AN EXPLORATION OF GRADES 10 – 12 COMPUTER APPLICATIONS TECHNOLOGY TEACHERS' PROBLEM-SOLVING SKILLS AND COMPUTATIONAL THINKING SKILLS IN THE FREE STATE.

by

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AN EXPLORATION OF GRADES 10 – 12 COMPUTER APPLICATIONS TECHNOLOGY TEACHERS' PROBLEM-SOLVING SKILLS AND COMPUTATIONAL THINKING SKILLS IN THE FREE STATE.

I, **Carlie Luzaan Schlebusch**, student number: **20495919,** do hereby declare that this research project submitted to the Central University of Technology, Free State for the Degree: Philosophiae Doctor: Educationis (PhD: Education), is my own independent work; and complies with the Code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State; and has not been submitted before to any institution by myself or any other person in fulfillment (or partial fulfillment) of the requirements for the attainment of any qualification.

CL Schlebusch

DATE

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DEDICATION

This thesis is dedicated to:

- My late grandmother, Carlie Bernard, who always believed in me! I know you would be proud!

- My mother, Irma van den Heever - her support, encouragement, and constant love have sustained me throughout my life.

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ABSTRACT

For learners to be effective computer applications users, they need three basic skills – computer literacy, computer fluency and intellectual and reasoning skills to apply computational techniques or computer applications to the problems and projects in a field.

Computational thinking as addressed in the first literature chapter is the description and the promotion of new ways of thinking in an increasingly digital age. A computational thinker must constantly engage in technology advancements. Computational thinking is a way of solving problems and is a cognitive or a thinking process. To flourish in the world of work, computational thinking has to be a fundamental part of the way learners think and understand the world. It describes the mental activity in formulating a problem to allow a computational solution. The solution can be carried out by the learner or the computer or a combination of learner and computers.

Problem-solving competency as addressed in the next literature chapter involves the ability to acquire and use new knowledge, or to use old knowledge in a new way to solve problems that are not routine. Problem-solving as a skill involves a range of processes that includes analysing, interpreting, reasoning, predicting, evaluating and reflecting. Learners need profound Computer Applications Technology (CAT) knowledge and a general reasoning ability as well as investigative strategies for solving ill-defined problems.

To address the research questions, the researcher employed the QUAN-QUAL design in this study. In this study the quantitative method was used to gather data relating to the education of teachers, in-service training received and answers to certain computational thinking skills and problem-solving skills. It was also used to test the relationship between problem solving and computational thinking skills. A Likert-scale type questionnaire was completed by 150 CAT teachers. In addition, this study also employed the qualitative method with semi-structured interviews to gather data relating to problem solving and computational thinking skills. Eight CAT teachers were interviewed to ascertain the afore-mentioned.

A pilot study was conducted with the aim to test the research approach and to identify potential problems that may affect the quality and validity of the results. The wording of some questions in the questionnaire was altered to ensure that the instrument measures what it is supposed to.

Descriptive statistics in this study was used to describe the findings and the inferential statistics used to test the hypotheses and draw conclusions from the quantitative statistics. For qualitative data, thematic analysis was used to analyse the original data obtained from the semi-structured interviews.

To promote critical thinking skills, teachers must engage learners in higher-order thinking. Findings show that teachers do not always use classroom practices that encourage critical thinking. It was encouraging that the majority of teachers do allow group work in the CAT classroom, as group work is an important facet in computational thinking and problem solving. The study culminates in a computational thinking and problem-solving toolkit developed by the researcher. This toolkit is intended primarily for facilitators (such as CAT subject advisors or CAT mentor teachers) to enable them to conduct workshops for fellow CAT teachers. By using this toolkit, teachers will gain an understanding of what computational thinking skills and problem-solving skills are and how to develop these skills in Grades 10 – 12 CAT learners.

Keywords: Algorithms, Analytical Thinking, Cognitive processes; Computer, Computer Applications Technology; Computational thinking; Critical thinking; Problem-solving; Group work; Technology.

TABLE OF CONTENTS

CHAPTER 1

ORIENTATION

CHAPTER 2

THE ESSENCE OF COMPUTATIONAL THINKING

CHAPTER 3

THE ESSENCE OF PROBLEM SOLVING

CHAPTER 4

RESEARCH METHODOLOGY

CHAPTER 5

RESULTS OF THE EMPERICAL INVESTIGATION

CHAPTER 6

FINDINGS, CONCLUSION AND RECOMMENDATIONS

CHAPTER 7

COMPUTATIONAL THINKING AND PROBLEM-SOLVING TOOLKIT FOR CAT TEACHERS

LIST OF FIGURES

LIST OF TABLES

LIST OF GRAPHS

LIST OF APPENDICES

CHAPTER 1

ORIENTATION

1.1 INTRODUCTION

This chapter puts forward the plan for conducting the study. The following are elaborated on for more clarity: background of the study, significance of the study, and the statement of the research problem which links with the emergent research questions. The aim and objectives of the study are also provided. A preliminary literature review briefly scrutinises current literature on the topic. The research design and methodology are discussed after which the study is delimited. This chapter concludes with some relevant definitions.

1.2 BACKGROUND TO THE PROBLEM

Computer Applications Technology (CAT) is a subject in the Further Education and Training phase (FET) for Grades 10 – 12 in South African schools. The National Curriculum Statement Grades R-12 (NCS) stipulates policy on curriculum and assessment in the schooling sector (Department of Basic Education (DBE), 2011a:3). The Curriculum and Assessment Policy Statement (CAPS) builds on the previous curriculum but also updates it and aims to provide clearer specification of what is to be taught (DBE, 2011a:iv). The CAPS document states "*that though teaching and practising the mechanical or technical skills and functions of applications are important for the learner to become familiar with the tool that he or she uses, it is also important to do so within the paradigm of computational thinking.*" It states that tasks given to learners should also involve procedural skills and encourage computational thinking (DBE, 2011a:40). One of the aims of the NCS is that learners should demonstrate an understanding of the world as a set of related systems by recognising that problem solving contexts do not exist in isolation (DBE, 2011a:5). Problem-solving is an integral part of the subject (DBE, 2011a:50). The Practical Assessment Task (PAT) is a project that assesses the learner’s procedural skills and individual interaction with data and information as well as the way in which he or she processes, manipulates and presents the information (DBE, 2011a:51). The researcher is of the opinion that teachers only teach application without the paradigm of computational thinking and not within the framework of problem solving.

1.3 PURPOSE OF THE STUDY

Taking the background above into account, the purpose of this study is to explore grade 10 - 12 CAT teachers’ problem solving and computational skills in the Free State province and to develop a toolkit that could be used by teachers to develop computational thinking skills and problem-solving skills in learners. The study will gather information on the development and improvement of computational thinking and problem-solving skills to ensure that the new curriculum is successfully implemented in the subject CAT in the FET phase in secondary schools.

1.4 SIGNIFICANCE OF THE STUDY

This study explores how CAT teachers can develop and improve computational thinking skills and problem-solving skills in CAT learners in the FET phase. The computer science community can play an important part in emphasising algorithmic problem-solving practices and applications of computing across various subjects, and help integrate the application of computational methods and tools across diverse areas of learning (Barr & Stephenson, 2011:49). To expose learners to computational thinking is multifaceted; it requires systematic change, teacher involvement and the development of substantial resources (Guzdial, 2008:25-28).

This study should assist officials of the Department of Basic Education in providing adequate in-service training to ensure that CAT is the instrument to introduce and develop learners’ computational thinking skills and problem-solving skills.

1.5 STATEMENT OF THE PROBLEM

Learners deal with problems in almost all subjects and quite often a computer is an appropriate tool for solving those problems. Mayer and Wittrock (2009) remark that a problem exists when a problem solver (a learner) has a goal but does not know how to accomplish it. It may therefore be assumed that, irrespective of the subject, a problem occurs when a learner has to provide an answer/solution based on what he or she has learned. A problem is therefore not just a simple task – a problem should contain a certain challenge or difficulty learners must provide answers or solutions to problems or activities relating to what was learned. This should be completed without assistance from the teacher on how to apply the learnt knowledge to solving the problem or complete the activity. Consequently, when a learner must use a computer in solving a problem, the teacher should also extend the range of the problem to find an answer on how to provide its computer solution.

It is important to develop computational thinking while solving problems within various disciplines with the help of computers; CAT should therefore be used to develop computational thinking in problem solving. In order to successfully implement the CAT CAPS it is important that the teachers, as the implementers of the curriculum, should have the necessary skills to achieve this (DBE, 2011a:23). Computational thinking and problem solving are required in all fields of learning, but this study will focus on the field of computer applications.

The challenge of this study is to address the lack of computational thinking and problem-solving skills among teachers and learners. In thinking about computing, teachers need to be attuned to the three drivers of computing: science, technology and society. Though the teaching and practice of mechanical or technical skills and functions of computer applications are important for the learner to become familiar with the tool that he or she uses, it is important that teachers do so within the framework of computational thinking.

1.6 RESEARCH QUESTIONS

The research questions that emanate from the research problem are:

- What are the essences of computational thinking and computational thinking skills with regard to CAT?
- What are the essences of problem solving with regard to CAT?
- How do teachers integrate computational thinking and problem solving in the CAT classroom?
- Which recommendations for teaching computational thinking and problem solving can be put forward?
- What should be included in a computational thinking and problem-solving training programme for CAT teachers?

1.7 RESEARCH AIM AND OBJECTIVES

The aim of this research is to determine what the essence of computational thinking is and how this is linked to problem-solving skills. Keeping this in mind, the applied aim is therefore to determine whether CAT teachers make use of computational thinking skills to implement and use problem-solving skills effectively in teaching CAT content to learners. This aim leads to the following objectives of the study:

- To determine the essences of computational thinking and computational thinking skills with regard to CAT.
- To ascertain the essences in problem solving with regard to CAT.
- To investigate how teachers integrate computational thinking and problem solving in the CAT classroom.
- To make recommendations for teaching computational thinking and problem solving.
- To develop a computational thinking and problem-solving training programme for CAT teachers.

1.8 HYPOTHESES

The following research hypotheses will be tested in this study:

H_1: There is a statistically significant relationship between problem solving and computational thinking skills in the subject CAT.

H_0: There is no statistically significant relationship between problem solving and computational thinking skills in the subject CAT.

1.9 DEFINITION OF TERMS

Algorithm is a set of rules that describe how to do something, or how to solve a problem. An algorithm may be described as a program, pseudo-code or a less formal step-by-step explanation (even a recipe) (Computing at School Workgroup, 2012:14).

Computational Thinking is the thought processes dealing with formulating problems and their clarifications in order for these clarifications to be represented in a form that can be successfully carried out by an information-processing agent – such as a computer (Wing, 2010:1).

Computer is a programmable, electronic device that accepts data, performs operations on that data, presents the results, and stores the data or results as needed. (Morley & Parker, 2011:10).

Computer Applications Technology is the study of the integrated components of a computer system (hardware and software) and the practical techniques for their efficient use and application to solve everyday problems (DBE, 2011a:8).

Computer Literacy is the knowledge and understanding of basic computer fundamentals (Morley & Parker, 2011:6).

Computation is a term for what a computer can do or any kind of information processing that takes place (Stuart, 2013:15; Crnkovic, 2010:38).

Computing is described as the study of natural and artificial information processes (Denning, 2007:15).

1.10 REVIEW OF LITERATURE

The concept of computational thinking signifies a generally applicable attitude and skill set to everyone – and not just to computer scientists. Wing (2006:33) points out that this skill should be added to the reading, writing and arithmetic skill of every learner.

In the United States of America the International Society for Technology in Education (ISTE) (2011:1) collaborated with leaders from higher education, industry, and K–12 education to develop an operational definition for computational thinking. This definition may be used as a framework for CAT teachers. According to ISTE computational thinking is therefore a problem-solving process, linked to the following characteristics:

- Teachers must make sure that problems are formulated in such a way that learners can use a computer to help them in solving the problem.
- Learners must have the ability to organise and analyse data logically.
- Representing data through abstractions such as models and simulations.
- Learners must reach a solution to the problem through making use of ordered steps (algorithms).
- Learners must be able break down a major problem into minor problems. They must therefore be able to identify and analyse different solutions in order to reach the best solution to solve the problem.
- Learners will be able to transfer knowledge gained from one problem-solving process to a variety of problems.

ISTE (2011:1) also states that the skills mentioned above can be reinforced and improved if learners show the following attitudes or characteristics:

- Learners must be self-reliant and independent when they are confronted with complex problems.
- Learners should have determination when they are dealing with a problem.
- Learners must be open-minded.
- Learners must be capable to work on or solve open-ended problems.

- Learners must be able to work and communicate in a team – the teacher must therefore allow for teamwork during class time.

Using different levels of thinking, to understand and solve problem more effectively, is what computational thinking means to Moursond (2010). For Phillips (2009:1) the core of computational thinking is that learners must think about data and ideas, and that they should use and combine these resources to solve problems. Phillips (2009:1) is of the opinion that teachers can support learners to "think computationally" by moving technology projects beyond "using" tools and information toward "creating" tools and information. He argues that if teachers want to encourage computational thinking in the classroom, questions related to problem solving and the use of technology must be asked. Examples of such questions are:

- What is the power and limit of human and computer intelligence?
- How difficult is the problem?
- How can the problem be solved?
- How can technology be applied to the problem?
- What computational strategies might be employed?

Linking to Phillips's notion as outlined above, the DBE (2011a:23) states that "*though teaching and practising the mechanical or technical skills and functions of applications are important for the learner to become familiar with the tool that he or she uses, it is important to do so within the paradigm of computational thinking*". Furthermore, as discussed in Chapter 2, Perković and Settle (2010:123) indicate that learners need skills such as computer literacy, computer fluency and intellectual and reasoning skills.

Computer Science for Fun (2011) concurs with Perković and Settle and states that computational thinking is a collection of different skills involved in problem solving that result from studying the nature of computation. Computational thinking may include some obviously significant skills that most subjects help develop, such as creativity, the ability to explain and to work in a team. It also consists of some very specific problem-solving skills such as the ability to think logically, algorithmically and recursively. Computer Science is unique in the way it brings all these diverse skills together. The current South African school curriculum does not offer Computer Science, but CAT and IT; therefore CAT can be the unique subject that brings all these diverse skills together.

Organisations such as Microsoft and Google have also lately started paying attention to computational thinking. Adding to the skills mentioned above, Google for Education (2012) states that another key skill for computational thinking is data skills. They define data skills as a learner being able to collect, analyse and represent data in a significant way. Teachers thus have the responsibility to teach learners how to become adept at working with large, sophisticated data sets.

The literature review reveals that recent examples in computational thinking are in mathematics and science (Committee for the Workshops on Computational Thinking, 2010:10-14). This is because patterns, algorithms and data are most naturally found in these subjects, and can easily be formalised into programs. However, there are many other opportunities for computational thinking to be applied to other subject areas such as CAT. For example, data skills can be developed in CAT whereby learners utilise statistics or population data to summarise findings.

Problem-solving is intertwined with computational thinking. The CAPS document states that "*learners are required to apply a combination of a series of procedures and techniques to new situations in order to provide a specific answer or accomplish a specific goal that encourages computational thinking*" (DBE, 2011a:49). Jonassen (2010:1) believes that the most important cognitive goal of education (formal and informal) in every educational context (public schools, universities and corporate training) is problem solving. Dijkstra, Krammer and Merriënboer (2010:282) view a computer as a means to enrich and improve a learner's cognitive skills and general problem-solving ability.

Herring (2012) points out that the Australian National Curriculum agrees with the aspect above. The Australian National Curriculum envisages learners to be computational thinkers and therefore learners will know how to articulate problems, will be able to organise and analyse data logically, and therefore be able to represent data in abstract forms such as data tables, digital graphs and spreadsheets. To reach the necessary solutions, learners will use their algorithmic and declarative logic. Moreover, to reach a solution, learners will be able to decide on the best combination of data, procedure, and human and physical resources to apply.

Herring (2012) recommends that for learners to be efficient computational thinkers and effective users and creators of digital technologies, it is essential that they know about:

- algorithms (the mathematical recipes that make up programs such as spreadsheets);
- cryptography (how confidential information is protected on the Internet);
- machine intelligence (how services such as YouTube, Google and Amazon predict a user's preferences);
- searching the Internet;
- recursion (a method where the solution to a problem depends on solutions to smaller instances of the same problem);
- heuristics (experience-based techniques for problem solving, learning and discovery); and
- critical thinking support (utilising IT applications to better develop critical thinking skills).

As we have seen with the integration of technology into education, learners are gaining skills to communicate, collaborate, create and innovate in dramatic ways. With computational thinking skills, learners will recognise when a computer can help in solving the problem. They will be able to recognise that computing enables them to collect and manipulate large data sets for decision making. They will be able to leverage the power of computing, because they know how to program; or they will have the vocabulary, skills and disposition to collaborate with a computer programmer or designer to solve the problem. By teaching learners the aforesaid, CAT has been successfully used to instill computational thinking skills and problem-solving skills amongst its learners.

1.11 RESEARCH METHODOLOGY

Research methodology is a way research is done to solve a specific research problem. To address the research questions, the researcher will employ a mixed research design where the quantitative approach will be enhanced by qualitative data in what is called the QUAN-QUAL model. This can also be referred to as the triangulation mixed method, according to Gay, Mills and Airasian (2009:463). They point out that both quantitative and qualitative data are equally weighted and that data are not collected in separate studies, but simultaneously during the course of the same study.

Fraenkel and Wallen (2010:453) are of the opinion that when a conclusion is supported by data collected from a number of different instruments, the validatiy of the study is enhanced. Two main advantages of the mixed method research are the ability to offer a more in-depth appreciatiation of the research problem as multiple forms of data surveyed are deemed more complete than data collected via either quantitative or qualitative methods alone. It also allows for the researcher to answer intricate research questions that may be difficult to address by employing quantitative or qualitative methods by themselves (McMillan, 2012:318).

Gay *et al.* (2009:7) assert that quantititave research is the collection and analysis of statistical data to describe, clarify, predict or control phenomena of interest. Leedy and Ormrod (2010:95) are of the opinion that quantitative researchers pursue explanations and predictions that can be generalised to other persons and places. The committment is to create, confirm or authenticate relationships and to develop generalisations that contribute to other theories. In this study the quantitative method is employed to collect data concerning the education of teachers, in-service training received by CAT teachers and answers to certain computational thinking skills.

The focus of qualitative research methods is on in-depth enquiry, concentrating on a fairly small number of individuals, while quantitative data normally represents statistical results which can be generalised to a wider population (Cant, 2003:121). Qualitative research is also called field research, critical research or interpretative research which all express data narratively in a non-numerical form (Du Plooy, 2002:29). Hennink, Hutter and Bailey (2011:10) state that qualitative research is useful when exploring new topics or attempting to understand multifaceted concerns. Qualitative research is used to gain insight into people's attitudes, behaviour, value systems, motivations, and aspirations. In this study the qualitative method is used to gather data relating to problem-solving, and teachers' knowledge and teaching methods.

1.11.1 Population and Sample

A population may be defined as the total number of possible units or elements that are included in the study (Gray, 2004:82). Castillo (2009) regards a distinct collection of individuals with related or parallel characteristics as the research population. Since the population is the group from which a sample will be drawn, Gorard (2013:78-79) emphasises that it should always be demarcated in advance as the target of one's research. The population of this study consists of FET phase (Grades 10-12) CAT teachers in Free State schools.

A sample is regarded as a segment of the population that is selected for the purpose of the research (Bryman, 2012:187). A sample may therefore be seen as a subset of the population. The results of the research may then be generalised back to the population from which they were selected.

The researcher will implement probability sampling for selecting respondents to provide quantitative data. According to Castillo (2009) and Trochim (2006), in probability sampling every individual in the population has an equal opportunity of being selected as a respondent for the research. This ensures that the selection process is unsystematic and without any prejudice. McMillan and Schumacher (2010:129) define probability sampling as respondents being selected from a larger population in such a way that the probability of selecting each member of the population is known. If this type of sampling is conducted efficiently, it will provide estimates of what is true for a population from a smaller group of respondents.

The researcher will employ simple random sampling for quantitative data, as this will ensure that every member of the population under study has an equal opportunity to be selected and the probability of a member of the population being selected is unaffected by the selection of other members of the population (Cohen, Manion & Morrison, 2005:100). In this study a Table of Uniform Random Numbers will be used to select the sample. A total of 150 CAT teachers will be sampled to respond to the questionnaire.

The researcher will employ purposive sampling for collecting qualitative data. The researcher will make use of purposive sampling otherwise known as criterion-based sampling. Sample units are based on the known features which might relate to factors such as experience, behaviour or roles that is relevant to the research topic. When purposive sampling is used, the units in the sample are chosen to represent a prescribed group (Ritchie, Lewis, Elam, Tennant & Rahim, 2014:145). Eight CAT teachers will be sampled to be interviewed. The researcher is of the opinion that the data collected from the qualitative sample will provide the necessary information to answer the relevant research questions.

1.11.2 Data collection methods

Creswell and Clark (2011:176-178) outline that the data collection element of research is shared by all fields of study, including education. Notwithstanding the study field or preference for defining data (quantitative or qualitative) to maintain the integrity of the research, honest and precise data collection is essential. Both the selection of appropriate data collection instruments (existing, modified or newly developed) and clearly delineated instructions for their correct use reduce the likelihood of errors occurring.

McMillan (2012:146–147) mentions that quantitative methods of data collection are used to measure, document and provide numerical values. This is accomplished by using objective and standardised data gathering for all participants. A questionnaire and rating scales will be used to measure and report quantitatively with statistics.

Qualitative methods of data collection are relatively unstructured and often open-ended through interviews. Mixed method design uses a combination of quantitative and qualitative data collection methods. In concurrent data collection, the quantitative and qualitative data are collected at roughly the same time (Tashakkori & Teddlie, 2003:229).

