This statement shows that Matthews attempted to encourage learners to investigate on their own and possibly draw conclusions using inductive reasoning. However, Matthew could not verify how he ensured that leaners draw realistic conclusions.

The design process provides learners with the opportunity to 'design' while solving technological problems. 'Design' requires learners to write a "design brief, generate possible solution, draw ideas, use graphic 2/3Dimension, take decision, and choose the best solution and justify that solution" (DBE, 2011:68). When learners write a design brief, one of the critical thinking skills that is needed is the ability to *categorise*. *Categorising* means being able to recognise the context for information that enable learners to understand a concept

(Facione, 1990:13). The results disclosed that the participants were ineffective at supporting learners to write a design brief when they sought a solution to a technological problem. Learners are required to generate possible solutions during the designing step of the design process - this is in line with the ability to *conjure alternatives*. Conjuring alternatives requires 'inference', which is a critical thinking skill (see Section 2.4). When the participants were asked whether their learners are able to formulate multiple alternatives in solving technological problems, three participants (John, Matthew, and Mark) admitted that their learners seldom formulated multiple alternatives. However, Luke indicated that her learners provided alternative solutions. The research results revealed that learners rarely formulated multiple alternatives when solving technological problems.

Designing provides learners with the opportunity to *draw ideas*. The critical thinking skills associated with drawing ideas, as shown in Table 2.1 (see Section 2.8.2), are the abilities to *examine ideas, identify arguments*, and *assess the credibility of claims*. To *identify arguments* signifies the capability to analyse while assessing the credibility of a claim implying the skills to evaluate (see Section 2.4). The results of this study indicate that the participants were not successful in supporting their learners to analyse and evaluate solutions. For instance, Mark admitted that he did not encourage learners to develop skills to analyse and evaluate arguments. The other three participants were not able to clearly articulate how they supported their learners to develop analysis and evaluation skills.

The design process requires learners to choose the best solution from a variety of ideas that they have developed and to justify their choices (DBE, 2011:68). The critical thinking sub-skills essential to these activities are the ability to *assess the credibility of the claims* and *assess the quality of the arguments made* using inductive reasoning. Learners are required to justify their choices and be able to provide credible explanations of what influenced their choices.

During the interviews, the participants were asked to explain how they supported learners in justifying their reasoning. The findings confirmed that some teachers were able to support learners in justifying their reasoning. This is commendable and is a good step towards developing basic critical thinking skills. For example, John asserted that "as long as learners fail to explain their answers, the answer is considered incorrect". However, the other participants (Matthew, Mark, and Luke) could not explicitly articulate how they supported their learners in justifying their reasoning.

'Explanation' is one of the essential critical thinking skills since it accords learners the opportunity to systematically and orderly present the process that has been followed until learners arrive at a particular solution. 'Explanation', as an essential critical thinking skill, allows learners to explain their interpretation, analysis, evaluation, and the inferences that led to the correct record of the process followed (Facione, 1990:15).

The design process also grants learners the opportunity to 'make' artefacts. Making requires learners to "use tools and equipment; build, test and modify the product; and adhere to safety and healthy atmosphere" (DBE, 2011:68). The appropriate critical thinking skills that technology teachers should connect with this aspect of the design process as they build, test and modify the product are the capacities to conduct *self-corrections* and *examine ideas*. With regard to *self-correction*, the results of this study divulge that all of the participants were ineffective in encouraging learners to correct their errors.

John indicated that he "does not belief in just giving learners corrections or feedback". Matthew mentioned that "learners do corrections after every reflection". Mark explained that "learners must go on their own and rectify the mistake". Luke admitted that "if [she] had a chance, [she] will question learners how they arrived at that particular solution". Mark did not understand the essence of self-correction during the design process. Self-correction implies that learners reveal defects, faults, and flaws while they build or test the artefact and develop a suitable strategy to provide a remedy. This is an opportunity that CAPS presents, but it is evident that some technology teachers fail to grasp and use this opportunity (DBE, 2011).

The design process provides learners with the opportunities to 'evaluate'. During 'evaluation', learners are obliged to "evaluate actions, decisions, and results; evaluate solutions and process followed; suggest necessary improvements; and evaluate constraints" (DBE, 2011:68). The results disclosed that technology teachers are unproductive in supporting learners to evaluate each step of the process.

The design process also offers learners the opportunity to communicate. Communication involves presentation and a record of the process (DBE, 2011:68-69). The critical thinking skills that are applicable to *communication* are the abilities to *state the results* and to *justify the procedures* followed. To state results and justify the process are sub-skills of 'explanation' (see Section 2.4). The results of this study disclosed that the participants were unsuccessful at supporting learners to a point where technology learners are able to provide a credible explanation of the process followed when solving a particular technological problem.