The Internet has opened up new ways for collecting data along with the improvement of data quality according to Fielding, Lee and Blank (2010:79-93). He further avers that the Internet is a medium available for conducting higher-quality data research through web-surveys (such as questionnaires), e-mails and other sources.

For this study the researcher will utilise various data collection methods, namely (1) questionnaires, (2) interviews, (3) e-mail surveys, (4) literature review. Each of these are now briefly discussed.

1.11.2.1 Questionnaires

A questionnaire is a list of printed questions, given or posted to participants who will complete the questionnaire in their own time (Laws, 2003:306-307). Questionnaires may be useful for the researcher when information from a larger sample is needed and if the required data or information is known to the researcher. A standardised format can be used and the respondents will be content to answer the questions.

The researcher will use a questionnaire in the study because it is a flexible instrument. By using a questionnaire the researcher will be able to organise the closed-ended questions. Closed-ended questions will allow the respondent to select an answer from among a list provided by the researcher. This will provide a uniformity of responses that can be processed to obtain the quantitative data (Babbie, 2013:255).

The Internet and other related communication technologies are changing modern research. For the researcher, online questionnaires can offer distinct benefits according to Dillman, Phelps,Tortora, Swift, Berck & Messer (2009:1-18). Some of these benefits are:

- a geographically dispersed population can be reached;
- there are substantial savings in travel costs;

- it is a fast alternative to a postal, face-to-face and telephonic survey – data or information can be supplied faster; and
- the effectiveness of the research will be enhanced and there is an increased response rate if used wisely and correctly as mixed-method methodology.

The researcher will distribute the questionnaires to CAT teachers who have e-mail addresses and to those teachers with no e-mail addresses the questionnaires will be delivered and collected by hand.

1.11.2.2 Interviews

Semi-structured interviews will be used to gather information-rich data. Glesne (2011:102) states that an interview is the face-to-face communication between at least two persons with the purpose of collecting data on a specific topic.

1.11.2.3 e-Mail surveys

E-mail surveys may exist in several forms: e-mail with a link point to web questionnaires; e-mail with attached questionnaire; and e-mail text without attachments or links (Dillman, 2007:358). The latter is useful for questionnaires, for example between three and five questions (Dillman, 2007:372) and is more suited for open-ended questions than pre-coded questions.

1.11.2.4 Literature review

Literature reviews can contribute to the understanding of the problem researched. It could also assist in establishing the results of a study in a historical perspective. Without reviews of relevant literature, difficulties could be experienced when constructing a volume of approved knowledge on any education topic (McLaughlin & Mertens, 2004:36). The literature review will assist in answering of the research questions, such as:

- What are the essences of computational thinking and computational thinking skills with regard to CAT?

- What are the essences of problem solving with regard to CAT?

The literature review will thus be used as the basis for the empirical research.

1.11.3 Data analysis

Data analysis involves the organising, accounting for, and explaining the data. It also includes making sense of the data in terms of the participants' explanations of situations, noting patterns, themes, categories and regularities. In qualitative research, data analysis commences during the data collection process (Cohen *et al*., 2005:147).

The following strategies can be used to analyse qualitative data: identifying themes; coding surveys, inverviews and questionnaires; asking key questions; doing an organisasional review; concept mapping; analysing experiences and consequenses; displaying findings (by means of charts, graphs and figures) and stating what is missing (Gay *et al.,* 2009:451).

To analyse the quantitative data, the researcher will employ descriptive statistics and inferential statistics to analyse the collected data. The questionnaire will include a five point Likert scale that will be used to analyse the quantitative data. This will allow the researcher to measure teachers' attititude towards a particular concept/s, computational thinking and problem solving (Fraenkel & Wallen, 2010:129).

The Pearson Correlation Coefficient will be employed to test the hypothesis mentioned previously. Jackson (201:162) mentions that the Pearson Correlation Coefficient is a measure of correlation that is appropriate if both the independent variable (problem solving) and the dependent variable (computational skills) are expressed as continuous data. The two variables will be measured through a Likert scale. In this study, problem solving will be correlated with computational skills. Correlation may range from -1.00 to +1.00 (McMillan & Schumacher, 2010:168). A coefficient near 0.00 will imply that problem solving and computational skills are not related.

To analyse the qualitative data of the semi-structured interviews, thematic analysis will be applied. Thematic analysis underpins most other methods of qualitative data and it is a method for recognising and organising patterns in content and meaning in qualitative data (Willig, 2013:59).

1.12 ETHICAL CONSIDERATIONS

- Prior to conducting this study, a written consent will be obtained from the Free State Department of Education.
- Teachers, who will be participating in the research, will be informed and anonymity will be assured.

1.13 DELIMITATION OF THE STUDY

This study resorts under the Didactical field of Education with a clear link to the field of Computer Applications Technology.

1.14 EXPECTED OUTCOMES

This study will:

- Reveal the essences of computational thinking and computational thinking skills with regard to CAT.
- Reveal the essences in problem solving with regard to CAT.
- Indicate how best teachers should integrate computational thinking and problem solving in the CAT classroom.
- Reveal effective for teaching computational thinking and problem solving.
- To develop a computational thinking and problem-solving toolkit for CAT teachers.

1.15 DIVISION OF CHAPTERS

The chapters fo this these are divided as follows:

Chapter 1: Orientation

The researcher presents a background of the research problem, and indicates the aim and objectives of the study. A brief literature overview provides definitions for certain key concepts. The methods of the research are outlined, indicating the research methodology, the design and the data collection and analysis procedures to be used.

Chapter 2: The Essence of Computational Thinking

Chapter 2 provides an in-depth literature study of concepts related to Computational Thinking. It investigates the different elements of Computational Thinking.

Chapter 3: The Essence of Problem solving

In Chapter 3 the researcher reviews literature related to principles of problem solving and effective teaching methods in order to promote problem solving. The aim of this review is to establish a sound pedagogical framework for developing problem-solving skills.

Chapter 4: Research Methodology

Chapter 4 gives a detailed account of the research methods implemented in this study.

Chapter 5: Results of the Empirical Investigation

This chapter explains how data was collected and analysed.

Chapter 6: Findings, conclusions and recommendations

Chapter 6 provides a summary of the findings, conclusions, recommendations and suggestions for future research.

Chapter 7: Computational Thinking and Problem-solving Toolkit for CAT teachers

This chapter is devoted to the computational thinking and problem-solving toolkit developed by the researcher. The toolkit consists of a Booklet for Mentor Teachers, Guidelines for Facilitators and a CD for Teachers and Facilitators that contains the PowerPoint presentations that accompany the toolkit.

CHAPTER 2

THE ESSENCE OF COMPUTATIONAL THINKING

2.1 INTRODUCTION

The purpose of this thesis is to determine whether teachers apply computational thinking and problem-solving skills in teaching CAT in Grades 10 – 12 in South African schools in the Free State province.

This chapter synthesises the literature in answer to the following research question:

- What are the essences of computational thinking and computational thinking skills with regard to CAT?

2.2 BACKGROUND

To prepare learners for the 21st century, they must be taught special skills to prepare them for the challenges of work and life in the 21st Century (Moyle, 2010:25–26). Greenhill (2010:8-10) contends that the key skills of 21st Century Learning are: Learning Skills, Literacy Skills and Life Skills.

For learners to be effective computer applications users, learners need three basic skills – computer literacy, computer fluency and intellectual and reasoning skills and be able to apply computational techniques or computer applications to the problems and projects in a field (Perković & Settle, 2010:1).

For learners to be successful in the world of work, learners must learn, within the context of core knowledge construction, skills such as critical thinking, problem solving, communication and collaboration (Partnership for 21st Century Skills[i], 2011:1). These skills link with the skills that are promoted in the CAPS document for CAT learners (DBE, 2011a:10).

With effective teaching in partnership with the specific aims of CAT (DBE, 2011a:10) it is clear that CAT as a school subject in the South African curriculum can be used as a tool to prepare learners for the 21st century.

- use end-user software applications proficiently to produce solutions to problems within a defined scenario;
- understand the concepts of ICTs with regard to the technologies that constitute a computing system;
- understand the various technologies, standards and protocols involved in the electronic transmission of data via a computer-based network;
- use the Internet and the WWW and understand the role that the Internet plays as part of the global information superhighway;
- find authentic and relevant information, process the information to draw conclusions, make decisions and communicate the findings in appropriate presentation media; and
- recognise the legal, ethical, environmental, social, security and health issues related to the use of ICTs and learn how to use ICTs responsibly.

As shown in *Figure 2.1*, on the next page, Greenhill (2010:10) indicates that curriculum and instruction, together with different learning environments, can be responsible for achieving the outcomes mentioned above. In the CAT class, the CAT teacher has the possibility for teaching learners Learning and Innovation Skills and Information, Media and Technology skills, within the CAT curriculum and learning environment.

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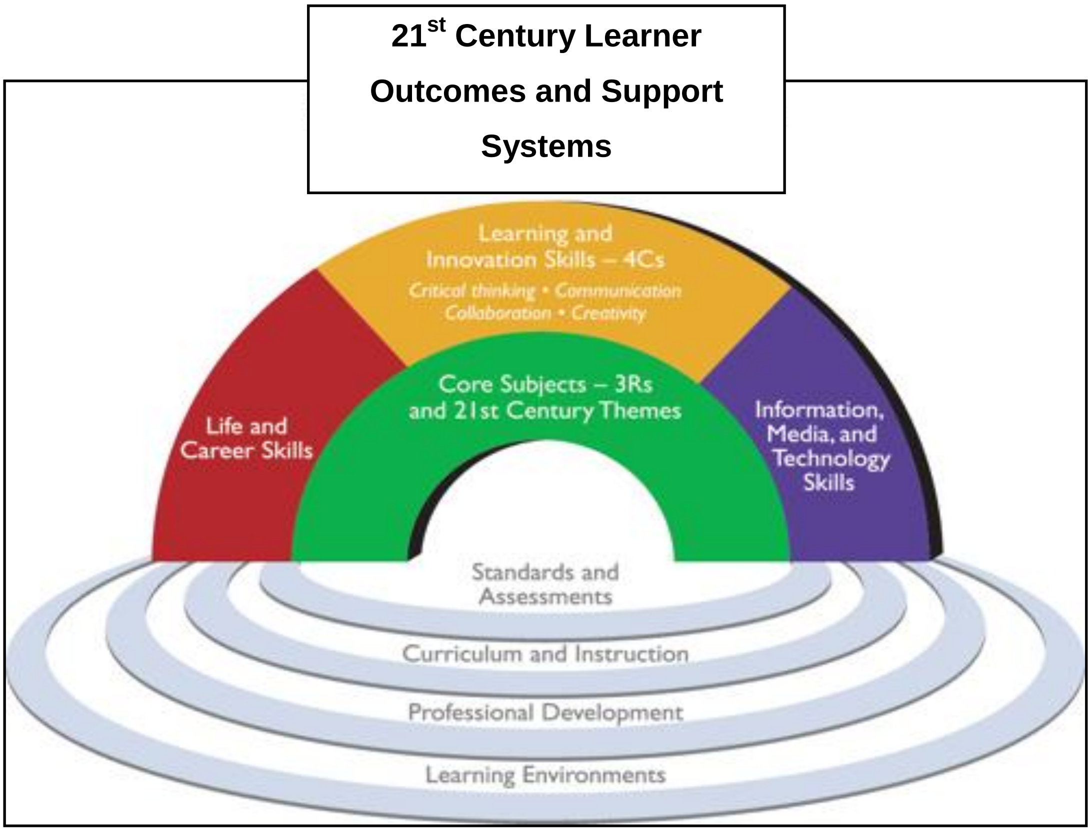
[i] Partnership for 21st Century Skills is an organisation based in the United States of America that advocates 21st century readiness for every learner. Its framework defines what learners

Figure 2.1: 21st Century Skills



Greenhill (2010:10)

Teachers should be aware of the different Learning and Innovation Skills or the 4 Cs:

- **Critical Thinking and Problem solving:** Learners effectively need to analyse and evaluate evidence, arguments, claims and beliefs; solve different kinds of unfamiliar problems in both conventional and innovative ways. This concurs with the third skill of Perković and Settle (2010:3) and with the type of learners that the National Curriculum Statement (NCS) envisages (DBE, 2011a:5). Unless CAT learners are taught this in an efficient way, they will not be able to solve different kinds of spreadsheet, database, theoretical and PAT problems that are given to them in scenarios in assessment tasks, tests and examinations. Critical thinking and problem-solving skills are not reserved only for the CAT classroom, but they are skills to be taught across the curriculum (all subjects).

- **Communication:** Learners must articulate thoughts, listen effectively, use communication for a range of purposes, utilise multiple media and technology and communicate effectively in a diverse environment (Trilling & Fadel, 2009:55). Learners must be able to communicate effectively using visual, symbolic and/or language skills in various modes (DBE, 2011a:5).

Possible examples of communication in CAT

- *PAT conclusions can be communicated through a PowerPoint presentation or an booklet using Desktop Publishing software such as MS Publisher.*
- *Different application software such as word processing (writing letters, sending invitations), spreadsheet graphs (summaring findings or presenting spreasheet information) and e-mails can be used for correspondence.*
- *Communication throught Skype/Google Hangout or any other social network media.*

- **Collaboration:** Learners must demonstrate the ability to work effectively and respectfully with diverse teams. Learners must learn how to compromise to accomplish a common goal and share responsibility; they should value the individual contributions (Trilling & Fadel, 2009:55). The NCS aims that learners should be able to work effectively as individuals and with others as members of a team (DBE, 2011a:5).

Possible examples of collaboration in CAT

- *Working together on a project by using a cloud application such as Dropbox.*
- *Working together in a group in class while solving a spreadsheet problem.*

- **Creativity and Innovation:** Teachers must find ways to nourish the creative thinking process and allow learners to develop original work through individual and group projects, e-portfolios and ways of authentic learning (Shelly, Gunter & Gunter, 2010:17). The key component of creative thinking is to generate ideas or thoughts that are original and useful. Creativity needs critical thinking in evaluating and judging new ideas (Lau, 2011:1-2).

Possible examples of creativity and innovation in CAT

- *Working together on a project by using a cloud application such as Dropbox.*

  - *Working together in a group while solving a spreadsheet problem.*

It is the teacher's role to ensure that the different skills mentioned must be taught to learners, as they need critical thinking skills to effectively and creatively solve any given problem. Linked with learning and innovation skills is the effective use of technology. Teachers must empower learners to be able to sort through the inundation of information that is available and extract the information they need to complete a task or solve a problem (Beers, 2011:11). To assist them with the previously mentioned 4 C's, learners must develop:

- **Information Literacy:** To access and evaluate information critically and competently and manage the flow of information from a wide variety of sources (Wilson & Grizzle, 2011:138). Learners must be able to use different forms of information efficiently, for example, the Internet and e-mail. Lau (2011:19) defines an information literate learner as one who is able to recognise when information is needed and to have the ability to locate, evaluate and use the required information effectively. This coincides with the essence of the PAT as described by DBE (2011a:51):

  > *"The Practical Assessment Task is a project that assesses the learner's procedural skills and individual interaction with data and information as well as the way in which he or she processes, manipulates and presents the information."*

  Through the PAT as an example, this skill is embedded in CAT and learners have the opportunity to apply this skill to solve problems.

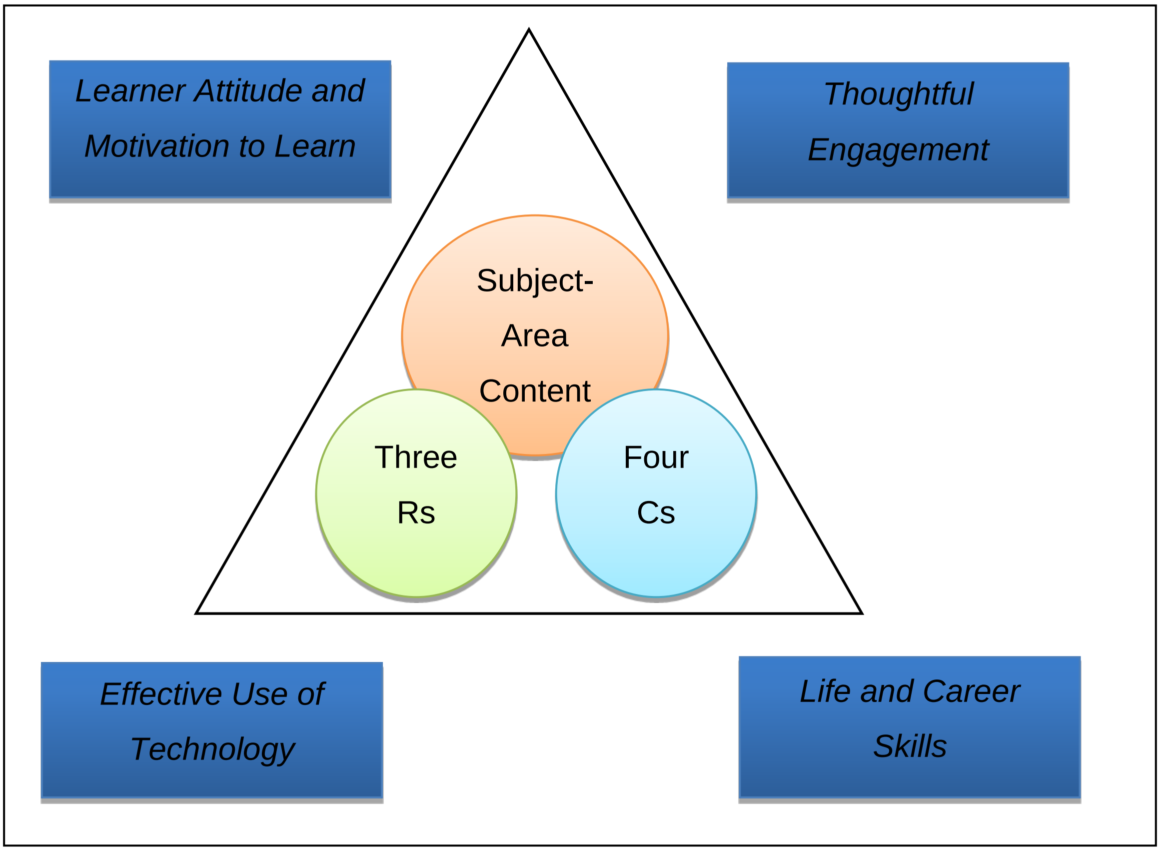
- **Media Literacy:** To understand both how and why media messages are constructed and to create media products by understanding and utilising the most appropriate media creation tools, characteristics and conventions (Wilson & Grizzle, 2011:70). The Media Literacy Project (2012) state that learners will get most of their information (such as needed for the PAT in CAT) through complex combinations of text, images and sound. Teachers must therefore ensure that learners have the skills to be able to navigate this complex media environment and they must be able to make sense of all the media messages that inundate them every day.

- **ICT (Information, Communications and Technology) Literacy:** To use technology as a tool to research, organise, evaluate and communicate information (Mandinach, 2009:144). This corresponds with the aims of CAT (DBE, 2011a:10).

All these skills can be mastered in CAT as the CAPS document (DBE, 2011a:8) clearly states that solutions to problems are designed, managed and processed via end-user applications and are communicated by using appropriate information and communication technologies (ICTs). The subject CAT creates opportunities to equip learners with the previously mentioned skills. CAT is defined in the CAPS document (DBE, 2011a:8) as the study of the integrated components of a computer system (hardware and software) and the practical techniques for their efficient use and application to solve everyday problems. For example, word processing and e-mail encourage communication skills, while database and spreadsheet programs encourage organisational skills (Honey, 2005).

To prepare learners for future success, teachers must ensure that learners exhibit a range of functional and critical thinking skills to be effective in a technology and media-driven environment marked by an abundance of information and rapid changes in technology. In *Figure 2.2,* on the next page, Beers (2011:8) indicates the relationship among the elements of learning and how teachers can integrate these elements to design learning opportunities that will produce 21st century learners.

Figure 2.2: Elements of 21st Century Teaching



Beers (2011:8)

To be educated as a skilled learner for the 21st century, such a learner must master all three elements inside the triangle. Firstly, learners need to master the specific subject content. Secondly, it is important that reading, writing and arithmetic (the three R's) with processing skills must be instilled in the content subject. Lastly, the four C's, that are not new areas of focus, are considered to be critical thinking, communication, collaboration and creativity. Teachers should integrate these four C's into the subject content (Foltos, 2013:2-3). In a world where information flows rapidly to a worldwide audience, communication and collaboration is vital. Learners need to be guided by the teacher to take responsiblitiy for their learning. They need to know how to identify a problem, pose questions as they search for possible solutions, analyse sources for reliability and accuracy and evalaute and select an approach to solve the problem. Creativity and critical thinking are of utmost importance in a global economy that rewards innovation and in which mundane tasks can be automated, but thinking cannot (Walsh & Sattes, 2011:106).

The four blocks outside the triangle are components that must be considered by teachers when teaching for the 21st century. The objective for teachers (in teaching a subject such as CAT) must be to produce learners who can express themselves using a variety of technologies. This should be coupled with creating a positive learning environment where learners take advantage of learning opportunities. In this way teachers will develop learners who are able to critically think when engaging with their own learning. In addition, such learners will develop personal skills, such as responsibility (Beers, 2011:9).

The promise of computational thinking is that it can improve problem solving and critical thinking by harnessing the power of computing (Falkner, Sooriamurthi & Michalewics, 2012:185-189). Learners will learn and practise new skills – computational thinking skills to take full advantage of the innovative changes that the rapid changes in technology have brought about (ISTE, 2010:7). Perković and Settle (2010:1) state that computational thinking will have an influence on every person in every field of enterprise. Computational thinking enables a learner to see problems that in a new way.

Perković and Settle (2010:1) assert that the development of computer technologies and computer science has been largely motivated by a desire to support, extend and amplify the human intellect. In order to understand the different computer technologies it is important that there must be a clear understanding between Information Technology (IT) and CAT as subjects in the South African curriculum.