5.4 Limitations of this study

Some of the limitations identified in this study may provide opportunities for further research. The first limitation of the study was that the learners were not given an opportunity to present their views on how they were encouraged to develop critical thinking skills. The focus of the study was on technology teachers - how they actualised critical thinking in the classroom. Several interviews with learners would have been ideal to determine their experiences. Learners could be interviewed for a follow-up study. The learners' involvement in the technology classroom was important in determining the success of the teachers' instructional strategies. However, the study disclosed that the participants had limited success in actualising critical thinking skills. It might be better to determine the extent to which they developed critical thinking skills with proper assistance.

Due to a lack of funds and resources, the study was confined to sampled schools in the Mankweng District near the City of Polokwane. However, the sampled schools were not well-resourced like former model C schools that might have produced different findings. The researcher expected to observe how technology teachers connect the opportunities that CAPS offers to actualising critical thinking skills while using the appropriate technology equipment.

The data was collected towards the end of Term 3. Some provinces do not allow researchers to collect data in Term 4 since schools are preparing for examinations. This resulted in time constraints as there was not time to conduct a pilot study. The interview questions, therefore, were only clarified during the interviews to ensure that the participants understood the questions before responding, and follow-up questions were made in instances where the participants did not understand the questions.

The participants demonstrated a limited understanding of critical thinking and how critical thinking is actualised in the classroom. They were also less than successful in connecting the opportunities offered by CAPS to critical thinking. This, to some extent, disempowered this study because there was no actual observation of how technology teachers connect the opportunities that CAPS offers to critical thinking.

It is acknowledged that, due to the nature of qualitative research, there was some subjectivity when the data was interpreted. When data is interpreted subjectively, this tends to provoke the aspect of bias in the study, which could be considered as a limitation. According to Flyvberg (2006:219), case studies are subjective and allow researchers to interpret their own data, and therefore the validity of the case studies may be questionable. Case studies present real-life experiences and multiple case studies are essential in developing a subtle perspective of reality (Flyvberg, 2006:219). In this study, multiple case studies were used to minimise the extent of subjectivity and bias.

A larger sample may provide a broader perspective on how to actualise critical thinking skills in the technology classroom. Flyvberg (2006:241) highlights that the advantage of a larger sample provides a widespread viewpoint. In most cases, a combination of quantitative and qualitative methods improved representation (Flyvberg, 2006:241). It is the viewpoint of the researcher that quantitative methods can enable researchers to firstly determine the extent to which technology teachers understand critical thinking, and subsequently, conduct qualitative investigations to gain insight. The fourth participant could not be observed due to unplanned cultural activities that took place in her school, despite numerous attempt to reschedule the observation.

5.5 Recommendations

5.5.1 Pedagogical recommendations

It is important that technology teachers have a firm grasp of the concept of critical thinking and its associated critical thinking skills. Technology teachers should be able to support learners to develop skills to interpret information, analyse information, evaluate statements, draw credible inferences, provide an explanation, and conduct self-regulation. These skills will help learners to develop critical thinking skills that could be useful beyond the classroom environment.

Technology teachers should also have a sound knowledge and understanding of the dispositions of critical thinking. This could enable technology teachers to foster the necessary characteristics within learners to develop critical thinking skills through inquisitiveness, open-mindedness, and reasoning objectively without being biased. Technology teachers should be acquainted with cognitive mechanisms as this could enable technology teachers to understand how learners develop cognitive skills and exploit their cognitive abilities. Being familiar with the concept 'critical thinking' will enable technology teachers to develop suitable instructional strategies that could help them to actualise critical thinking skills in the classroom.

The researcher recommends that technology teachers become *au fait* with the CAPS document for technology in order to realise the purpose of technology. Most importantly, technology teachers should acquire a solid understanding of the design process and how to engage with it while solving technological needs or problems. All the steps of the design process (investigate, design, make, evaluate, and communicate) are essential and should be exploited fully since they provide opportunities to develop critical thinking skills. For instance, through investigation, learners are required to seek information, conduct research, and grasp concepts and gain insight. These activities require higher order thinking and therefore technology teachers should use these activities to develop learners' critical thinking skills.

5.5.2 Recommendations for future research

It was made clear that the focus of this study was on teachers - how they view and actualise critical thinking. A follow-up study focusing on learners is recommended. The study disclosed that the participants were less than successful in actualising critical thinking skills in the classroom. Future research is recommended to determine the extent to which technology teachers develop critical thinking skills with proper assistance. Also, well-developed schools (former model C) could be used to investigate how teachers actualise critical thinking skills. The subject (technology as a generic and domain non-specific subject) is not offered in the Further Education and Training (FET) band in South Africa. Therefore, it is recommended to investigate how critical thinking is actualised in FET technology classrooms. A larger sample could be used with both quantitative and qualitative approaches to provide a widespread perspective.

5.6 Conclusion

This study investigated how technology teachers actualise critical thinking skills in solving technological problems. The research results disclosed that the participants were not conversant with the concept of 'critical thinking'. The participants in this study were unable to fully support learners to develop critical thinking skills such as interpretation, analysis, evaluation, inference, explanation, and self-regulation. This implies that the participants were less than successful in realising the purpose of technology as a subject. CAPS stipulates that the purpose of technology is to encourage learners to be inventive, and it develops their creative and critical thinking skills. The participants used CAPS and a textbook, which collectively supported the participants to actualise critical thinking skills. Unfortunately, the participants were ineffective at using the CAPS document.

The CAPS document, and the textbook used by participants, outlined the explicit processes that technology teachers should adhere to while teaching electrical systems and control, but the participants demonstrated that they did not follow CAPS or the textbook as they should. The CAPS document provides learners with opportunities to solve problems by applying innovative methods using authentic contexts. However, the participants were not very successful in supporting their learners to build authentic technological solutions. By implication, the design process was compromised and this is where critical thinking skills should have been developed.

The design process emphasises that technology teachers should set the scenario in order to demonstrate how a particular activity meets a need and solves a technological problem. In this case, the participants should have persuaded learners to try to understand how the electric circuits meet a need or solves a technological problem. The participants did not set the scenario. In essence, setting the scenario enables technology teachers to stimulate learners to be creative and generate their critical thinking skills. In contrast, by failing to set the scenario, the participants deprived learners of an important opportunity to develop critical thinking skills, which are emphasised by this study as vital to learning technology as a subject. Critical thinking skills are not only applicable to technology, but also to finding solutions to the problems and needs that arise in adult life.

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APPENDIX A

STRUCTURED QUESTIONS

1) What is your definition of critical thinking?

2) One of the primary aims of CAPS is to produce learners that are able to identify and solve problems and make decisions using critical and creative thinking. How do you actualise critical thinking skills in teaching technology?

3) What are your personal characteristics that enable you to teach critical thinking skills?

4) Interpretation is one of the factors of critical thinking. What kind of approach do you use to encourage learners to interpret information?

5) Do you allow learners to describe experiences, situations, beliefs, events, etc. in order to understand the meaning of a particular context? Kindly substantiate.

6) How do you support learners to recognise the significance of interpreting their learning experience?

7) Do you provide learners with the opportunity to clarify meaning? Kindly give an example.

8) Analysis as an aspect of critical thinking enables learners to identify the intended and actual inferential relationships among statements. How do you motivate learners to analyse statements?

9) How do you support learners to examine ideas during the learning experience?

10) When learners are contesting some claims or opinions in the classroom, how do you assist them to recognise arguments within those claims or opinions?

11) How do you encourage learners to analyse arguments? Kindly substantiate.

12) Evaluation is one of the important factors of critical thinking whereby learners assess the credibility of statements. How do you persuade learners to evaluate the credibility of statements?

13) Do you think learners are able to recognise the factors relevant to assessing the degree of credibility?

14) Do you allow learners to judge the strength of an argument's premises and assumptions with a view towards determining the acceptability of the argument?

15) Inference as an aspect of critical thinking stimulates learners to identify and secure elements needed to draw reasonable conclusions. How do you support learners to draw their own conclusions when solving technological problems?

16) Do you think learners are able to query evidence in an attempt to develop a credible argument? Kindly substantiate.

17) Are learners able to formulate multiple alternatives in solving technological problems? Kindly give examples.

18) Explanation is one of the important factors of critical thinking that encourages learners to justify their reasoning. How do you support learners in justifying their reasoning?

19) Do learners produce clear descriptions of the results? Kindly substantiate.

20) How effective are learners when presenting the procedures they have followed in solving technological problems? Kindly substantiate.

21) Self-regulation as one of the essential aspects of critical thinking teaches learners to monitor their cognitive activities. Do you encourage learners to reflect on their own reasoning and verify the results produced?

22) How do you encourage learners to correct their errors?

APPENDIX B

OBSERVATION SCHEDULE

CRITICAL THINKING SKILLS / DESIGN PROCESS	**Interpretation**	Categorize	Translate significance	Clarify meaning	**Analysis**	Examine ideas	Identify argument	Analyse	**Evaluate**	Assess credibility of claim	Assess quality of arguments	**Inference**	Query evidence	Conjure	Draw conclusions using inductive	**Explanation**	State results	Justify the procedure	Present argument	**Self-regulation**	Self-examination	Self-correction
Investigation																						
Investigate solutions																						
Investigate the nature of problem																						
Incorporate electronic circuits into design																						
Design																						
Design specifications																						
Identify constraints																						
Draw circuit diagram																						
Team meet and examine individual suggestions																						
Decide final solution																						
Make																						
Develop a plan																						
Team draw working drawing																						
Authentic problem																						
Communication																						
Team presentation																						
Compile a report																						