2.3 INFORMATION TECHNOLOGY AND COMPUTER APPLICATIONS TECHNOLOGY

It is important that a clear differentiation must be made between Information Technology, the discipline, and Information Technology as a school subject in the South African school curriculum. It is also important to highlight the difference between IT and CAT as school subjects in the South African school curriculum.

2.3.1 Information Technology as a discipline

IT as a discipline seeks to understand and explore the world around learners, both natural and artificial, in computational terms. IT is particularly, but not exclusively, concerned with the study, design and implementation of computer systems, and understanding the principles underlying these designs (Computing at School Workgroup, 2012:3-4). Aksoy and DeNardis (2008:8) define IT as systems of hardware and/or software that capture, process, exchange, store and/or present information using electrical, magnetic, and/or electromagnetic energy. According to Baldauf and Stair (2011:27), the term IT may be defined as issues related to the components of a computer-based information system.

2.3.2 Information Technology as a school subject

IT as a school subject is described as the study of the various interrelated physical and non-physical technologies used for capturing data, the processing of data into useful information and the management, presentation and dissemination of data (DBE, 2011b:8). Consequently IT studies the activities that deal with the solution of problems through logical and computational thinking. This includes the physical and non-physical components for the electronic transmission, access and manipulation of data and information.

2.3.3 Computer Applications Technology as a school subject

CAT was introduced in 2006 as a new FET school subject in the South African school curriculum. DBE (2011a:8) states that CAT deals with the purposeful application of computer systems to solve real-world problems, including issues such as the identification of business needs, the specification and installation of hardware and software and the evaluation of usability. CAT is thus the productive, creative and explorative use of technology. CAT as a school subject is seen as a subset of the broader knowledge domain of information and communication technologies (ICTs), where ICTs are the combination of networks, hardware and software as well as the means of communication, collaboration and engagement that enable the processing, management and exchange of data, information and knowledge.

By definition, CAT as a school subject is the study of the integrated components of a computer system (hardware and software) and the practical techniques for their efficient use and application to solve everyday problems. The solutions to problems are designed, managed and processed via end-user applications and communicated by using appropriate information and communication technologies (ICTs) (DBE, 2011a:56). IT and CAT are complementary subjects. IT teaches a learner how to be an effective *author* of computational tools (i.e. software), while CAT teaches how to be a thoughtful *user* of those tools with computational thinking in mind. Both these subjects deal with computing and computation and therefore the next section will define these very important concepts in greater detail.

2.4 DEFINING COMPUTING AND COMPUTATION

For the sake of clarity it is important that there is a clear understanding of computing and computation.

2.4.1 Computing

The meaning of computing depends on the context in which it is used. Computing may be defined as any goal-oriented activity requiring, benefiting from or creating computers. Computing is any activity of a technical nature involving computers (Computing Curricula, 2005:9-10). Computing is about problem solving and about applying computing technologies to improve human existence (Hoganson, 2008:5).

Computing is the study of information processes that use technology. Denning (2007:15) analysed the many computing technologies and identified seven principles on which computing are based, namely computation, communication, co-ordination, recollection, automation, evaluation and design. These principles interact with the fields of physical, life and social sciences, as well as with computing technology itself. Not one of the mentioned domains (physical, life and social sciences) are fundamentally concerned with the nature of the information processes and their transformation, although computing knowledge is essential in these domains (Denning, 2010:371).

For Isbell, Stein, Cutler, Forbes, Fraser, Impagliazzo, Proulx, Russ, Thomas and Xun (2009:198) computing as a subject uses different models, languages and machines to represent and generate processes. Learners live in a digitised, computerised world and as such they should have a basic understanding of the underlying algorithms of, for example, bidding on an eBay auction, as well as the security and privacy issues that arise when information is transmitted and stored digitally. These are computing issues (Computing at School, 2014). Computing as a discipline explores foundational principles and ideas (such as techniques for searching the Web), rather than a particular computer program, although it may use the latter to illuminate the former.

The common theme running through these statements of what computing is, either implicitly or explicitly, is that computing comprises transformation of information or alternatively information processing (Rosenbloom, 2013:8).

The DBE (2011a:10) states in the CAPS document that learners should understand the concept of ICTs with regard to technologies that comprise a computing system. In the context of CAT as a school subject, computing is therefore the required skill to be able to do computation as discussed in the next section.

2.4.2 Computation

Computation is a broad term that encompasses different tasks, concepts and techniques.

An historical view on the word computation is given by Denning and Wegner (2010:1). In the 1930s computation was the action of people who operated calculator machines. By the late 1940s computation was steps carried out by automated computers to produce definite outputs. Ultimately computation is those actions of an agent carrying out computational steps. When learners take the subject CAT, the agent will be the computer that the learners use in class.

Computation may be defined as the execution of a process; when a computer runs a program, reads input data and goes through a sequence of intermediate states until a final, goal state is reached. Computation is thus a name for what a computer can do (Stuart, 2013:15).

Computation is consequently a transformation or function applied to information (Bajcsy, 2010:1), and therefore a process and not thinking as such (Egnor, 2011). Crnkovic (2010:38) agrees with this by defining computation as any kind of information processing. This includes processes such as human reasoning and any calculations that are performed by a computing device such as a computer or any other electronic device. In CAT it can therefore be said that computational thinking means the carrying out of a process that a learner must follow to get to a solution to a specific problem.

Computing and computation are combined to derive at the words computational thinking (Tiensuu, 2012:36). According to Tiensuu (2012:36), computing sets the objectives for thinking (a direction). The encountered influences (knowledge, problem-solving situations, tools, experiences and similar terms), together with the objectives, affect thinking and shape the computational thinker. The word “computational” in “computational thinking” refers to the outcomes, not to the thinking process itself.

To take advantage of these revolutionary changes that are brought about by the rapid change in technology, teachers must ensure that learners learn and practise new skills such as computational thinking skills (Syslo & Kwiatkowska, 2008:5-8). The next section investigates computational thinking.

2.5 COMPUTATIONAL THINKING

Jeanette Wing named the intellectual and reasoning skill set ‘computational thinking’ in 2006 (Perković & Settle, 2010:123). The DBE (2011a:23) affirms that teaching and learning in CAT must be done along the *“paradigm of computational thinking”*. As computational thinking is a relatively new concept and currently has no exact definition, it is important for the researcher to try to define the concept of computational thinking within the context of CAT.

2.5.1 Defining computational thinking

The term computational thinking was introduced in 2006 (Wing, 2006:33) by Jeanette Wing when she defined the term as:

> *"Computational thinking is a fundamental skill for everybody, not just for computer scientists. To reading, writing, and arithmetic, we should add computational thinking to every child's analytic ability."*

Computational thinking is how learners think about solving problems; it is not an attempt to get learners to think like computers. Computational thinking is the thinking process that is involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent (computer) (Wing, 2006:33). Computational thinking is thus a set way of thinking that will assist a learner to solve a problem in a systematic and logical way. The method used can then be abstracted and applied to more than one problem (Bridge, 2013).

Computational thinking is similarly perceived by stating that computational thinking integrates the power of human thinking with the capabilities of computers (Phillips, 2009). The essence of computational thinking is therefore thinking about data and ideas, and using and combining these resources to solve problems.

Computational thinking is the description and the promotion of new ways of thinking in an increasingly digital age. The Committee for the Workshops on Computational Thinking (2010:11) points out that a computational thinker must constantly engage in technology advancements. Computational thinkers must be able to find the appropriate technology for a problem and be able to apply the technology to solve that problem.

The International Society for Technology in Education (ISTE) (2011:13) developed in conjunction with the Computer Science Teacher Association, United States of America, an operational definition of computational thinking. Computational thinking is therefore problem-solving process that embraces, but are not limited to, the following characteristics:

- Formulating problems in a way that enables learners to use a computer and other tools to assist in solving the problem.
- Logically organising and analysing data.
- Representing data through abstractions such as models and simulations. This is the ability to filter out information that is unnecessary to solve a certain type of problem and generalise the information that is necessary. Pattern generalisation and abstraction allows learners to represent an idea or a process in general terms (e.g., variables) so that they can use it to solve other problems that are similar in nature.
- Automating solutions through algorithmic thinking is the ability to develop a step-by-step strategy for solving a problem. Algorithm design is often based on the decomposition of a problem and the identification of patterns that help to solve the problem.
- Identifying, analysing and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources.
- Generalising and transferring this problem-solving process to a wide variety of problems.

Computational thinking is a way of solving problems and is a cognitive or a thinking process. To flourish in the world of work, computational thinking has to be a fundamental part of the way learners think and understand the world. It describes the mental activity in formulating a problem to allow a computational solution. The solution can be carried out by the learner or the computer or a combination of learner and computers. Computational thinking means creating and making use of different levels of abstraction to understand and solve problems more effectively. Thinking techniques that learners must have are problem representation, pattern recognition, pattern generalisation, algorithmic design and data analysis and visualisation (Selby & Woollard, 2014:4; Herring, 2012; Yeh, Xie & Ke, 2011:2; Soman, Manu Unni, Krishnan & Sowmya, 2012:1).

The researcher's opinion is that it is necessary to investigate whether teachers do teach CAT with computational thinking in mind. If learners are not taught how to think computationally, they will not be able to solve problems effectively.

Four criteria were identified that must be taken into consideration for a definition for computational thinking, namely, what are the skills that the learners must demonstrate?; what would computational thinking look like in the classroom?; what would a teacher need to put computational thinking into practice?; and what are teachers already doing that could be modified and extended? (Barr & Stephenson, 2011:52).

To create a definition for computational thinking in CAT (in the South African curriculum context), these four criteria must be investigated. Computational thinking skills will be investigated in the next section.

2.5.2 Computational thinking skills

Computational thinking is a collection of diverse skills that deal with problem solving that results from studying the nature of computation. Computational thinking may include some obviously important skills that most subjects help develop, such as creativity, ability to explain and team work (Computer Science for Fun, 2011). It also consists of some very specific problem-solving skills such as the ability to think logically, algorithmically and recursively. Computer Science is unique in the way it interlocks all these diverse skills. The current South African curriculum does not include Computer Science as a subject, but CAT and IT. These two school subjects are then ‘tasked’ to bring all these diverse skills together.

Yeh *et al*. (2011:1) describe some characteristics of computational thinking to illustrate the skill sets involved in computational thinking:

- Automation of abstractions: Computational thinking focuses on the ability to manage complex situations by generating abstractions and maintaining the relationships among them. An algorithm is an abstraction of a step-by-step procedure for taking input and producing some desired output (Wing, 2008:3718). In the context of CAT, it means breaking down a problem (PAT/spreadsheet/database) into concrete questions and then finding the answers with the aid of ICTs.
- Precise representations: To generate abstractions, learners need to have formal

representations that reflect their cognitive processes and structures (discerning aspects of the situation).

- Systematic analysis: This characteristic of computational thinking will enable learners to generate hypotheses and systematically search for a plausible solution.
- Repetitive refinements: During problem solving, learners consistently evaluate the current situation against their previous experience or their prediction until the best solution is reached.

To reach the aims that are set in the CAT CAPS document, teachers must ensure that CAT learners in Grades 10 – 12 become computational thinkers. Learners must have an understanding of how to use ICT and digital tools to solve problems. The next section will therefore elucidate why computational thinking is important in CAT.

2.5.3 Why computational thinking?

The essence of computational thinking is thinking about data and ideas, and using and combining resources to solve problems (Phillips, 2009:1). Teachers can encourage learners to “think computationally” by moving technology projects beyond “using” tools and information toward “creating” tools and information. Computational thinking provides the intellectual tools to assist learners in managing information. These tools require procedural thinking (National Research Council of National Academies, 2010:41).

Computational thinking develops a variety of skills (logic, creativity, algorithmic thinking, modelling/simulations), involves the use of scientific methodologies, and helps develop both creativity and original thinking. The best way to learn this important skill is through experience, interactions and managing information with intellectual tools in the classroom (Einhorn, 2012:2). In the CAPS (DBE, 2011a:26) it is stated that though teaching and practising the mechanical or technical skills and functions of applications are important for the learner to become familiar with the tool that he or she uses, it is important to do so within the paradigm of computational thinking. To acquire these skills in CAT, learners utilise different application programs (such as spreadsheets, database and HTML) to find solutions to given problems.

Yeh *et al.* (2011:1) pronounce that modern technologies are so pervasive that mere computer literacy is no longer enough. Computational thinking assists learners to develop analytical skills and problem abstractions that help them solve problems. For instance, learners who use word processors should know that text content is separated from its format so that they can control any portion without affecting others; learners who use databases should know how data is processed behind the scenes so that they could better manipulate data without violating rules. Computational thinking means generating and making use of different levels of ideas to comprehend and solve problems more effectively (Moursond, 2010).

To further clarify computational thinking, it is obvious that teachers must have a clear understanding of what computational thinking is not – this will enable them to ensure that learners are taught computational thinking skills in the classroom.

2.5.4 What computational thinking is not

Computational thinking is not computer literacy. Committee for the Workshops on Computational Thinking (2010:20-21) argues that computer literacy, traditionally seen as the ability to use specific programs or features of given computer systems such as word processing or spreadsheets, does not demonstrate the ability of a learner to engage in computational thinking.

Computational thinking is neither equivalent to computer science nor programming. Computational thinking is not fluency with information technology (FIT). FIT learners need three kinds of knowledge, such as contemporary skills (ability to use computer applications), foundational concepts (basic principles of computers, networks and information) and intellectual capabilities (the ability to apply information technology in complex situations) (Syslo & Kwiatkowska, 2008:6).

FIT is the capability to learn and use new technology as it evolves. Many of the features often ascribed to computational thinking are also part of FIT, including concepts and capabilities. The primary difference between FIT and computational thinking is that FIT includes skills components, which are designed to enable individuals to use common current applications such as Word, Excel and Access. By contrast, computational thinking tends to put less emphasis on specific technical skills in favour of broad problem-solving skills. This implies that CAT teachers do not always need to specify which function or formula to use in a specific spreadsheet assignment, but leave room for learners to decide for themselves which formula or function would be appropriate to solve a specific problem (Committee for the Workshops on Computational Thinking, 2010:20-21).

2.5.5 Computers and computational thinking

Computational thinking means integrating the power of human thinking with the capabilities of computers[ii], and it is a required skill for 21st century success (CSTA, 2005). A computer is therefore a critical aspect of computational thinking to the extent that it is an instrument that can deterministically understand a set of instructions in a clear-cut manner.

Information technology has advanced dramatically throughout its history and rapid change is likely to characterise future information technology (Committee for the Workshops on Computational Thinking, 2010:28). It is therefore important that a computational thinker must be able to use modern information technology to solve problems and to conduct other useful applications. From this perspective computational thinking involves finding the relevant technology for a problem and applying the technology to resolve that problem.

This might require learning how to use the appropriate technology, debugging the solution and communicating the outcome. In this view computers and other computational devices enable computational thinking.

[ii] Morley and Parker (2011:I4) defines a computer as a programmable, electronic device that accepts data input, performs processing operations on that data, and outputs and stores the results.

2.6 COMPUTATIONAL THINKING AND LEARNING

The following section discusses how computational thinking and learning takes place. This section will investigate constructivism as a paradigm for teaching and learning, mindtools as cognitive tools, computational thinking and higher-order thinking skills.

2.6.1 Constructivism as a paradigm for teaching and learning

Jonassen's constructivist learning environments is a learning model used to design constructivist learning environments. In the digital age, these environments are typically (and often) technology-enabled. Jonassen proposes a model for developing a suitable interactive environment through the use of authentic problems which can take one of several forms from the simple to complex. According to Jonassen, learners should be presented with interesting, relevant and meaningful tasks and activities in order to trigger learning (Moallen, 2001:120). Activities in the learning environment should promote exploration, experimentation, construction, collaboration and reflection. This co-incides with activities that promote computational thinking (cf. 2.5).

Additionally constructivism is not a theory of teaching, it suggest taking a radically different approach to teaching form what is used in most schools. A constructivist view of learning suggest an approach to teaching that give learners the opportunity for concrete contextually meaningful experience through which they can search for patterns, raise questions; and model, interpret and defend their strategies and ideas. The constructivist classroom is seen as a mini-society, a community of learners engaged in activity, discourse, interpretation, justification and reflection (Fosnot, 2005:158). Likewise Barajas (2003:21-22) states that a dominant characteristic of construtivist learning is a collaboration among learners. Learners construct meaning from their experiennces through communication with other (learners or teacher). A constructivism learning environment is thus then advantageous for computational thinking and problem solving (cf. 2.8.1; 2.8.3.1.5 and 3.9.1.1).

Fosnot (2005:158) warns that a misunderstanding regarding constructivism is that teachers should never tell learner anything directly, but instead, should always allow them to construct knowledge for themselves. Constructivism assumes that all knowledge is constructed from previous knowledge (e.g. Grade 11 knowledge is constructed from Grade 10 knowledge), regardless of how the learner is taught. Even listening to a teacher involves active attempts to construct new knowledge.

Futhermore, Yevdokimov and Passmore (2008:329) are of the opinion that the main activity in a constructivist classroom is solving problems. As stated paragraph 2.5.1 computational thinking is a way of solving problems. Learners ask questions, investigate a topic, and use a variety of resources (such as the Internet) to find solutions and answers. As learners explore the topic, they draw conclusions, and, as exploration continues, they revisit those conclusions. Exploration of questions leads to more questions. In the classroom, the constructivist view of learning can point towards a number of differentteaching practices. In the CAT classroom the teacher must encourage the learners to use real-world problem solving to create more knowledge and then to reflect on and talk about what they are doing and how their understanding is changing.

Once learners have mastered the computational thinking skill, they can use it in their normal learning. Computational thinking therefore places the computer as a tool to aid the development of thinking processes. Solvie and Kloek (2007:9-10) state that a central assumption of constructivism is that learning is mediated by tools and signs.

However, by focusing on the learner, the role of technology can support new understandings and capabilities, thus, offering a cognitive tool to support cognitive and metacognitive processes. Cognitive tools, along with constructivist learning environments, guide and activate cognitive learning strategies and critical thinking (Conole, 2012b:258). Furthermore, cognitive tools help in knowledge construction and not knowledge reproduction. The knowledge constructed by the learners reflects their comprehension and conception of the information. To illustrate, when learners build knowledge bases with databases, they need to analyse the content domain and engage in critical thinking.

2.6.2 Computational thinking as a cognitive tool

Any tool that can support aspects of a learner's cognitive processes is referred to as a cognitive tool (Laru, 2012:19). Cognitive tools are applications such as calculators, databases, spreadsheets, communications software, semantic network tools and knowledge construction tools. The quality of cognitive tools is not in the information and knowledge that they carry, but in the forms of learner activity and engagement that they support and encourage (Koç, 2005:5).

A computer as a cognitive tool offers the learner an intellectual partnership. The execution of an intellectual task (problem) is shared between the learner and the computer. The computer carries out the lower level computational and graphic operations, thus allowing the user to create links and draw conclusions. The computer as a cognitive tool is thus useful when it promotes and cultivates thinking (Solomon, 2012:181).

Cognitive tools are defined by Iiyoshi, Hannafin and Wang (2005:282) as both mental and computational devices that scaffold the cognitive processes associated with learning or performing. These tools can reinforce cognitive functioning, facilitate the creation of personal knowledge and scaffold the performance of meaningful, complex and authentic tasks. The functions and the effectiveness of cognitive tools depend on why and how learners use these tools.

As illustrated in *Table 2.1* below, cognitive tools support five functions in learner-centred learning environments, namely information seeking, information presentation, knowledge organisation, knowledge integration and knowledge generation.

Table 2.1: Functional cognitive tool classification, roles and examples

Classification	Roles of tools	Examples
Information seeking	1. Support learners as they attempt to identify, locate and retrieve relevant information. 2. Enable multiple ways of information seeking. 3. Address various learner attributes.	Keyword search tools - Google Special purpose searching.
Information presentation	1. Support learners as they attempt to present the information that they encounter. 2. Select relevant attributes and details while ignoring the irrelevant. 3. Select information that enhances interpretation. 4. Assist in providing varied representations of information.	Visualisation tools. Textual or conceptual map.
Knowledge organisation	1. Support learners to establish conceptual relationships in to-be-learned information. 2. Assist learners in tentatively structuring (or restructuring) information and manipulation representations and relationships. 3. Simplify the organisation processes and eliminate unnecessary task complexity. 4. Support learners' metacognitive abilities to manipulate information.	Linking tools Notebook tools Outline processor
Knowledge integration	1. Support learners in connecting the new with existing knowledge and the testing of presumed relationships between them. 2. Facilitate the processing of content at deeper levels. 3. Address various learner characteristics and their learning needs.	Simulation tools Knowledge mapping tools Elaboration tools

Classification	Roles of tools	Examples
Knowledge generation	1. Mirror knowledge generation processes and strategies. 2. Support the manipulation and generation of knowledge. 3. Help learners to represent their newly generated knowledge flexibly and meaningfully.	Template tools Presentation generation tools

Iiyoshi *et al*. (2005:284)

Computers provide new and effective ways for learners to gather, analyse and present information, that will support them in acquiring facts and skills (Thorson, 2009:17–18). The Internet is the main tool for gathering information. Internet browsers (such as Internet Explorer, Modzilla Firefox), search engines (such as Bing, Google Chrome, Yahoo) and e-mail (such as Microsoft Outlook, Gmail, Yahoo) are all tools that learners can use to gather information and communicate, but they need to know more than just how to get the information - they must know what to do with the information. Learners need the necessary skills to determine whether information is fact or opinion. They also need to know how to cite information and they need to appreciate copyright issues (Lenburg, 2005:24).

Computer users frequently use applications such as database, spreadsheets, intentional search engines, visualisation tools, multimedia publishing tools, live conversation environments and computer conferences (Kirschner & Wopereis, 2003:108-109). Most of these applications have been developed as aids in the execution of work, or to make learners more productive, but apart from being a productivity tool, these same tools can be used as an intellectual partner that enhances the cognitive powers of human beings during thinking, problem solving and learning; in other words, these tools can be used as mindtools.

Computational thinking is not about getting human beings to think like computers, but rather about developing a full set of mental tools necessary to effectively use computing to solve complex problems (Wing, 2006:34). Lu and Fletcher (2009:2) assert that programming should not be essential in the teaching of computational thinking, and that the emphasis should be on understanding (and being able to manually perform) computational processes and not on their manifestations in particular programming languages.

Computational thinking should be a method of thinking about using the cognitive tools (National Research Council of National Academies, 2010:17). Many affordances[iii] are created through technology innovation such as mass communication through the creation of the printing press, radio, television and the Internet. Information technology and the computer are a set of new tools with possibilities of their own and understanding the possibilities depends on the education, training and the experience of the user, as well as on the design of the tool. Some tools, such as a word processor, require more formal training and skills to access the affordances they offer. Others, through their very design or through imitation, are simpler to manipulate and may not require formal training; examples might include telephones or video games.

Cognitive tools most probably assist the learner by extending mental functions and altering cognitive processing qualitatively (Iiyoshi *et al.,* 2005:291). They further state that cognitive tools assist through mindful manipulation. Providing learners with a variety of tools may be needed to support learners with different prior knowledge levels and different tool use skill levels, or a tool itself could guide learners to better usage so that the way that learners use the tool can progress gradually as they learn.

The complexity of effective information seeking is often belied by the simplicity of “point-and-click” responding (Iiyoshi *et al.,* 2005:285). Effective information seeking

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[iii] Affordances describe learning opportunities and actions for learners within ICT-rich learning environments. In the school environment, affordances are provided by the interaction between the software such as PowerPoint, the teacher and the learners. These affordances can therefore support certain types of teaching and learning actions (Wang & Woo, 2008:184 and Kinchen & Cabot, 2007:195).

involves recognising and interpreting the problem, establishing a plan for searching, conducting the search, evaluating the results, extracting and reorganising useful information and making preliminary and final judgements. Metacognitive abilities and prior expertise greatly influence such processes. Tool familiarity largely affects the success or failure of information seeking efforts. Factors that can influence information seeking activities are: gender, motivation, cognitive style, self-regulatory skills and epistemological beliefs (Henry, 2005).

Cognitive tools are technologies, tangible or intangible, that enhance the cognitive powers of human beings during thinking, problem solving and learning (Jonassen, 2000:693). As seen in *Table 2.2* cognitive tools can include (but are not necessarily limited to) database, spreadsheets, semantic networks/concept maps, expert systems, multimedia or hypermedia construction software, computer-based conferencing, collaborative knowledge construction environments, computer programming languages (not applicable in CAT) and Microworlds[iv] (not applicable in CAT).

[iv] Microworlds is a program that uses the Logo programming language. It uses a turtle object which can be moved around, given commands and eventually make shapes or even an animation (Garnett, 2010).

Table 2.2: Classification, roles and examples of cognitive tools

Classification	Roles of Tools	Examples
Database	• Are useful for enhancing the learning of concept-rich content, such as the theory in CAT. • Support the storage and retrieval of information in an organised manner; structure is inherent in all knowledge, so using a database that helps learners to structure what they know will facilitate understanding.	Database management systems (DBMSs) such as MS Access.
Spreadsheets	• Are computerised, numeric record-keeping systems. • Qualitatively change educational processes that require manipulation or speculation with numbers and are easy to adapt and modify. • Support speculation, decision making and problem solving. • Useful tools that are most effective in solving quantitative problems. • Three primary functions: storing, calculating and presenting information.	MS Excel

Classification	Roles of Tools	Examples
Expert systems	• A computer application that performs a task that would otherwise be performed by a human expert (Heathcote, 2001:228).	Not applicable in CAT. Artificial intelligence applications.
Multimedia/hypermedia construction software	• Multimedia involves the integration of words and pictures of more than one medium into a form of communication (Mayer, 2009:3). • Web pages, Hypermedia, and PowerPoint are examples of powerful software programs that enable teachers and/or learners to create dynamic multi-sensory presentations. • Learners are much more mentally engaged by developing materials than by studying materials. • Multimedia allows for the creating of real representations of abstract ideas - learners are actively engaged in creating representations of their own understanding by using their own ways of expression. By doing this, learning becomes less teacher-centred and more learner-centred and therefore develop critical theories of knowledge.	Web pages, Hyper-media and PowerPoint.
Computer-based conferencing	• Support learners to construct their knowledge	e-mail, bulletin board service, discussion board

Classification	Roles of Tools	Examples
Collaborative knowledge construction environments	• Encourage learners to engage in knowledge construction. Learners work together to elaborate on concept by constructing arguments and counter arguments (Weingberger, Stegmann, Fischer & Mandl, 2007:193-195). • Knowledge within a specific domain is acquired.	Class discussions

Jonassen (2000:693)

Cognitive tools are unintelligent tools, relying on the learner, not the computer, to provide the intelligence (Jonassen, 2000:697). This means that planning, decision making, and self-regulation are the responsibility of the learner, not the technology. Cognitive tools can thus serve as powerful catalysts for facilitating these skills, assuming that they are used in ways that promote reflection, discussion and collaborative problem solving. This coincides with the thinking of Phillips (2009) and Wing (2006:1) that computational thinking is the integration of human thinking with the capabilities of computers.

2.6.3 Using mindtools as cognitive tools

Johnson, Musial and Johnson (2009:248) state that the concept of mindtools originated with educational psychologist, Gavriel Salomon. Jonassen has elaborated on this concept and defines mindtools as:

> *"Cognitive application and reorganisation tools …, generalizable computer tools that are intended to engage and facilitate cognitive processing – hence cognitive tools …, critical thinking devices …, intellectual partners."*

The use of the mindtools concept aligns well with the 21st century skills concepts with their focus on active, constructive, intentional, authentic and collaborative mindful thinking (Spector, Lockee, Smaldino & Herring, 2013:6). Mindtools represent a constructivist use of technology. Constructivism is concerned with the process of how we construct knowledge (Spears, 2009:133). When learners work with computer technologies, instead of being controlled by the computers, they enhance the capabilities of the computer, and the computer enhances their thinking and learning. The result of an intellectual partnership with the computer is that the whole of the learning becomes greater than the sums of its parts. Computers do not control the learning; rather, computers are used as a tool that helps learners to build knowledge (Lajoie & Derry, 2013:182–184).

Mindtools may be described as computer applications that, when used by learners to represent what they know, necessarily engage them in critical thinking about the content that they are studying. In other words, mindtools require learners to think about what they know in different, meaningful ways (Cinnamon, Ross & Ertmer, 2010:81).

Mindtools modify computer applications to embrace learners in critical thinking (Spears, 2009:122). The use of mindtools in education and therefore specifically in CAT will help learners to represent what they know as they transform information into knowledge and the use of mindtools assist learners to engage in and facilitate, critical thinking and higher-order learning (Kirschner & Wopereis, 2003:105). Mindtools are critical thinking devices which help learners to think for themselves, to make connections between concepts and to create knew knowledge. Mindtools are also intellectual partners – as a partner they are responsible for that which they can perform best. Computers should calculate, store and retrieve information, while the learner should be responsible for recognising and judging patterns of information and their organisation (Kirschner & Wopereis, 2003:110).

Mindtools can be inclusive of the following: semantic organisation tools, modelling tools, information interpretation tools, knowledge construction tools and conversation and collaboration tools (Spears, 2009:122). These tools are thus selected computer programs that stimulate learning and thinking in learners. In CAT teachers must teach learners how to use end-user application programs to stimulate their learning and thinking.

It is thus important that teachers use mindtools as cognitive tools to facilitate learners' computational thinking skills. Once learners have mastered this skill, they will be able to transfer it to their normal learning.

2.6.4 Computational thinking and higher-order thinking skills

When learners encounter unfamiliar problems, uncertainties or questions, higher-order thinking skills such as critical, analytical, thoughtful, metacognitive, and creative thinking are activated (Mainali, 2012:5). To understand computational thinking and how a teacher can teach computational thinking to a learner, it is necessary to analyse the information processing analysis of computational thinking, cognitive structures of computational thinking and the metacognitive structures of computational thinking. These are explained in the next paragraphs.

2.6.4.1 Information-processing of computational thinking

Information processing analysis traces the sequence of mental operations and their products in the performance of a particular cognitive task. Information-processing analysis of computational thinking involves the following processes: identifying a task and collecting as much information about the task and its contents as possible; stating the goal in the form of a representative question; and decomposing the problem into subproblems (Voskoglou & Buckley, 2012:31).

2.6.4.2 Cognitive processess of computational thinking

Yadav (2011) states that computational thinking and cognitive processes can be divided as follows:

- Lower-level processes: using basic facts and skills.
- Higher-level processes: performing a complex operation with the relevant information.

Effective applications of the skills result in explanations, decisions, performances and products that are valid within the context of accessible knowledge and experience, promoting the continued growth in these and other intellectual skills. Higher-order thinking skills are grounded in lower-order skills such as discriminations, simple application and analysis, cognitive strategies, and are linked to prior knowledge of subject matter content. Suitable teaching approaches and learning environments enable their growth as do learner persistence, self-monitoring and open-minded, flexible attitudes. King, Goodson and Rhohani (no date:2) further state that psychological research suggests that skills taught in one domain can be generalised to others. Over long periods of time, learners develop higher-order skills (intellectual abilities) that apply to the solutions of a broad spectrum of complex problems. A learner’s task performance will be influenced by his or her content knowledge, discourse and strategies (Cheng, Annetta & Vallett, 2012:146).

Task performance is highly influenced by content or domain knowledge. Domain knowledge is defined as declarative, procedural and conditional knowledge. Declarative knowledge is the factual information that a learner knows; it can be declared, either in speech or in writing (Peirce, 2004).

Procedural knowledge (knowing how) is defined by Voutsina (2011:194) as knowledge which enables the application of rules, algorithms and procedures for solving problems and the use of spreadsheet functions such as the IF-function (Avram, 2007:44). Procedural knowledge is what enables a learner to use application software such as word processors or spreadsheet programs (Antonitsch, 2013:35). Cheng *et al.* (2012:146) suggest that procedural knowledge is the knowledge of how to do something, of how to perform the steps in a process – such as how to do a troubleshooting process – thus it is computational thinking. Gibson (2008:8) maintains that problem solving within technology, however, is an important component of procedural knowledge. He further states that there is a close link between problem solving and conceptual knowledge; there is therefore a close link between computational thinking and problem solving. Gibson (2008:8) also states that problem solving is context-dependent or domain-specific and therefore cannot be applied in a universal manner. Learners involved in one situation will not necessarily have the required knowledge and understanding to enable them to solve problems in other areas.

Conditional knowledge is knowledge about when to use a procedure, skill or strategy and when not to use it; why a procedure works and under what conditions; and why one procedure is better than another (Peirce, 2004). The quality and quantity of domain specific knowledge is essential to initiate effective learning with computational thinking (Cheng *et al*., 2012:146).

2.6.4.3 Metacognitive structures of computational thinking

Metacognition means being aware of the thought process: of how learners think, plan and remember (Efklides & Misialidi, 2010:371). For the constructivist, metacognition is an important concept, because through using it, learners can actively engage with their own thinking at a higher level. Teachers can help improve learners' metacognitive abilities by ensuring that learners possess three kinds of content or domain knowledge (Peirce, 2004).

To instill computational thinking in learners, teachers need to develop learners in a certain manner through guidance. The next section investigates computational thinking and learners.

2.7 COMPUTATIONAL THINKING LEARNERS

If CAT is to be used as a vehicle in the South African school curriculum to teach learners computational thinking, teachers must understand how learners will learn computational thinking.

2.7.1 How learners learn computational thinking

Computational thinking influences all fields and not just CAT, such as life sciences, physical science, linguistics, economics and statistics. It allows learners to solve problems, design systems and understand the power and limits of human and machine intelligence. It is a skill that empowers, and that all learners should be aware of and have some competence in (Syslo & Kwiatkowska, 2008:6). It is therefore important that teachers know how learners learn computational thinking. Computing at School Workgroup (2012:3) maintains that learners studying computing gain insight into computational systems of all kinds, whether they include computers or not.

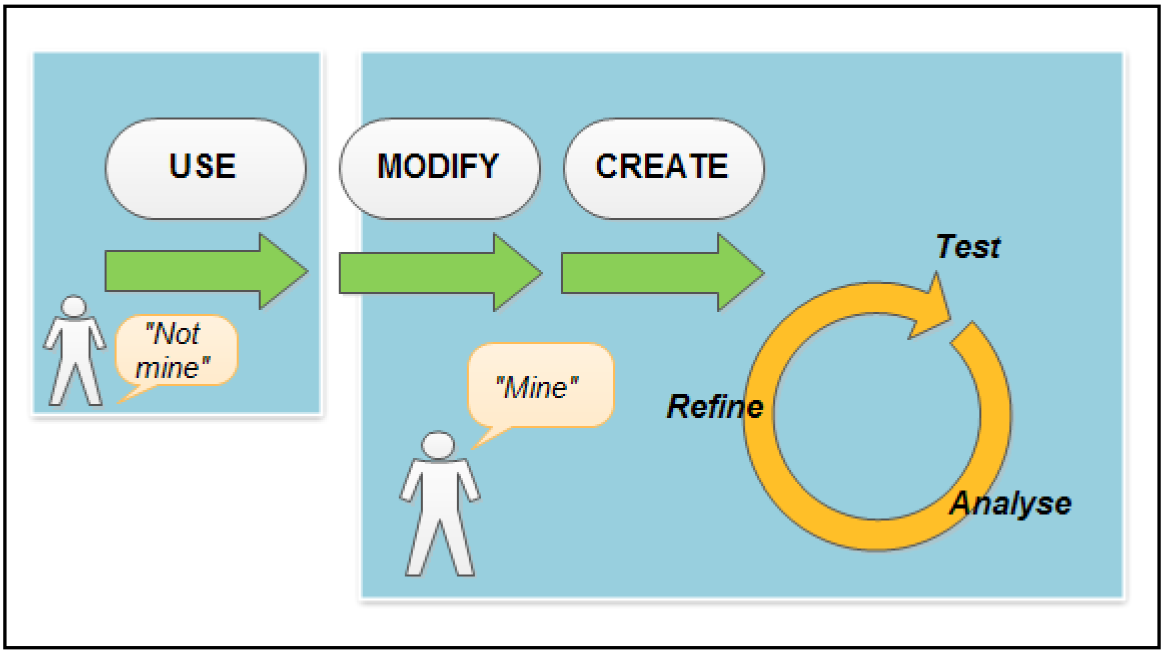
Furthermore, learners who can think computationally are better able to conceptualise and understand computer-based technology, and so are better equipped to function in modern society. Einhorn (2012:2) is of the opinion that computational thinking is a learned approach and that there is no better way to learn it than through programming. However, programming is not part of the CAT curriculum, and therefore learners must learn it in CAT through other means such as application software (word processing, spreadsheets and database).

Since the inception of computers, enhanced technological capabilities have provided increased opportunities for solving problems (Hoag, 2008:3). In the early days of computer solutions in mathematical problem solving, traditional programming languages were used. This process required specialised knowledge in program development. Today, electronic spreadsheets have replaced the need to rely on programming languages and have become the predominant method for application programming where end-users have become spreadsheet programmers. As stated earlier, programming does not form part of the curriculum of CAT, and therefore this research aims to prove that teachers can teach learners computational thinking to solve problems through other concepts than programming in CAT.

A sound understanding of computing concepts will help learners realise how to get the best from the systems they use, and how to solve problems when things go wrong (Computing at School Workgroup, 2012:4). Moreover, learners who can think in computational terms would be able to understand and rationally argue about issues involving computation, such as software patents, identity theft, genetic engineering, electronic voting systems for elections, and so on. In a world inundated by computation, every school-leaver should have an understanding of computing (Computing at School Workgroup, 2012:6).

Lee, Martin, Denner, Coulter, Allan, Erickson, Malyn-Smith and Werner (2011:35) argue that learners develop computational skills based on a three-part framework as shown in *Figure 2.3* on the next page. They believe that growth in computational thinking often begins with *using* rich computational environments. Over time these environments are *modified* with increasing levels of sophistication. As learners gain skills and confidence, they *create* computational models based on original designs. This implies that learners can maintain their sense of cognitive flow as they progress iteratively through a series of projects; in other words, learners will tackle increasingly more difficult tasks as their skills and capabilities increase. Activities or projects that were once too challenging for learners become probable with appropriate, increasingly mentally challenging experiences. However, there are no clean break points from using to modifying to creating. Learners may move back and forth between the different stages (Repenning & Ioannidou, 2008).

Figure 2.3: The use-modify-create framework



Lee *et al.* (2011:35)

USE: During this phase, learners learn how to use different interfaces and different tools; it may involve exploring different kinds of software. Work at this stage establishes the foundation for higher levels of engagement with computational thinking. Teachers will make use of the Grade 10 CAT curriculum to lay the foundation in computer usage, the different tools and the different packages such as MS Office Package and the Internet.

Example 1a: Computational thinking (Use)

Teachers will allow learners to work in a spreadsheet application – learners will do only what is required from them from the instructions. The spreadsheet model is given to learners and they just fill in the blank cells.

MODIFY: As learners become more comfortable in using the different tools, they will start to experiment more. In this phase, learners begin to understand how they can control underlying mechanisms to bring about different results, a skill that they will later use in making original creations.

Example 1b: Computational thinking (Modify)

During this phase teachers will gradually allow learners to start building their own spreadsheets with hints on how to create the spreadsheet, instead of giving step by step instructions. Learners are provided with some information, but not all.

CREATE: In this phase, learners apply their growing computational thinking skills to create a substantially original product such as the PAT. This work will show increasing levels of abstraction and automation than may have been present in an earlier exploratory experience. Implicit in the development, of course, is that the creation will be used and modified over time.

Example 1c: Computational thinking (Create)

Teachers expect from learners to create their own spreadsheet from a scenario and to do the necessary statistical analysis and information presentation.

If teachers want to enable learners to become computational thinkers, they must ensure that learners master and understand the following components: algorithms, programs (such as MS Office), data and information, computers and communication and the Internet (Computing at School Workgroup, 2012:13-19).

- **Algorithms**

An algorithm is a precise set of instructions to achieve some desired outcome (Bridge, 2013). Computational thinking, as well as procedural thinking, is fundamental in any computer and information science. A computer is a machine that automatically, rapidly and accurately carries out steps in certain types of procedures. These procedures are algorithmic – a step-by-step set of directions to achieve a specific outcome or a solution to a problem (Moursund & Ricketts, 2011).

When teaching learners algorithms, the understanding must be formed that algorithms are sets of instructions for achieving goals and that an algorithm is composed of pre-defined steps. Teaching basic algorithms does not necessarily require a classical programming environment. Algorithmic thinking can also be taught to learners in tasks which are wrapped in word processing or spreadsheets.

Learners think that they are creating a document and a table, but there is algorithmic thinking behind the process (Csernoch & Bujdosó, 2010:51). A list of different algorithms in CAT appears below:

Example 2

Teachers let learners do Internet searchers on definitions. The learner enters the word "define …" in the Google search engine, followed by the word that must be looked up.

The search engine will very rapidly provide the learner with some definitions or tell the learner that the word he or she wants to find a definition for is not in its dictionary. In this search engine approach, the learner's brain decides for what word he or she wants to find a definition. The brain directs the fingers to key the appropriate search information to the Google search engine. The learner reads the results, thinking about which of the definitions best fits his or her need. This provides a good example of computational thinking. Learners use their physical and mental capabilities, as well as their sense of purpose, to work with the capacities of the Web and the Google search engine to solve a problem (Cormen, 2003:6).

Example 3

When teaching spreadsheets, teachers explain how to use formulae and expressions with numbers, operators, cell references and functions.

Text processing in spreadsheets, such as strings operators like concatenate, can also be seen as an algorithm (Riley & Hunt, 2014:223–237).

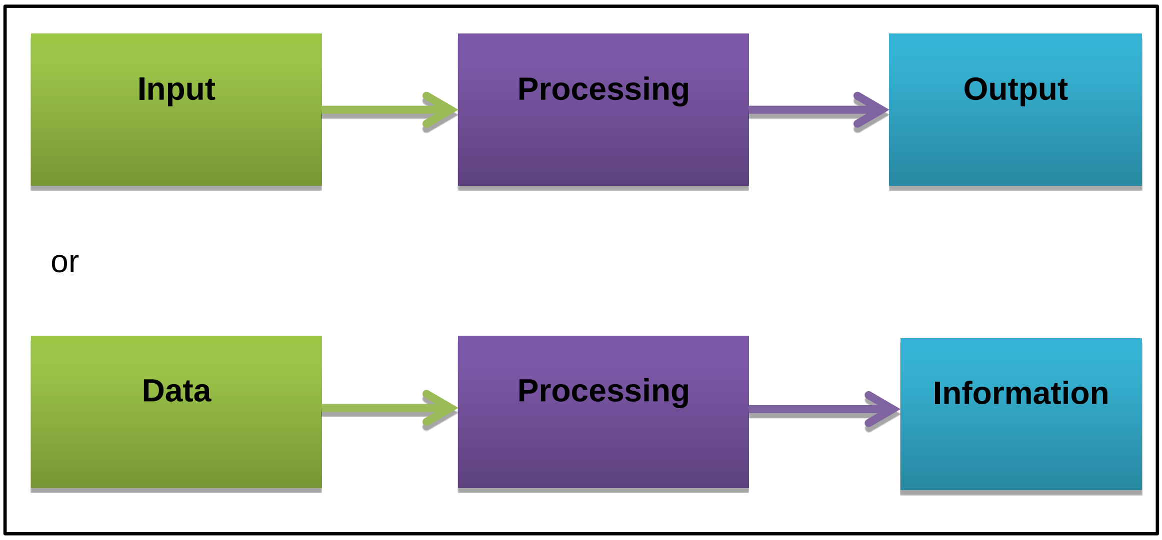
Example 4

Converting a table of a webpage to either a spreadsheet table or a word processing table.

From the examples provided (cf. 2.7.1), it is clear that algorithms can vary in complexity as affirmed by Eggen and Kauchak (2007:268).

Teachers must make learners aware that the algorithm for solving a computer-based problem comprises three steps or phases as shown in *Figure 2.4* (Cormen, 2003:5). What is available to the learners to solve the problem? What steps will they follow in their effort to solve the problem? What will the end result be?

Figure 2.4: Phases in solving an algorithm



Cormen (2003:5)

Each of these figures clearly indicates that for the learner to complete the algorithm he or she must receive data (input) that must be processed to render meaningful results (output or information).

In other words,

- Input is processed to render meaningful output.
- Data is processed to render meaningful information.

Example 5

The teacher provides learners with the following scenario: The manager of a company asks a learner to do some part-time work during the holidays for which he will be paid per hour. The learner will have to know how many hours he has to work, at what rate of pay, before he can calculate the final amount he will receive. In this case the input (data) to this algorithm will be the hours and the hourly rate of pay.

The input (data) must be processed to give the output (information), i.e. the amount the learner will receive.

- **Programs**[v]

The CAPS document (DBE, 2011a:12) states that for CAT, the programs (applications) that should be taught should include word processing, spreadsheet, database and presentation applications. Computing at School Workgroup (2012:13-19) maintains that a learner should know how to write executable programs in at least one language. The CAPS document (DBE, 2011a:12) asserts that learners should master HTML/Web design as a programming/coding language.

- **Data**[vi]

A learner inputs data into a computer, and then the computer processes the data. Any kind of fact or set of facts can become computer data. Words in a letter, numbers in a monthly budget, images in a photograph or the facts stored in an employee's record can be data. When data is processed into a meaningful form, it becomes information. Computing at School Workgroup (2012:13-19) states that structured data can be stored in tables with rows and columns. Data in tables can be sorted. Tables can be searched to answer questions. Searches can use one or more columns of the table. Data may contain errors and this will affect the search results and decisions based on the data. Errors may be reduced by using verification and validation. Teachers must ensure that learners can take data and use it meaningfully to present information.

- **Computers**

A computer is a programmable, electronic device that accepts data, performs operations on that data, presents the results and stores the data or results as needed (Morley & Parker, 2011:10). To these authors programmable means that a

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[v] Morley and Parker (2011:16) refer to programs as the software that is used to tell the computer hardware what to do.

computer will do whatever the instructions tell it to do. Computing at School Workgroup (2012:13-19) argues that a learner should know the main components that make up a computer system, and how they fit together (their architecture). The CAPS document (DBE, 2011a:13) refers to this as system technology[vii]. The components of the system are independent units which are designed to perform a particular function, including hardware, peripherals and software components are connected as a unit to perform the basic functions of a computing system, which include input, processing, output, storage, communication and transfer of data in an electronic format.

- **Communication and the Internet**

The CAPS document (DBE, 2011a:15) states that Internet technologies include the WWW and all interrelated processes in the digital presentation of multimedia data on a web page. Internet technologies are defined as a set of related and interconnected technologies that enable the establishment of global networks for various purposes such as collaboration, electronic data interchange, electronic commerce, electronic communication and social networking. For Computing at School Workgroup (2012:13-19) this means that a learner should understand the principles underlying how data is transported on the Internet.

Teachers can encourage critical thinking and thus teach learners to think computationally when they use the Internet. If teachers want learners to think critically, learners must be stimulated with questions that lead them to other questions and so on. The two factors that can influence a successful Internet search and learners' development of critical thinking are set out by Turturean (2012:3) as:

- Teachers must ensure that the learners' knowledge of Internet searching is comprehensive and that they have knowledge of a selection of different Internet resources and search strategies.
- Learners must be motivated, goal orientated in their learning and they must have

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[vi] Data is raw, unorganised facts (Morley & Parker, 2011:11).
[vii] Physical and non-physical components of a computer system (DBE, 2011a:13)

self-efficacy in the subject (in this case CAT) and the Internet. If teachers use the five components as discussed in the previous paragraphs, learners will derive great benefits from computational thinking.

2.7.2 Benefits of computational thinking to learners

Once teachers have successfully introduced computational thinking to learners' world of thinking, they are moved beyond technology literacy. Learners develop into problem solvers instead of software (application) users. Computational thinking encourages creativity and problem solving thus enhancing many of the problem-solving skills that learners possess (Yadav, 2011). Thus CAT learners will become problem solvers with the ability to use application software efficiently, if they become efficient computational thinkers.

Being able to think computationally implies that learners can think critically. Some of the benefits of critical thinking are the ability to transfer learned content to new applications and an improved understanding of their own thinking processes (Alwali, 2011).

2.8 TEACHING AND COMPUTATIONAL THINKING

If computational thinking is, indeed, a key to developing the capacity to discover, create and innovate, teachers need to understand computational thinking and how it connects to the CAT curriculum.

2.8.1 Teachers and computational thinking

Committee for the Workshops on Computational Thinking (CWCT) (2011:27) states that teachers who teach computational thinking need knowledge of the subject (content knowledge) and teaching skills when learners have to work together to solve problems. A primary challenge for computational thinking teachers is to ensure that the learner's interest is at the centre of problem posing. Teachers may very often feel that they have lost control over the learning process – especially if learners can work on their own – and may then become uncomfortable. Teachers therefore need skills to assist them in guiding individual learners; they must know the fundamentals of computational thinking and they must understand how to integrate computational thinking into teaching and learning. Teachers must use their knowledge of learner development, subject matter, instructional resources and teaching strategies to make subject matter accessible to all learners (UNESCO-IICBA, 2012:17-18).

Supporting learners engaging in self-directed[viii] collaborative learning processes requires an ability to diagnose difficulties and give tips rather than supplying solutions (CWCT, 2011:27). Designing effective assignments is a further challenge.

To be effective teachers must understand where learners are starting. Furthermore, teachers must determine the types of understandings that learners must have to be successful and to design new ideas or computational activities to provoke learners to engage in computational thinking (CWCT, 2011:27). Quinlan (2012) notes that learners in some cases may have more technical skills than their teachers in the area of using computers; teachers often find ways to make individual learners class “experts” on troubleshooting the operating system or accessing online materials to take advantage of available technical skills. Teachers therefore need professional development to become proficient in teaching computational thinking.

Allan, Coutler, Denner, Erickson, Lee, Malyn-Smith and Martin (2011), argue that to enable computational thinking in schools requires teachers to have a set of skills that is not currently taught in most teacher education programmes. Teachers simply need to be computational thinkers themselves to teach it effectively. Thus, providing in-service training is necessary but fraught with challenges. Fisher and Frey (2008:89) maintain that if teachers focus classroom activities on the learning of isolated facts, learners will believe that school learning is a process of absorbing information by memorisation and repeating it later. Teachers should instead focus class time and activities on doing things with information, such as applying information to new

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[viii] Knowles (1975:18) described self-directed learning broadly as “*a process in which individuals take the initiative, with or with out the help of other, to diagnose their learning needs, formulate learning goals, identify resources for learning, select and implement learning strategies, and evaluate learning outcomes*”.

situations, using information to solve problems. Only then will learners acquire the necessary cognitive process and skills that will serve them well in the world beyond the classroom.

If CAT teachers want to encourage computational thinking in the classroom they must ask different questions related to problem solving and the use of technology (Phillips, 2009). They must ask:

- What is the power and limit of human and computer intelligence?
- How difficult is the problem?
- How and with what technology can the problem be solved?
- Are there any computational strategies that can be employed?

Once CAT teachers understand their role in teaching computational thinking, they must understand and possess the knowledge of how to teach learners computational thinking skills.

2.8.2 How to teach computational thinking skills

It is not enough to provide learners with a computer or an iPad and leave them to their own devices (Burk, 2010), nor is it enough to train them to be literate in PowerPoint or how to be good users of information from the Internet. Learners must learn how to think computationally and algorithmically for them to fully understand what a computer can and cannot do, and learners must be able to instruct the computer to do so. Burk (2010) further states that thinking computationally is about learning when to use a computer so solve a problem; it is about identifying when and where computers will be useful to help solve a problem.

One essential computational thinking skill is function abstraction which computer scientists use directly and indirectly almost every day (Yeh *et al.,* 2011:2). The ability to use functions correctly and effectively requires several computational thinking skills such as data representation, data processing, abstraction and procedural thinking. CWCT (2010:11) defines procedural thinking as development and representation, testing and debugging procedures, and indicates that an effective procedure is a detailed step-by-step set of instructions that can be mechanically interpreted and carried out by a computer.

Based on the characteristics of computational thinking and the complexity levels of function learning, Yeh *et al.* (2011:3) are of the opinion that learning to use spreadsheet functions can be divided into three categories: recall, application and problem solving; teaching learners spreadsheets can thus be a tool in teaching computational thinking.

The recall category is rote memorisation of function definitions and arguments. This is the lowest level of learning in the cognitive domain in Bloom's taxonomy of learning hierarchy (Jacobs, Vakalisa & Gawe, 2011:80). In the application category, learners are presented with a set of data for which spreadsheet functions should be used to generate the right answers. In the problem-solving category, learners are asked to solve a problem scenarios using function(s) of their choice. The problem-solving category, hence, is uncued where the learners have to search in their knowledge repository for a set of suitable functions to generate an expected answer. Every category requires different levels of cognitive processes, which in turn can be facilitated by different instructional strategies. To teach the use of spreadsheet functions effectively, CAT teachers must understand the knowledge acquisition of all three categories and any underpinning problems when they experience trouble.

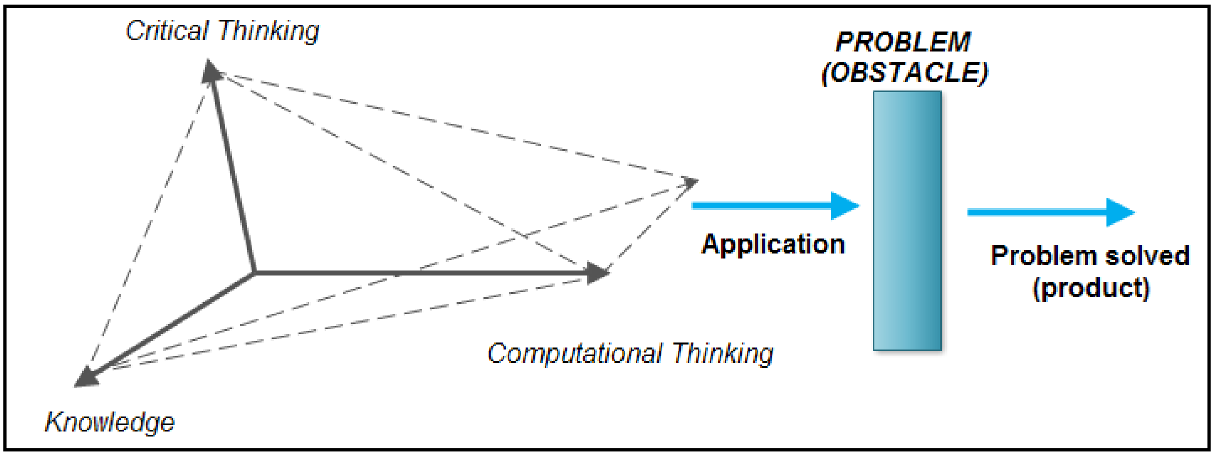
The application of computational thinking in teaching and learning means that learners (Yadav, 2011):

- Know how to solve problems by understanding the principles. An example of this in CAT can be that learners must know that information can be integrated from one application to another without "re-doing". When learners are taught mail merge, they should understand the principles so that they can do mail merge whether it is in a database, a spreadsheet or from an e-mail list.
- Are able to apply computational thinking as the automation of abstractions.
- Are able to analyse complex sets of data (especially in spreadsheets) and not just 10 lines of data. This will expose them to modelling and simulation.
- Are encouraged to build their own models and simulations. While completed

databases can be given to learners at the beginning of the learning process, as they progress they must be allowed to construct their own database from information given.

- Can use existing knowledge and skills to solve an unanswered question, problem solving has been mastered. In *Figure 2.5*, the process of problem solving with computational thinking is illustrated by Voskoglou and Buckley (2012:37). Learners may see a problem as an obstacle. To overcome this obstacle the connection between critical thinking and computational thinking is bridged by existing knowledge. Indeed, no real problem can be solved without an undisputed higher-order thinking skill such as a critical thinking, which leads any form of thinking skill in problem solving. If the problem is solved then the solution is the product of those cognitive actions. Computational thinking is applied when a learner solves the problem by combining existing knowledge with critical thinking (Voskoglou & Buckley (2012:37).

Figure 2.5: Problem-solving model



Voskoglou and Buckley (2012:37)

The next section examines how cognitive tools (mindtools) in the subject CAT can be used to teach learners the required computational thinking skills.

2.8.3 Use of cognitive tools (mindtools) in CAT to teach computational thinking skills

The CAT curriculum is divided into topics and sub-topics in the CAPS document (DBE, 2011a:9). *Table 2.3,* on the next page, shows the relevant topics and sub-topics:

Table 2.3: CAT curriculum topics and sub-topics

Topic	Sub-topic
Solution Development	Word processing Spreadsheets Database Fourth Application (HTML)
System Technologies	Concepts of Computing Hardware Software Computer Management
Network Technologies	PANs LANs and WLANs WANs
Internet Technologies and World Wide Web	E-communications
Information Management	Find and Access Data and Information Process Data and Information Present Solution
Social Implications	Impact on Society Legal and Ethical and Security Issues Health and Ergonomic Issues Environmental Issues

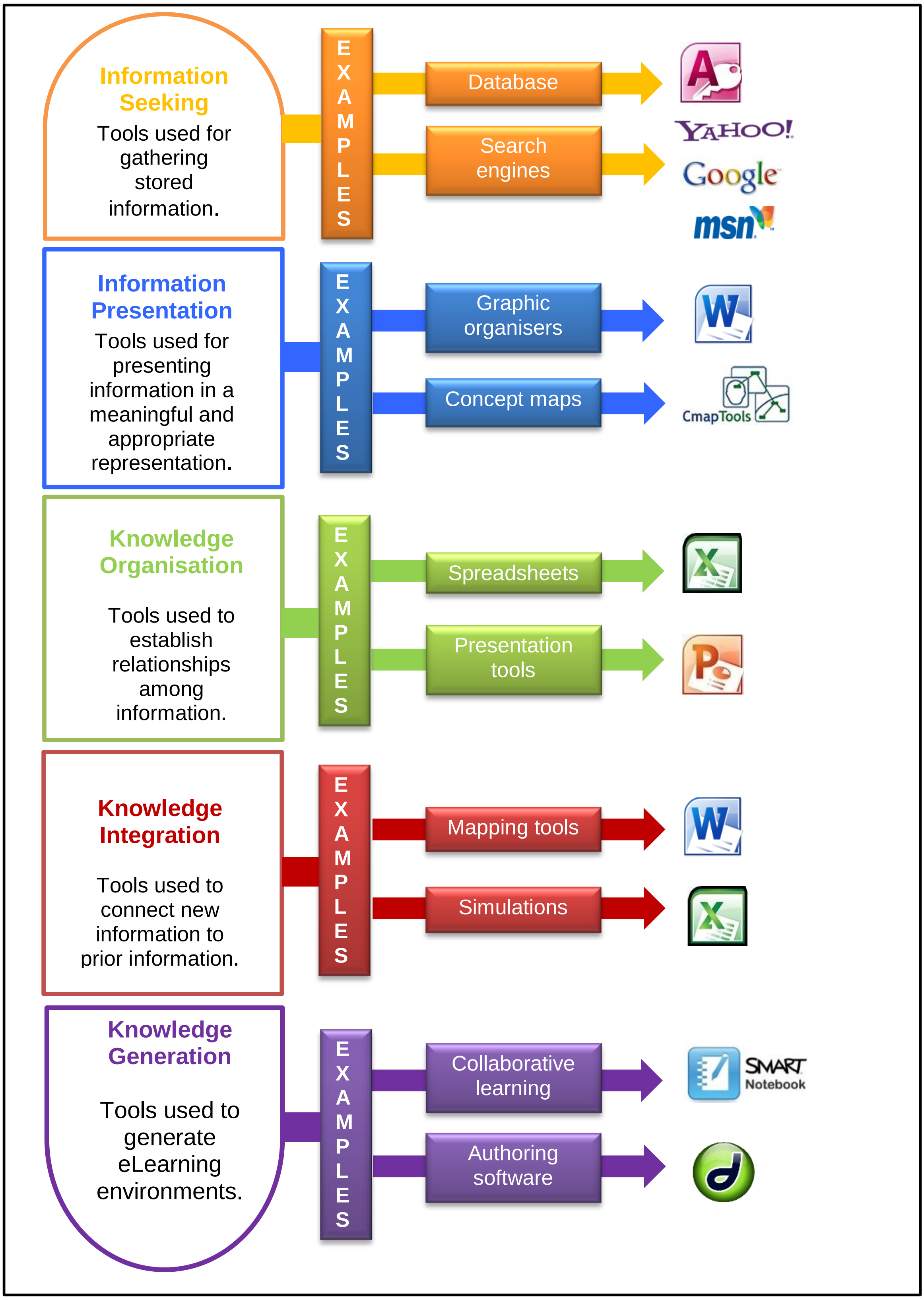
DBE (2011a:9)

One may deduce from the *Table 2.3* that Solution Development concentrates on the practical side of computing; Information Management concentrates on the PAT; the other topics are to give learners the necessary theoretical background on computers. It is the researcher's opinion that cognitive tools, as discussed in section 5, must be employed to teach these topics in computational thinking for learners to solve problems efficiently.

2.8.3.1 Cognitive tool affordance

As discussed earlier (cf. 2.6.2), cognitive tools (mindtools) have multiple roles**.** These roles allow learners to interact with information to acquire, synthesise, create and share new knowledge**.** By examining their roles, teachers can consider their implementation and impact on learners' learning. As indicated in *Figure 2.6,* on the next page, the researcher combined the different cognitive roles with different examples that link to the CAT curriculum. The researcher will discuss how each of these topics, with the aid of tools, can enhance computational thinking in learners.

Figure 2.6: Roles of cognitive tools, examples and specific technologies



Adapted from: Robertson, Elliot and Robinson (2007)

The next section elaborates on how the relevant examples of the different cognitive tools can be employed in CAT to entrench computational thinking in learners. In the next paragraphs the cognitive tools mentioned in *Figure 2.6* are discussed.

2.8.3.1.1 Information Seeking

Information seeking is a skill by which learners search for information for the purpose of research, personal interests and problem solving (Heintz, 2008:191-192). With the assistance of a computer, this process enables learners to access and retrieve information beyond the limitations of memory, enabling them to return to previous information throughout the learning process (Robertson, Elliot & Robinson, 2007). The next paragraphs discuss database and search engines as information seeking tools.

- **Database**

When a database is used as a mindtool, it helps learners to integrate and connect separate sections of content to make them more meaningful and more significant (Kirschner & Wopereis, 2003:109). Jonassen (2000:710) states that the organised and defined nature of a database facilitates the attainment or collection of information and the analysis of content domains through breaking down information into its basic parts; content databases can therefore function as a cognitive tool.

If teachers want to integrate databases as cognitive tools, they need to use effective instructional strategies to further enhance teaching and learning (Ou & Zhang, 2006:49). Learners must be guided through meaningful learning activities to learn how to use databases to facilitate their own thinking. Teaching with databases should proceed gradually, starting with learners working with completed databases, then to partially completed databases and finally to databases created by learners themselves. This process suggests how to provide different scaffolding to learners with different database skills. Gulmans (2004:39) is convinced that learners' critical thinking and problem-solving skills should be developed gradually from learning with guidance to learning independently. In the researcher's opinion it is therefore important that learners must first be able to work with a completed database, before they attempt to construct their own database in the PAT. This can be done by giving the learners simple exercises to construct a database, and from there the learners can learn how to extract information from the constructed database.

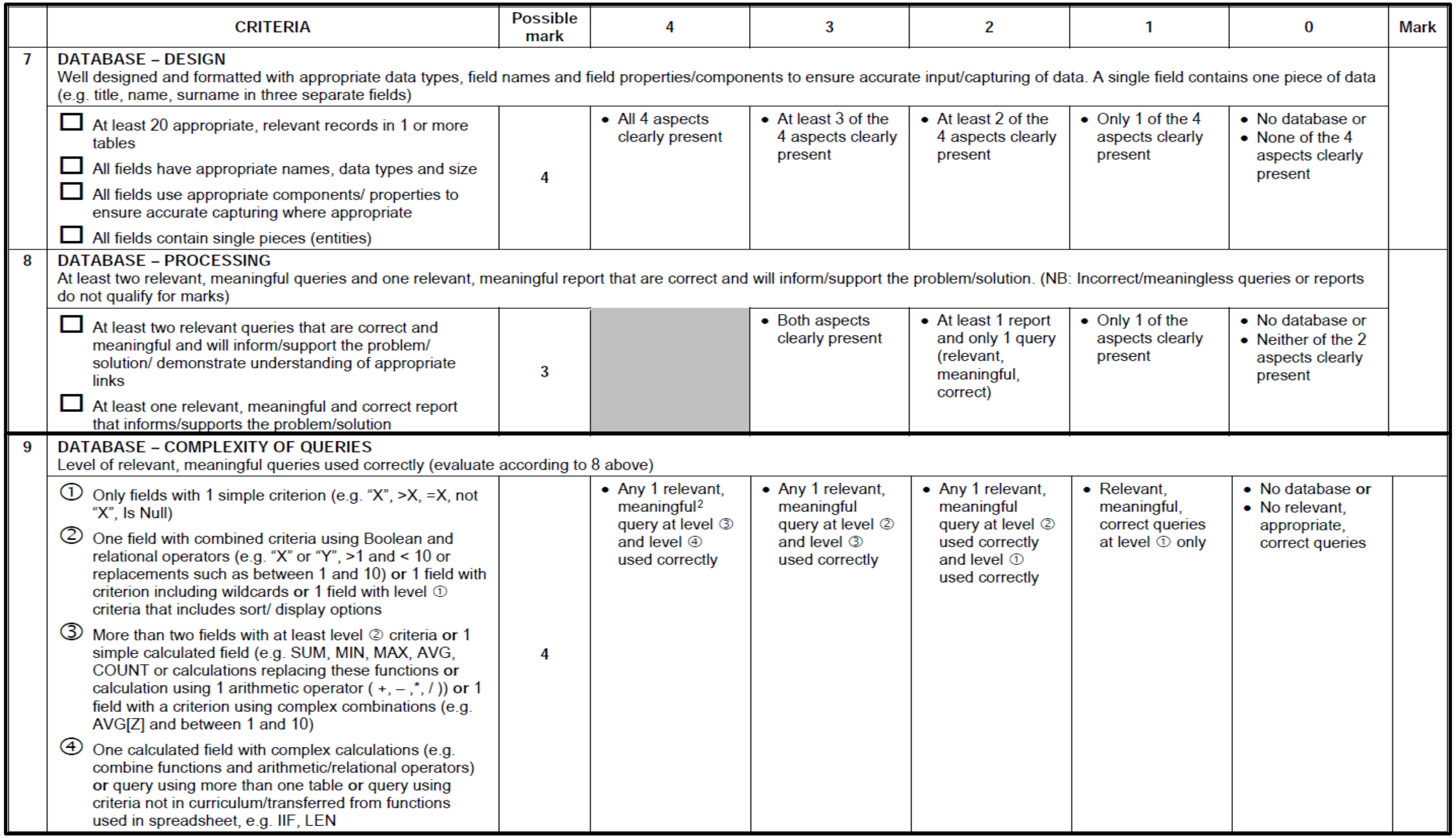
Learning with databases may be constructive and meaningful when learners are actively engaged in knowledge construction by asking questions, analysing data, seeking answers and drawing conclusions (Ou & Zhang, 2006:50). Learners may furthermore develop higher-order thinking skills in appropriate database activities. Computer technology and Internet resources provide teachers with both challenges and opportunities in teaching with databases as cognitive tools. Teachers can integrate authentic database resources available from the Internet conveniently into database-supported lessons.

Creating content databases assists learners in developing a data structure, locating relevant information, inserting the information into appropriate fields and records, and searching and sorting the database to answer content queries (Jonassen, Carr & Yeah, 1998:2). The creating of databases are an essential part of the CAT curriculum as stated in the CAPS document (DBE, 2011a:12). All these activities involve higher-order thinking skills such as analysing (creating queries), evaluating (creating reports which involve evaluation – deciding on best fields to use) and creating (inventing new fields that will answer more questions) (Cronon, 2009; Li & Liu, 2008:78).

Example of database in PAT

The grade 12 PAT's rubric as indicated in Figure 2.7, on the next page, shows how learners must be able to use a database to extract or find relevant information (DBE, 2014:27-28).

Figure 2.7: Rubric used to assess the use of a database as an information seeking tool



	CRITERIA	Possible mark	4	3	2	1	0	Mark
7	**DATABASE – DESIGN** Well designed and formatted with appropriate data types, field names and field properties/components to ensure accurate input/capturing of data. A single field contains one piece of data (e.g. title, name, surname in three separate fields)							
	☐ At least 20 appropriate, relevant records in 1 or more tables ☐ All fields have appropriate names, data types and size ☐ All fields use appropriate components/ properties to ensure accurate capturing where appropriate ☐ All fields contain single pieces (entities)	4	• All 4 aspects clearly present	• At least 3 of the 4 aspects clearly present	• At least 2 of the 4 aspects clearly present	• Only 1 of the 4 aspects clearly present	• No database or • None of the 4 aspects clearly present	
8	**DATABASE – PROCESSING** At least two relevant, meaningful queries and one relevant, meaningful report that are correct and will inform/support the problem/solution. (NB: Incorrect/meaningless queries or reports do not qualify for marks)							
	☐ At least two relevant queries that are correct and meaningful and will inform/support the problem/ solution/ demonstrate understanding of appropriate links ☐ At least one relevant, meaningful and correct report that informs/supports the problem/solution	3		• Both aspects clearly present	• At least 1 report and only 1 query (relevant, meaningful, correct)	• Only 1 of the aspects clearly present	• No database or • Neither of the 2 aspects clearly present	
9	**DATABASE – COMPLEXITY OF QUERIES** Level of relevant, meaningful queries used correctly (evaluate according to 8 above)							
	① Only fields with 1 simple criterion (e.g. "X", >X, =X, not "X", Is Null) ② One field with combined criteria using Boolean and relational operators (e.g. "X" or "Y", >1 and < 10 or replacements such as between 1 and 10) **or** 1 field with criterion including wildcards **or** 1 field with level ① criteria that includes sort/ display options ③ More than two fields with at least level ② criteria **or** 1 simple calculated field (e.g. SUM, MIN, MAX, AVG, COUNT or calculations replacing these functions **or** calculation using 1 arithmetic operator (+, – ,*, /)) **or** 1 field with a criterion using complex combinations (e.g. AVG[Z] and between 1 and 10) ④ One calculated field with complex calculations (e.g. combine functions and arithmetic/relational operators) **or** query using more than one table **or** query using criteria not in curriculum/transferred from functions used in spreadsheet, e.g. IIF, LEN	4	• Any 1 relevant, meaningful[2] query at level ③ and level ④ used correctly	• Any 1 relevant, meaningful query at level ② and level ③ used correctly	• Any 1 relevant, meaningful query at level ② used correctly and level ① used correctly	• Relevant, meaningful, correct queries at level ① only	• No database **or** • No relevant, appropriate, correct queries	

DBE (2014:27-28)

- **Search Engines**

When a learner in CAT conducts a project such as the PAT, the project requires the learner to do some planning/preparation/investigation/research/data gathering to solve the identified problem or task (DBE, 2011a:48).

The Internet has changed the world we learn and teach in. It is crucial for every learner to know and explore at least 20-30 different search engines (Averill, 2005:2). It is therefore essential for CAT teachers to be experienced in Internet searching to teach the necessary skills to CAT learners. Kirschner and Wopereis (2003:109) affirm that the intentional information search engine can be used to address a complex information need, where learners have to use complex search strategies (e.g. AND, OR, NOT) for relevant information and to evaluate and to communicate the results of the intentional search. For example, learners can use intentional search engines to look for information on the benefits and disadvantages of different networks.

2.8.3.1.2 Information Presentation

Presenting information involves the organisation, formatting and verbalisation of knowledge conveyed through cognitive tools (Robertson, Elliot & Washington, 2013). The next paragraphs discuss graphic organisers and concept maps as information presentation tools.

- **Graphic Organisers**

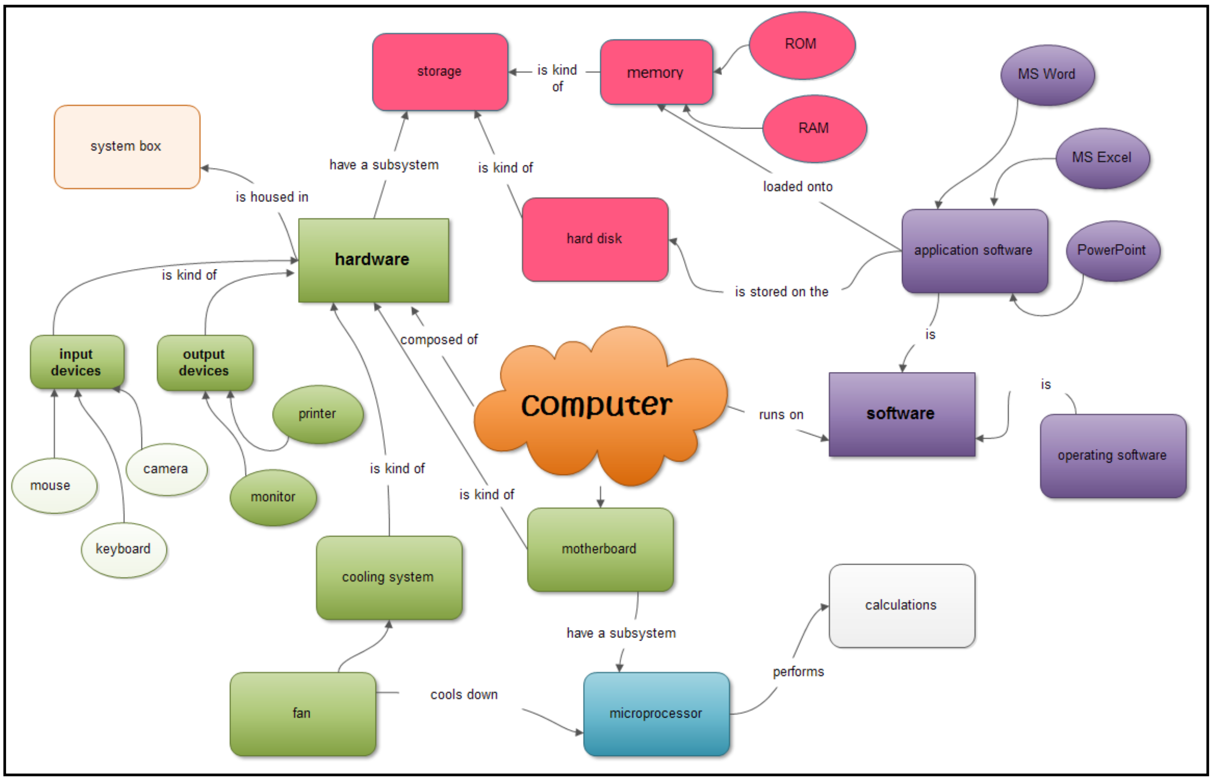
Graphic organisers may be defined as communication devices that show a relationship between facts, terms or ideas within a learning task (Dale & Tanner, 2012:118). Spatial arrangements depicting the information’s structure reduce the cognitive demands on the learner. The learner does not have to process as much semantic information to understand the information (Hall & Strangman, 2013). Graphic organisers develop thinking skills such as ordering, classifying, understanding and analysing (Dale & Tanner, 2012:120). Graphic organisers are effective visual learning strategies for learners. CAT teachers can utilise graphic organisers to assist learners to learn theory, to help in problem solving, decision making, studying, planning research and brainstorming. A word processing application can be used for this purpose (Wolny, 2011:4-7). Examples of graphic organisers are also sometimes referred to as knowledge maps, concept maps, story maps, cognitive organisers, advance organisers or concept diagrams.

- **Concept Maps**

CAT learners are exposed to a vast amount of information and new learning material that is very specific, technical and new to them. Unless CAT teachers provide a learning environment that promotes understanding through interaction, learners might only commit unassimilated information to their short-term memory through rote learning, and no meaningful learning will occur. CAT learners must be able to link learned facts, concepts and principles with new knowledge.

Concept mapping is a very powerful constructivist learning tool. Constructing a concept map provides a means of visually demonstrating existing understandings and knowledge and to reflect on, expand and deepen it. It is a graphical tool that can be used to organise and represent knowledge by using enclosed circles or boxes, and showing the relationship between concepts with a connecting line. Linking words on the line specify the relationship between the concepts. Learners can use it as useful tool for examining a topic or for analysing the thinking process itself (Novak & Canas, 2008). Concept maps may be used very effectively in the theory of CAT as seen in *Figure 2.8,* on the next page, (Derived from Grade 10 System Technology and created with freeware downloaded from the Internet).

Figure 2.8: Example of a concept map for System Technology



Constructivist learning theories argue that if teachers integrate new knowledge into existing structures, learners will remember and receive meaning from the new knowledge (Doyle, 2008:75). Concept maps stimulate this process as it compels the learner to pay attention to the relationship between concepts. CAT teachers can use this mindtool very successfully to incorporate known theory into new theory that must be learnt. Doye (2008:75) further argues that learners show some of their best thinking when they try to represent something graphically, and that thinking is a necessary condition for learning.

Experiments have shown that subjects using concept mapping out-perform non-concept mappers in longer term retention tests (Stoica, Moraru & Miron, 2010:10). Teachers can therefore improve learners' performance in the theoretical paper by using concepts maps.

2.8.3.1.3 Knowledge Organisation

Learners enable numerous cognitive skills through the organisation of information as an in depth analysis of relationships among ideas and beliefs between the learner and information. Knowledge organisation occurs by learners according to their own unique experiences and interpretations, rather than duplicating the organisation provided by the teacher. Examining the relationships within certain information, learners are faced with different cognitive tasks; the cognitive load is shared by the cognitive tools in this process (Iiyoshi *et al.*, 2005:287-288). When information is organised and grouped into organised chunks, learners will find it easier to learn and to recall (Ozcelik & Yildirim, 2005:299). The next paragraphs discuss spreadsheets and presentation tools as knowledge organisation tools.

- **Spreadsheets**

Computer software, such as the electronic spreadsheet, provides capabilities for solving application operations accurately and quickly. By using spreadsheets as cognitive tools, learners have gained the competence to solve problems, develop models and analyse data that were previously difficult or impossible (Hoag, 2008:2).

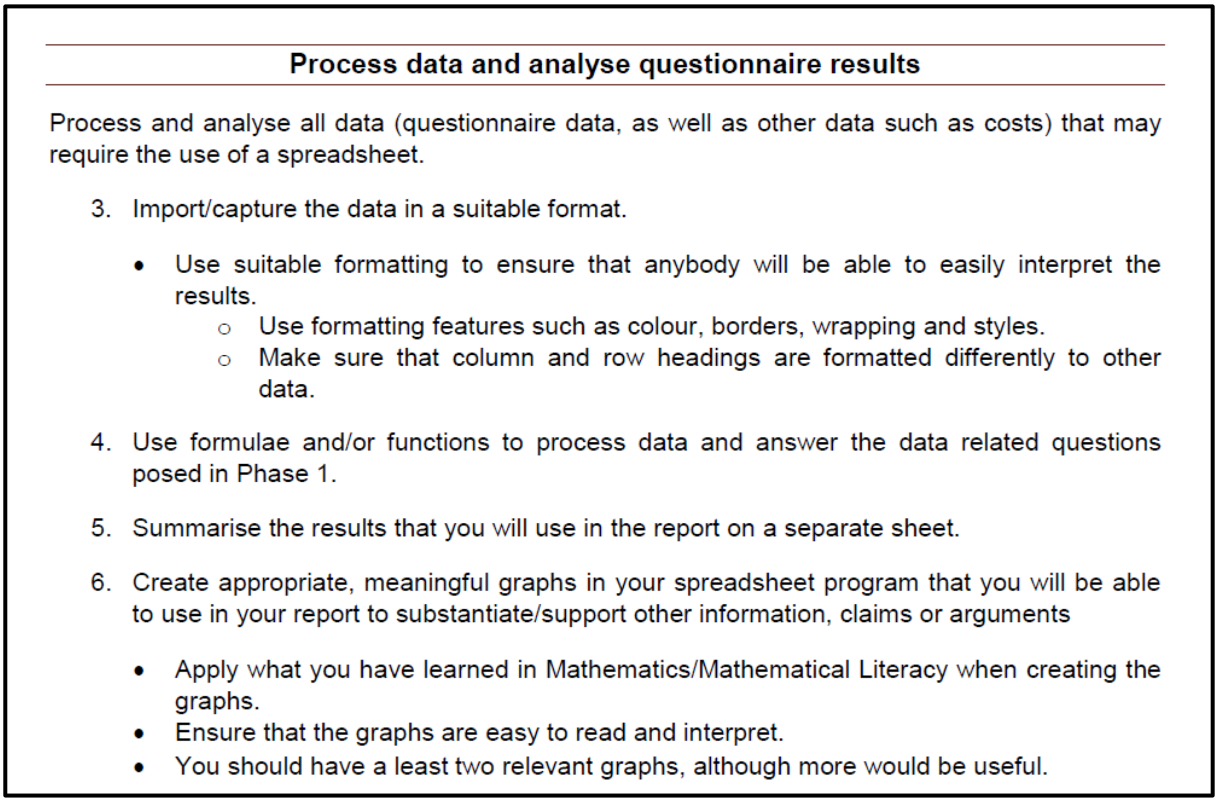
Creating or designing a spreadsheet requires abstract reasoning by the learners, thereby matching one of the important goals of cognitive thinking (Jonassen, 2000:712). Calculating values in spreadsheets requires the learner to identify relationships and patterns among the data that he or she wants to represent in the spreadsheet. Kirschner and Wopereis (2003:109) assert that learners engage in critical thinking when they design and fill in values and formulae in a spreadsheet. This requires the application of existing rules, generating new rules to describe the relationship and organising information. Defining the organisation of values, formulae and functions in a spreadsheet involves analysis-level learning to identify relationships and describe them in terms of higher-order rules, thereby forcing learners to think more profoundly.

Building spreadsheets requires learners' abstract reasoning, with the functional and graphic capabilities of the spreadsheet providing them with a context for analysing and connecting multiple representations (Hoag, 2008:58). Spreadsheets can be used in situations with complex quantitative relationships. The “what-if”-thinking supported by spreadsheets requires learners to consider the implication of conditions or options, which entails higher order reasoning.

Example of spreadsheets to organise knowledge in PAT

The grade 12 PAT’s as indicated in Figure 2.9 shows clearly how learners must be able to use a spreadsheet to organise knowledge and data (DBE, 2014:14).

Figure 2.9: Engaging with and use information and data



Process data and analyse questionnaire results

Process and analyse all data (questionnaire data, as well as other data such as costs) that may require the use of a spreadsheet.

3. Import/capture the data in a suitable format.
    - Use suitable formatting to ensure that anybody will be able to easily interpret the results.
        - Use formatting features such as colour, borders, wrapping and styles.
        - Make sure that column and row headings are formatted differently to other data.
4. Use formulae and/or functions to process data and answer the data related questions posed in Phase 1.
5. Summarise the results that you will use in the report on a separate sheet.
6. Create appropriate, meaningful graphs in your spreadsheet program that you will be able to use in your report to substantiate/support other information, claims or arguments
    - Apply what you have learned in Mathematics/Mathematical Literacy when creating the graphs.
    - Ensure that the graphs are easy to read and interpret.
    - You should have a least two relevant graphs, although more would be useful.

DBE (2014:14)

▪ Presentation Tools

A teacher can use the presentation tools such as MS PowerPoint to create a mental picture (Averill, 2005:2). By using this mindtool or cognitive tool a complete lesson may be covered through words and pictures. The researcher believes that topics such as System Technologies and Network Technologies offer the teacher an opportunity to use this mindtool to complete an entire lesson, part of a lesson or to review a lesson. The teacher can also use sound and video in creating a lesson.

2.8.3.1.4 Knowledge Integration

Making sense of new information by interpreting the information in relation to prior knowledge is a characteristic of thinking. Domain specific prior knowledge is one of the most important determinants of subsequent learning (Schneider & Stern, 2010:73). Cognitive tools (such as mapping tools) allow this through their ability to allow lower level thinking skills to be managed for higher-order thinking skills to be stimulated (Iiyoshi *et al.*, 2005:289). Graphic organisers such as mapping tools can be used by both teachers and learners to integrate new theoretical knowledge with previous knowledge. Spreadsheets can be used to simulate real life situations such as a budget. Functions and formulas can be included in a pre-defined budget.

Example of knowledge integration in CAT

When teachers teach a learner how to link a graph in a spreadsheet application from one sheet to another, learners can use this knowledge to create a link from a spreadsheet graph to a word processing document. Spreadsheet formulas and functions can be used in spreadsheets to simulate different situations such as a personal budget. Mapping tools can be used in theory – this will enable learners to link previous knowledge to new acquired knowledge.

2.8.3.1.5 Knowledge Generation

The generation of knowledge applies to a learner's abilities to represent knowledge in a significant format that mirrors cognitive skills and strategies employed through the interaction with the information (Iiyoshi *et al.*, 2005:290).

- **Collaborative learning**

One of the most meaningful ways to support individual learning is collaborative learning and knowledge building where learners are engaged in a co-ordinated effort to solve a problem or perform a task together (Laru, 2012:26). Examples of such tools that can be incorporated in the CAT class are blogs, wikis, social bookmarking, video sharing and Google Docs.

For teachers to be competent in using collaborative learning as a cognitive tools to teach computational thinking skills, it is important that they create a computational thinking environment and receive support from the relevant stakeholders such as the School Management Team and the Department of Basic Education. The next section will investigate the computational thinking classroom.

2.8.4 The computational thinking classroom

The essence of computational thinking is thinking about data and ideas, and using and combining resources to solve problems. The creation of new information requires thinking processes (CSTA, 2009:1). It is thus teachers' (the providers of effective teaching and learning) responsibility to foster a thinking culture in the CAT classroom environment.

Teachers can employ different teaching strategies to promote higher-order thinking skills in the classroom environment. Higher-order thinking skills must be taught daily within the context of academic disciplines and subject matter. Higher-order thinking skills should not be taught as a separate entity, but rather within the context of day-to-day academic topics. The development of higher-order thinking skills, such as critical thinking, requires practice and teachers' encouragement (Sharma & Elbow, 2000:3).

Teachers must create a classroom environment where learners feel free to ask questions; where such questioning would not be regarded as a challenge to the teacher's authority. Questioning is the cornerstone of critical thinking (Sharma & Elbow, 2000:3). Teachers must guard against traditional classroom discussions, explained by Copeland (2005:42-45) as a teacher standing in front of a class and posing a question to learners to engage their minds. Normally one or two learners answer the question, the teacher dismisses the incorrect possibilities or answers, imparts the correct answer and moves on to the next question. Teachers should instead create an atmosphere of inquiry and openness, allowing learners to ask questions and solve problems by themselves. Instead of providing the solution or fixing the problem, teachers can ask learners what they think should be done. When asking questions, teachers should use the correct vocabulary such as “opinion”, “analyse” and “compare”. Instead of asking “what”, teachers might ask “why” and “what if” questions (Conklin, 2011:47-48).

Teachers should thus create an environment where learners can share thoughts, information and be allowed to talk to each other and to work together (Crawford, Saul, Mathews & Makinster, 2005:7). Such a positive classroom environment can be created through discussions. When learners are asked to search the Web for information, teachers should discuss how this could be done effectively. Similarly, when learners are engaged in learning how to apply a spreadsheet software program, ways to employ such a program to solve problems should form part of the discussion (Hu, 2011:227).

Computational thinking manifesting in the classroom through active problem solving is envisioned by Barr and Stephenson (2011:115). Learners must engage in applying tools to solve problems; they should be comfortable with trial and error; and learners should work in an environment where problems can be solved collaboratively. In addition, learners should use key concepts, talk about sequences, inputs, outputs, saved values, as well as how complex the solution is. These authors further believe that learners whose learning thrives on opportunities for computational applications would portray a more solid foundation for problem solving. Learners should understand that problems can be solved in multiple ways by being open-minded and flexible; such learners would have reasonable expectations for producing a working solution to whatever problem they must solve.

Teachers and learners must accept that first-time success is not a given, but that failed attempts at a solution are part of the learning experience. Collaborative teamwork that allows for decomposition, abstraction and negotiation are all part of a computational thinking culture (Barr & Stephenson, 2011:52). Bridge (2013) describes decomposition as the breaking down of a problem into smaller problems. If learners possess the ability to analyse the core problem (individually or collaboratively), it becomes easier to recognise the problem areas the computer is to be employed for.

Example 1

If a CAT teacher gives Grade 10 learners a problem that requires them to create a graph that will show the profit of each product, and no help is provided, they might struggle. Learners can work in a group to determine what must be done first (working out of the profit), to eliminate unnecessary detail from the problem, and discuss the solution. Thereafter if will be easier for them to create a graph to solve the problem. If learners can therefore look at the problem and work out the main steps, they will have a much better chance of solving it.

Teachers should pursue content in depth rather than superficially. This implies that classroom material should be linked to real-world situations and problems. Content must be used flexibly and creatively and learners should not only learn content once; they must master the content (Theall, 2005:1-2).

Example 2

Learners must search the computers in the classroom for viruses and activate the anti-virus software. They must also regularly update software.

Example 3

Learners must physically do trouble shooting when computers have problems.

Teachers must create several and different opportunities for learners to apply content to new situations and problems. Activities used must be authentic and similar to real-world scenarios. In fact, Barron and Darling-Hammond (2008:1) state that research has shown that when activities are linked to the real-world and the activities inspire creative applications, this strategy is grounded in the constructivist theory. Activities can also emulate problem-based learning, allowing learners to acquire new knowledge and skills as they work on complex problems similar to those that occur in the real world.

CAT teachers can pursue subject-specific simulation and modelling to nurture computational thinking (CSTA, 2009:1). Examples of such learning activities are spreadsheet models that include formulae, graphs and charts that will allow learners to discover and explain relationships, predict events and learn procedural skills.

The increased use of computational vocabulary to describe problems and solutions will add to the computational thinking environment. CSTA (2011:14) provides a list of examples of computational thinking vocabulary with a progression chart. This may be adapted for the CAT curriculum as indicated in *Table 2.4* on the next page.

Table 2.4: Computational thinking vocabulary and progression

Computational thinking Vocabulary	Computational thinking definition	Grade 10	Grade 11, 12
Data Collection	The process of gathering appropriate information.	Design a questionnaire to collect appropriate information to answer questions. For example asking how many learners where absent from school in the past month and whether they were suffering from flu.	Learners develop a questionnaire to collect both open-ended and close-ended questions to be used in the PAT.
Data Analysis	Making sense of data, finding patterns and drawing conclusions.	Create a graph and answer relevant questions.	Use appropriate statistical methods (formulae as set out in the CAPS) to answer "if-questions".
Data Representation	Depicting and organising data in appropriate graphs, words or images.	Plot data using different graph formats and select the most effective visual presentation.	Make use of more complex graphs to represent data. Use webpage/PowerPoint to re-present data.

Computational thinking Vocabulary	**Computational thinking definition**	**Grade 10**	**Grade 11, 12**
Abstraction	Reducing complexity to define main idea.	After teaching theory content, identify key concepts.	Choose a social network medium and analyse the essential characteristics of the social media network.
Algorithms and Procedures	Series of ordered steps taken to solve a problem or achieve some end.	Converting a word table to a spreadsheet.	Converting an html table to a spreadsheet.
Automation	Having computers do repetitive or tedious tasks.	Sorting of data.	Insert page numbers.

Adapted from: CSTA (2011:14)

To enhance the computational thinking environment, literature reveals that infrastructure and teacher support are necessary to maintain a computational thinking environment. The next section discusses these two issues.

2.8.5 Infrastructure and teacher support needed for teaching computational thinking

As regards the CAT classroom infrastructure needed for teaching computational thinking, present developments point to the disappearance of the computer "as a computer" in the future - the computer will become increasingly invisible (National Research Council of National Academies, 2011:91). If so, teachers of computational thinking will have to find pedagogical approaches that do not necessarily depend on the computer as such. It further states that computers are a valuable instructional tool when teachers are comfortable with them, when activities are learner-centred, and when enough equipment is available. From its perspective, schools do have many computers - but these computers are not well matched to the required pedagogical tasks. It advocates an infrastructure based on open-source software. If the resulting computational problem-solving environment does not have the tools that learners would choose to use, for example Facebook, Gmail, and so on, the unavailability of familiar tools are likely to inhibit learner learning.

The successful implementation of computational thinking concepts into the Grades 10 – 12 CAT curriculum requires efforts in two directions (Barr & Stephenson, 2011:112):

- Education policy must be changed to overcome significant infrastructure hurdles; and
- Grades 10 – 12 CAT teachers (skilled with computational thinking and problem-solving skills) must have sufficient resources such as updated computers, updated software and Internet connectivity.

National Research Council of the National Academies (2011:28) reports that difficulties with hardware and software and Internet access can inhibit the promotion of computational thinking. The report further states that access to computers and provision of technical support are very important, as these are the tools that learners will use in the workplace. Teaching computation without fully operational classrooms is not really preparing learners for the real world. Many schools lack access to technology or only have productivity tools such as application software (word processing and spreadsheets) rather than computational environments**.** In South African schools it is the responsibility of the school to maintain the infrastructure, equipment and the finances of the computer classroom that is used to teach CAT (DBE, 2011a:11).

It is thus obvious that to teach computational thinking in the CAT classroom, the classroom must have access to technology such as working and updated computers, up to date software and connectivity to the Internet.

2.9 CONCLUSION

The purpose of this chapter was to conduct a literature review on the essence of computational thinking. From the literature it is clear that, although computational thinking is normally associated with Computer Science, it is a skill that all learners must master to be able to be successful in the 21st century. Computational thinking is essentially a problem-solving skill that integrates the human brain with the capabilities of computers; it is not necessarily computer programming. CAT as a subject in the South African school curriculum can be a vehicle to teach learners this skill.

Computational thinking is a skill that encompasses skills such as abstraction, representation and analysis and it will foster higher-order thinking skills among learners. Learners will benefit from computational thinking as they will develop into problem solvers instead of merely being application users.

This chapter also investigated how teachers can incorporate computational thinking into their classrooms. The use of cognitive tools as instruments to teach computational thinking was examined. Cognitive tool affordance, the role of cognitive tools and specific technologies that can be implemented in teaching computational thinking, was also investigated. Literature revealed what a computational thinking environment, such as the classroom, must embrace. The infrastructure needed to create such an environment was also investigated.

A significant portion of computational thinking involves problem solving, which is discussed in the following chapter.

CHAPTER 3

THE ESSENCE OF PROBLEM-SOLVING

3.1 INTRODUCTION

One of the most important aims of education overall is to prepare learners for the unknown future, for the work situation and to be able to solve real-life problems (DBE, 2011:4-5). To do so, it is important that school-related knowledge gained by learners should not be fragmented, but should be a systematised knowledge, applicable and transferable to novel situations, where not only the quality matters, but the quantity as well.

This chapter synthesises the literature to answer the following research question:

- What are the essences of problem solving with regard to CAT?

3.2 BACKGROUND

Since the arrival of computers, improved technological capabilities have amplified problem-solving opportunities. By using computer software such as the Internet and application packages such as word processing, spreadsheets and database, solving certain problems can be done accurately and quickly (Hoag, 2008:1).

Computational thinking is a requirement when learners use computers in problem solving (Voskoglou & Buckley, 2012:28). As discussed in Chapter 2, computational thinking is a set of thinking skills that learners must have and that is integral to solving problems when using a computer (cf. 2.5). Teachers and learners must become conscious that they live in an information era with rapid advancement in technology and that problem solving, where knowledge and technology are used in combination, is one of the most important 21st century skills (Voskoglou & Buckley, 2012:29). Creativity and innovation are thus driven by tacit knowledge, and critical thinking driven by logic, making judgements, analysis and synthesis and so on, become the tools for problem thinking and problem solving. If technology is added as another tool then computational thinking is another consequence.

Problem-solving as a skill is a central objective within the education programmes of many countries such as South Africa, England, the United States of America, the Netherlands and some Asian countries such as Singapore and Hong Kong (China) (Anderson, 2009:2–6 and DBE, 2011a:5). Key findings of research conducted by the Organisation for Economic Co-operation and Development (OECD, 2013:120) on the basic profile of knowledge and skills among 15-year-old learners revealed the following:

- In some countries 70% of learners could solve relatively complex problems, while in others countries fewer than 5% could do so.
- In most countries, more than 10% of learners were unable to solve basic problems.
- On average in OECD countries[ix], half of the learners were unable to solve problems that are more difficult than basic problems.
- Patterns of within-country variation in learners' problem-solving proficiency differed considerably across countries.
- Patterns of within-country differences between problem-solving proficiency and domain-related proficiencies (mathematics, reading and science) differed considerably across countries.

From this it is clear that problem-solving competency is a significant problem among learners; it should therefore be central in any education curriculum.

The CAT curriculum addresses the "how" of computer use, but rarely the "when" or "why." When learners learn isolated skills and tools of “how” to use a computer, they

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[ix] Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States of America (OECD, 2014).

might still lack an understanding of how those various skills fit together to solve problems and complete tasks. Learners must be able to use computers flexibly, creatively and purposefully. All learners should be able to recognise what they need to accomplish, determine whether a computer will help them to do so, and then be able to use the computer as part of the process of accomplishing their task. Individual computer skills take on a new meaning when they are integrated within this type of information problem-solving process, and learners develop true computational thinking skills and problem-solving skills because they have genuinely applied various computer skills as part of the learning process.

Problem solving is a generic life skill in the world of work, and therefore required from every learner (Russel, Water & Turner, 2014:26). The main aim of the subject CAT is to focus on practical techniques for the efficient use and application of integrated components of a computer system to solve everyday problems (DBE, 2011a:8).

It is therefore important that all CAT teachers and all CAT learners are competent in problem solving.

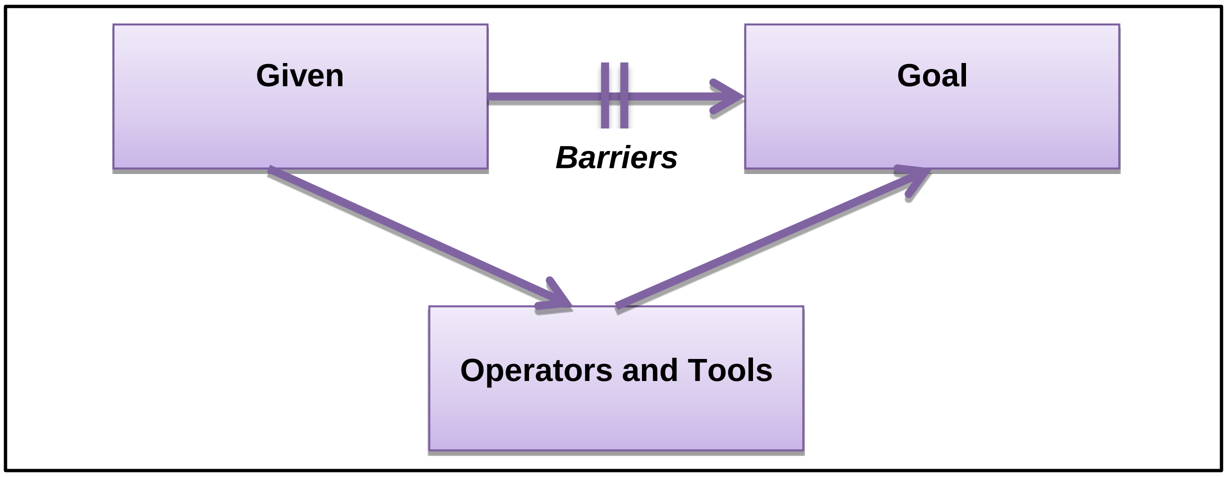
3.3 PROBLEM-SOLVING COMPETENCY

To understand the term, problem-solving competency, fully and in the correct context, the researcher is of the opinion that terms such as “problem” and “problem solving” must be clarified.

3.3.1 What is a problem?

In the context of this study, a problem occurs when a CAT learner has a goal, but does not know how to attain that goal (OECD, 2013:121). *Figure 3.1,* on the next page, explains this definition in greater detail.

Figure 3.1: Problem situation



OECD (2013:121)

The given is the learner's knowledge about the problem at the beginning. This is the information that is given to the learner. The operators and tools are the acceptable actions that can be performed to achieve the desired goal with the assistance of the available tools. Barriers that must be overcome stand in the way of achieving the goal. Such barriers can be lack of knowledge or lack of a problem-solving strategy.

A situation becomes a problem when there is a "felt need" or difficulty that drives one towards an answer (Jonassen, 2011:1). It is therefore important for teachers to realise that learners must believe the question or problem is worth an answer. If the learner does not perceive a need to answer a question, the learner might not believe that ther is a problem. Jonassen (2011:1) further argues that the latter attribute may eliminate most formal, in-school problems from the category of real problems because learners do not perceive a need to find the unknown to the type of problems posed in schools. However, because their teachers do perceive such a need, they are normally regarded as problems. It is therefore important that teachers choose the correct problem to ensure that learners have the maximum educational benefit from their problem-solving experience.

3.3.2 What is a good problem?

As indicated in paragraph 3.3.1, there must be a reason for any problem that a learner must solve. For a problem to have value, it must also have an educational value. This implies that a problem should improve learners' knowledge; they must gain a deeper understanding of the subject content, and the problem must be relevant to the subject domain. A good problem will also be within the learners' capacity and be stimulating; they must be able to produce solutions within a realistic timeframe (Badger, Sangwin & Hawkes, 2010:26).

A good problem often requires multidisciplinary solutions (Hmelo-Silver, 2004:244). For example, when learners do the PAT, they require knowledge and skills from several content areas to solve the problem (for example, in a spreadsheet learners need mathematical skills, whilst in word processings learners may need language need language skills). The necessity of gathering knowledge from a wide range of sources allows learners to see knowledge as a useful tool for problem solving. Communication skills will also be fostered in a good problem as learners must present, either through a presentation or a verbal document, their solution to the teacher or the rest of the class.

3.3.3 What is problem solving?

Problem-solving is an activity that employs cognitive and physical means to overcome an obstacle (problem) and develops a better idea of the world that surrounds us (Voskoglou & Buckley, 2012:30). Jonassen (2011:3) and OECD (2013:122) concur by stating that problem solving is a cognitive process that is focused on transforming a given situation into a goal situation when no apparent answer is available. Problem-solving refers to a situation in which the solver develops and implements plans with the intention of moving from a problem state to a goal state within a range of constraints (Chrysikou, 2006:935). Anderson (2009:1) states that problem solving as a skill involves a range of processes that includes analysing, interpreting, reasoning, predicting, evaluating and reflecting.

Moreover, problem solving is the application of ideas, skills or factual information to achieve the solution to a problem or to reach a desired outcome. Problem-solving is the key skill that develops learners' ability to try new and different ways of thinking about situations, issues and problems and to attempt them by using creative, analytic and planning skills (Education Portal, 2010). The focus is on helping learners to learn how to undertake problem solving systematically – one of the most vital skills for employability and, increasingly, for education and training at all levels (Gariulo & Metcalf, 2013:388). For teachers, problem solving thus involves:

- taking time to make sure that the learner really understands the nature and detail of the problem, including the limitations to be faced, such as time limits, Internet access and ICT availability;
- agreeing what would count as a successful solution or outcome;
- considering a range of ways of tackling the problem, rather than simply doing whatever first comes to mind;
- deciding which approach has the best chance of success;
- systematically planning and implementing the chosen approach;
- considering whether the problem has been solved;
- learning from the experience so that learners can improve their approach to problems (Education Portal, 2010).

Problem-solving is regarded as a cognitive process which is directed at achieving a goal when no solution method is obvious to the problem solver (learner) (Mayer & Wittrock, 2006:287). To them problem solving comprises four parts:

- problem solving is cognitive; that is, problem solving occurs within the problem solver's cognitive system and can only be inferred from the problem solver's behaviour;
- problem solving is a process; that is, problem solving involves applying cognitive processes to cognitive representations in the problem solver's cognitive system;
- problem solving is directed; that is, problem solving is guided by the problem solver's goals; and

- problem solving is personal; that is, problem solving depends on the knowledge and skill of the problem solver.

Examples of problem solving in CAT may be:

Example 1
The CAT grade 11/12 class is hosting a workshop on Internet Security. As a CAT learner you are asked to do the following:

Design the workshop flyer. (Word processing)
Create a form that participants can complete electronically. (Word processing)
Using this form, create a database. (Database)
The database will be used to create queries. (Database)
Create an electronic certificate to hand to all participants who passed the exam. (Mail merge)

Example 2
Use the Internet to find statistics on a certain topic such as the crime rate of 2014 in South Africa. This information must be used in a spreadsheet where you must scrutinise the information and present it through a presentation package such as PowerPoint.

Because problem solving occurs in many different formats in CAT, learners taking CAT must be taught the necessary thinking skills to be competent in problem solving. The next section will discuss problem-solving competency.

3.3.4 What is problem-solving competency?

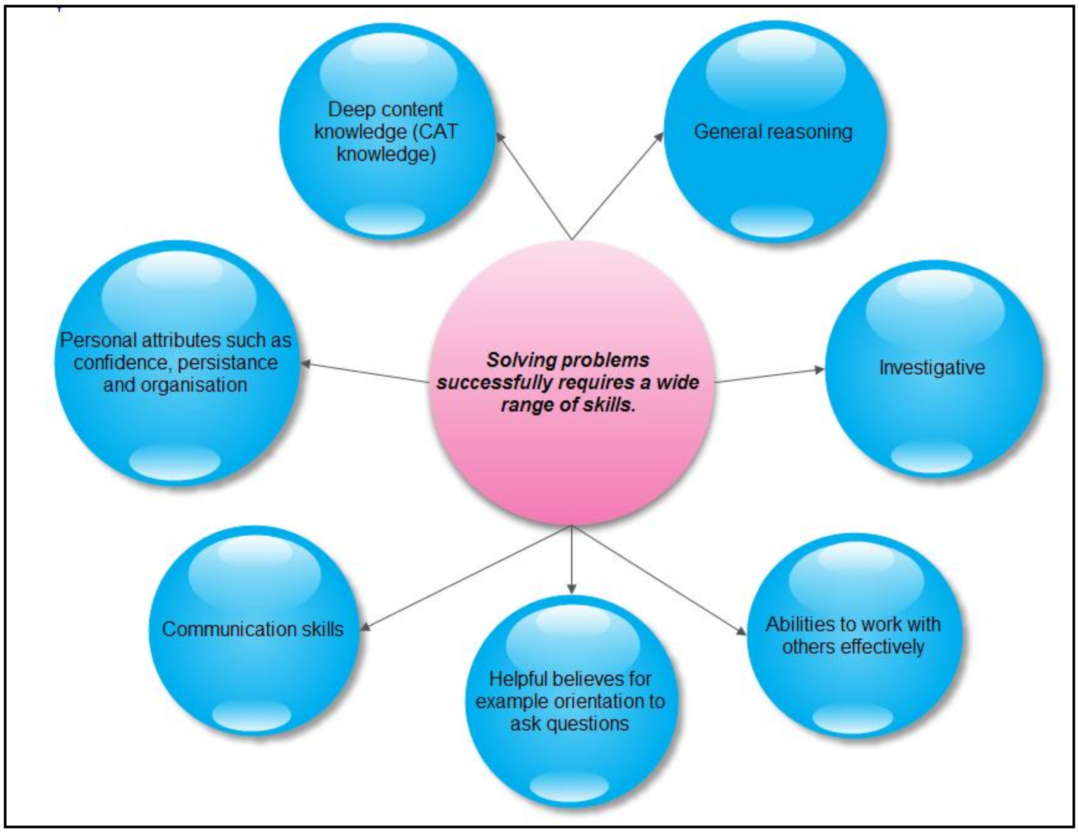
The OECD (2013:122) defines problem-solving competency as follows:

> *"Problem-solving competency is an individual's capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious. It includes*

> *the willingness to engage with such situations in order to achieve one's potential as a constructive and reflective citizen."*

Competency involves more than the duplication of accumulated knowledge. OECD (2013:122) states that problem-solving competency involves the ability to acquire and use new knowledge, or to use old knowledge in a new way to solve problems that are not routine. Learners need profound CAT knowledge and a general reasoning ability as well as investigative strategies for solving ill-defined problems. Personal attributes such as organisational skills, confidence and persistence are also necessary. Effective communication skills and the ability to work in groups will also assist in being a good problem solver (Stacey, 2005:342-345). Learners must have the ability to ask questions in order to think critically and to reason through the problem. The purpose of setting questions is to be clear about what must be asked in order to find reasonable answers that show learners' insight and understanding (Wallowitz, 2008;223). *Figure 3.2,* on the next page, gives a clear picture of the problem-solving skills that must be instilled in learners.

Figure 3.2: Problem-solving skills that contribute to successful problem solving



Adapted from: Stacey (2005:342)

There are many factors that can influence a learner's ability or competency to solve a problem (Jonassen, 2011:20). He is, however, of the opinion that the three primary individual differences that facilitate learners' ability to solve problems are:

- prior domain knowledge;
- prior experience in solving similar problems; and
- their cognitive skills.

For learners to become problem-solving competent, the CAT teacher should make sure that learners acquire the necessary skills as indicated in paragraph 3.3.4 and *Figure 3.2.* The next section will investigate how problem solving can become a kind of thinking for learners.

3.4 PROBLEM-SOLVING AS A WAY OF THINKING

As stated in Chapter 2, learners must have critical thinking skills to solve any given problem effectively.

Learners do not automatically think critically and their prior knowledge very seldom leads them to think critically (Paul & Elder, 2002:236). Because learners are not born with critical thinking skills, Snyder and Snyder (2008:92-95) urge teachers who want their learners to develop this skill, to first model this behaviour. Therefore, before learners can apply the skill to a content scenario, they must be taught how to think critically. Research on questioning shows that teachers are not asking enough of the open-ended questions that will facilitate critical thinking. Of the questions that teachers ask in class 75% are of a factual or literal nature (Cecil & Pfeifer, 2011:4). By asking the right questions, teachers can encourage learners' critical thinking skills. To encourage learners to engage in critical thinking, the teacher must ask higher-order questions. When learners are asked a higher-order question, they might use facts and details in the process of answering the question, but, they must go beyond the facts and details to construct a rationale for the response (Crawford *et al*., 2005:5–7).

When teachers ask questions during class time, these questions should require learners to evaluate the clarity and accuracy of their thinking. They must determine whether the content they are using is relevant and if their thinking process is logical. Types of questions that will engage learners in critical thinking are: clarifying questions, cuing questions, focusing questions and probing questions (Cecil & Pfeifer, 2011:13). Sample questions that CAT teachers can ask to assist learners with this process can include the following (with reference to Social Implications (DBE, 2011a:17)):

- *What is the influence of ICT on your daily life style?*
  - *Why do you think that has an influence on your daily life style?*
  - *What is your knowledge based on?*
- *What does it imply and presuppose?*
- *What explains it, connects to it, leads from it?*

- *How do you view the influence of ICT on your daily life style?*
- *Should it be viewed differently?*

They further state that when teachers start teaching with the emphasis only on testing and examinations, it will distract the learning process from learner-centred teaching and will place the emphasis only on the content. To promote critical thinking, teachers must focus on teaching and learners must be given the freedom and responsibility to explore content, analyse resources and apply information.

In addition, class activities should be structured in such a way that the activities include the following four elements (Boardbear, 2003:7):

- ill-structured problems;
- criteria for assessing thinking;
- learner assessment of thinking; and
- improvement of thinking.

Teachers must use ill-structured problems like questions, case studies and scenarios that do not have a definite right or wrong answer. The answers should be debatable and reflective judgements must be made. An example of this with reference to Internet Technologies (DBE, 2011a:15) is:

Learners can compare and evaluate two similar websites, such as Gumtree and XLO, and think about the content, the format and the usability of the website.

Learners who can think critically are able to solve problems effectively (Snyder & Snyder, 2008:90). Having only knowledge or information is not enough. By implication this means that even if CAT learners have knowledge and the skills of applications software, it does not mean that they will be able to solve problems efficiently. To be effective in the workplace (and in their personal lives), learners must be able to solve problems to make effective decisions; they must be able to think critically.

Teachers are warned that they should be aware of learners' initial resistance to solve problems and guide them through the process to create a learning environment where learners feel comfortable thinking through an answer rather than simply having an answer (Snyder & Snyder, 2008:96).

It is also important for CAT teachers and CAT learners to be aware that problems can be set in different ways.

3.5 TYPES OF PROBLEMS

Problems are categorised as ill-defined or well-defined, based on how problem and goal are represented (Hardin, 2002:227). Problems with complex representations and/or more than one solution are termed ill-defined. Problems with discrete representations and finite goals are termed well-defined.

3.5.1 Ill-defined problems

During everyday life and work learners will encounter ill-structured problems and these problems emerge independently without warning (Jonassen, 2011:6-7). The solutions to ill-structured problems are not expectable or convergent. They require the integration of several content domains; they possess multiple solutions, solution paths or no solutions at all. Ill-structured problems often require learners to make judgement and to express personal opinions or beliefs about the problem.

Example of ill-defined problem

Learners are asked to compile a database of computer stores in their town. This problem will require learners to decide on the information needed for the different fields, records, tables, forms and reports without the help of the teacher.

Example of ill-defined problem

Learners are asked to keep track of their week of how many hours per day they spend on:

- *learning;*
- *sleeping;*
- *eating;*
- *watching TV;*
- *exercising (sport at school or at home);*
- *relaxing; and*
- *other.*

This information must be transferred to a spreadsheet and must be presented graphically to the class.

3.5.2 Well-defined problems

Most of the problems that learners encounter during a school day are well-defined problems (Jonassen, 2011:6-7), normally given to learners after specific content has been done. Exercises at the end of the content chapters, and test and examination questions are classic examples of well-defined problems. When learners are therefore presented with a well-defined problem, all the information that they need to solve the problem in the problem representation are given to them. All that is expected is to use a prescribed solution process whereby they straight forward apply rules and principles to determine the correct answer without noteworthy originality.

Example 1a of well-defined problem

Determine the total of monthly expenses in a spreadsheet application where the different expenses are given to the learners.

Example 1b of well-defined problem

Explain what e-commerce is and describe some of its advantages and disadvantages.

When learners learn to solve well-defined problems effectively, Jonassen (2005) states that it will have an positive impact on how they solve ill-structured problems. It is therefore important for teachers to make sure that learners have the necessary practise, skills and knowledge in solving well-defined problems before they present learners with ill-structured problems. It is therefore important for teachers to make sure that learners are familiar with methods for solving problems, regardless of whether the problems are well-structured or ill-structured. Learners must understand the problem-solving process and this process must have meaning to them. Learners must make mental associations between what they know about the problem and their existing knowledge, skills and experiences.

The effective use of cognitive strategies and metacognitive activities can direct the thinking processes and can enhance the effective solution of problems. Teachers should be skilful in supporting learners to use cognitive and metacognitive activities to solve problems effectively.

3.6 COGNITIVE STRATEGIES AND TECHNIQUES FOR PROBLEM-SOLVING

It is very clear that if teachers want learners to solve problems effectively they must ensure that learners have different kinds of reasoning and understanding skills (Jonassen, 2011:22). Learners further must have different kinds of knowledge, thinking skills and knowledge representations. Because all problems are not always solved by using the same strategy. It is important that learners' thinking process is developed so that they have a variety of problem-solving strategies.

The four foremost reasoning processes in problem solving for Mayer and Wittrock (2006:288) are:

- Representing, in which the learner as a problem solver constructs a cognitive representation of the problem. During this process the learner seeks to understand the problem.
- Planning, in which the problem solver devises a plan for solving the problem.
- Executing, in which the problem solver carries out the plan.
- Self-regulating, in which the problem solver evaluates the effectiveness of cognitive processing during problem solving and adjusts accordingly.

According to Mayer and Wittrock (2006:289) the problem-solving process depends on different kinds of knowledge. This includes factual knowledge, conceptual knowledge, procedural knowledge, strategic knowledge, beliefs and metacognitive knowledge. Hardin (2002:227) claims that for learners to have problem-solving knowledge, they must have declarative knowledge and procedural knowledge. Both declarative and procedural knowledge are activated in the working memory as problem solving takes place. Klieme (2005:87) claims that a learner's problem-solving ability depends on knowledge of concepts and facts (declarative knowledge) and knowledge of rules and strategies (procedural knowledge) in the relevant subject domain. Klieme further states that one of the most important insights of research in cognitive psychology is that demanding problems cannot be solved without knowledge in the domain.

Problem-solving depends on cognitive, metacognitive and effective skills that will subsequently be discussed.

3.6.1 Knowledge for problem solving

Cognitive researchers are convinced that a learner's preceding domain knowledge is among the most important influences of that learner's problem-solving ability (Jonassen, 2011:20-21). However, it is important to realise that not only the learner's quantity but also the quality of knowledge is important. The next section will therefore outline the different types of knowledge a CAT learner should have to be an effective problem solver.

3.6.1.1 Declarative/factual knowledge

Terminology related to the subject (such as hard drive, memory, Internet), discrete facts and basic elements are factual knowledge (Pickard, 2007:49). Pickard further states that factual knowledge is basic information that learners must have on a specific subject; Mayer and Wittrock (2006:289) agree; and they consequently feel it is important for teachers to choose what information is critical to remember and what can be acquired when needed, for example, by using the Internet. For learners to understand a problem fully and to create a solution to the problem, they must have a thorough factual knowledge base.

Examples of CAT topics regarding factual knowledge are: knowledge about hardware, software, memory, storage, formulae, network and social networks.

Example of a factual knowledge question

Various communication technologies such as Skype, IM and e-mail can be used for learners to stay in touch with family and friends.

1. *What does IM stand for? Give an example of an application using this technology.*
2. *Give TWO differences between IM and e-mail.*
3. *Name TWO hardware components required to communicate by using an application such as Skype.*

To answer the above questions learners must have factual knowledge which relates to various communication technologies.

3.6.1.2 Conceptual knowledge

Conceptual knowledge for Arends and Kilcher (2010:269) is that learners must have knowledge of the interrelationships among the basic elements. To be able to solve a problem, learners must have acquired the ability to recognise relationships between the basic elements involved, explain the kind of relationship and its relevance to the problem to be solved, and apply the relationship in the problem-solving process.

Example of understanding concepts

Learners must understand different concepts of sending an e-mail, how the Internet works and how cell referencing works in a spreadsheet.

Conceptual knowledge is flexible and not tied to specific problem types; it is therefore generalisable (Alibali, 2005). It involves understanding the principles that run a field and interrelations between units of knowledge in a field. Pickard (2007:49) claims that conceptual knowledge is more complex than factual knowledge. Only when learners can clarify or explain concepts in their own words and transfer information to new situations they have acquired conceptual knowledge; conceptual knowledge therefore deals with generalisations.

Example of a conceptual knowledge question

Your mother is compiling a letter to your aunt in the United States of America. She is experiencing problems, because while she is typing some of the words on the screen are underlined. Indicate the problem to her and how she can solve that problem.

- *The word processing program highlights words that she is sure are correct, as a spelling error – e.g. "color" instead of "colour".* (Spelling and Grammar check)

In order to solve the problem, learners should have conceptual knowledge to know that the language for the spelling and grammar check is set on South African/US.

3.6.1.3 Procedural knowledge

Procedural knowledge in CAT is crucially important. Archer and Hughes (2011:11) declare that procedural knowledge relates to how something is done. It is therefore the knowledge that learners must have to know how to perform certain skills or steps in a process or in a strategy.

Procedural knowledge is the learners' ability to execute action sequences to solve problems. Procedural knowledge is tied to specific problem types and therefore is not widely generalisable (Alibali, 2005). Arends and Kilcher (2010:268) are of the opinion that, for learners to acquire procedural knowledge, they need to have factual or conceptual knowledge. Example: Before a teacher teaches learners about creating graphs, learners need to know and understand how to create a spreadsheet.

Example of a procedural knowledge question

- *how to create or use a formula in a spreadsheet application;*
- *how to save a document in different file formats;*
- *how to import data from one application to another application; and*

- *how to do an Internet search.*

In order to solve the problems the learner should have procedural knowledge on how to

- create or use a function in a spreadsheet application;
- save documents in different formats;
- to import data from one application to another; and
- the steps to follow to do a proper Internet search.

3.6.1.4 Metacognitive knowledge

Metacognitive knowledge is the knowledge and the ability to understand, control and manipulate the cognitive processes (Efklides & Misailidi, 2010:371). They further explain that metacognitive knowledge is declarative knowledge that is stored in memory. It also encompasses information about people as well as knowing when and where to use particular strategies for learning and problem solving, as well as how and why to use specific strategies.

Example of metacognitive knowledge

Learners know that they must check their grammar and spelling before they send an e-mail.

Metacognitive skills can be promoted in learners if the teacher:

- explicitly teaches knowledge on thinking processes, types of problems and strategies to solve problems; and
- consciously creates opportunities in class for learners to contemplate what they know about themselves as learners, what they know about different types of problems and their requirements, and what they know about appropriate strategies to solve a problem successfully.

3.6.1.5 Strategic knowledge

Strategic knowledge helps learners organise the problem-solving process by showing them which stages they should go through to reach a solution (Solaz-Portolés & Sanjosé López, 2008:107). This implies that learners should have knowledge of general methods, such as how to break a problem up into parts.

Example of strategic knowledge

Steps when integrating documents such as a word processing document and a database document (mail merge) or the linking of an embedded spreadsheet into a word processing document.

The researcher also believes that declarative -, conceptual -, metacognitive and strategic knowledge alone is not enough for problem solving. Learners should be taught different strategies in problem solving. To teach different strategies in problem solving, it is important that teachers understand how the problem-solving process works. The next section deals with the problem-solving process.

3.7 PROBLEM-SOLVING PROCESS

In conducting the literature review the researcher came to the conclusion that different authors think differently of the cognitive processes involved in solving a problem; however, there is also a great deal of commonality in their understandings**.**

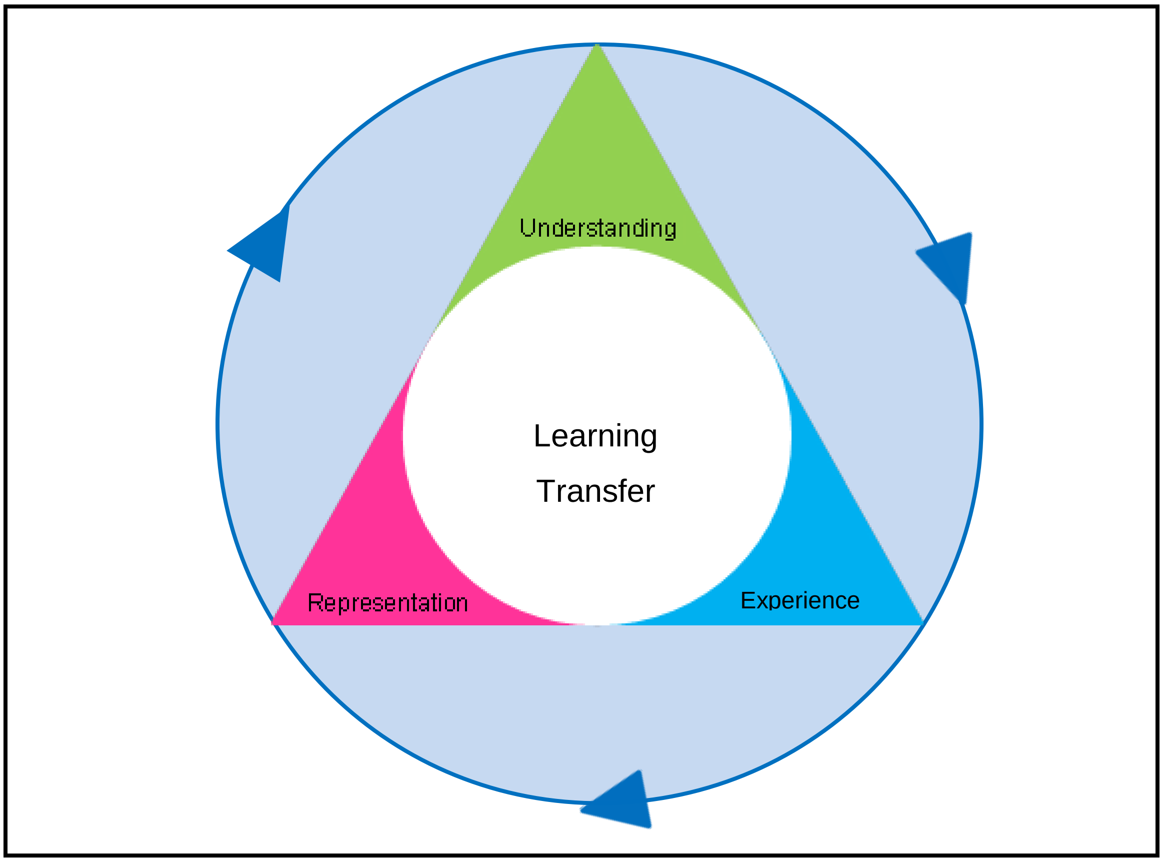
3.7.1 Problem-solving triad

The problem-solving process involves several aspects from which three major facets arise (Sutton, 2003):

- the learner’s representation of the problem (problem representation);
- the learner’s background experiences; and
- the learner’s understanding of the problem and its structure.

Figure 3.3, on the next page*,* represents Sutton’s (2003) problem-solving process. The base of the triangle shows the learner's experiences and representation of the problem as the foundation for problem solving. The researcher will scrutinise the different components of this triad in the paragraphs that follow on the next page.

Figure 3.3: The Problem-Solving Triad: Key Components in the Problem-Solving Process



Sutton (2003)

3.7.1.1 Understanding

A learner's understanding of a problem and the ability to transfer previously learned concepts and skills to the current problem are inextricably linked to the learner's ability to properly represent the problem (Dixon & Brown, 2012:5). They further state that a good understanding of the problem will also reflect in how the learner uses metacognitive skills. This refers to how learners will self-regulate the strategies that they use.

3.7.1.2 Problem representation

Solving a problem simply means representing it to make the solution transparent

(Petrina, 2007:295). That is, problem representation is central to problem solving. Representing the problem in a logical way is the key to solving problems. For Sutton (2003:57) a problem representation is how a learner mentally processes or represents the information contained within the problem. This representation is directly related to the learner's existing knowledge of the content of the problem. When presented with a problem, the learner encodes the information to form a mental representation of the problem. These associations are established with conceptual knowledge. Different learners have different conceptual knowledge and learners will make different associations with their knowledge.

In some cases a learner may fail mentally to encode some of the information provided by the problem statement, may establish some relationships different from those intended by the problem statement, or may fail to establish some relationships. Not only is representation subject dependent, but Jonassen (2005:364) claims that problem representation is the key to problem solving. When a problem is represented with a computer, we call this a computer model or a computer representation of the problem. For some problems, a computer model has some of the same characteristics as a mental model. Some computer models are easy to change and allow easy exploration of alternatives.

Suppose the problem that the learners face is writing a high quality report on research that has been done for the Practical Assessment Task (PAT). The report will be compiled using a word processor. Thus, the learner produces a computer model of the report. This is much more easily done with a computer model of a report than it is with a paper and pencil model of a report. Changes to the document can be made. The document can be saved and retrieved to add or delete information. In addition, a computer can assist in spell checking and can be used to produce a professionally formatted final product. In the representation of problems, computers are useful in many respects. For example, a computer can easily present data in a variety of graphic formats, such as a line graph or bar graph. To do this, learners will need the skill of working with spreadsheets.

3.7.1.3 Experience

A learner's prior experiences and the representation of the problem work together to establish an understanding of the problem. It enables the learner to understand the problem and its underlying structure. The process of understanding is iterative and circular, as depicted by the arrows around the outside in *Figure 3.3*. Full understanding of the problem does not usually occur immediately. A learner will make mental representations of different aspects of the problem, based on associations with his or her experiences. These associations and representations work jointly to build an understanding. As the problem-solving process continues, the learner builds on already established representations until a complete understanding of the problem emerges.

Although learners bring a wealth of knowledge to each learning situation they may fail to connect everyday knowledge to subjects that are taught in school, unless the teacher gives specific guidelines (Dixon & Brown, 2012:4-6). The learning experience will become more self-regulated and automatic when problems are solved as their metacognitive skills develop and they can make a connection between the learning experience and what is beyond the walls of the classroom.

The thinking process may be limited by a lack of experience and knowledge (French & Rhoder, 2011). For example, this implies that when learning about sending an e-mail, learners must not only have theoretical knowledge, but they must have the opportunity to practically learn how to send an e-mail. They further state that learners' ability to think effectively within a certain domain will be limited if they do not have knowledge about the specific domain.

Transfer of learning is represented at the centre of the circle. Once the learner completely understands the problem and its underlying structure, then transfer to similar situations can occur.

3.7.1.4 Transfer of learning

To transfer knowledge, it is necessary for learners to understand the internal connections between problems and domain knowledge. The transfer of learning is at the centre of the model because it represents the heart of all learning, applying what has been learned to novel situations.

The context of the original learning will affect the transfer of learning (Dixon & Brown, 2012:4-6). This means that although learners might know how to use the IF function in a simple activity, they can fail to transfer this concept to another context. When teachers expose learners to various contexts that comprise examples that demonstrate a wide application of what is being taught, learners will develop a flexible representation of knowledge and are likely to abstract the applicable features of concepts that make two unique problem scenarios similar.

Transfer of learning is the effect of previous learning on new learning or problem solving (Mayer, 2009:4). According to Haskel (2001:24), the challenge facing all computer instruction is to teach not merely the keystrokes (training) necessary to perform program tasks, but to develop mental models of the underlying structure (learning) of the different user interfaces. With the trend of moving towards common user interfaces based on graphics such as Microsoft Windows, transfer of learning is accelerated. Haskel (2001:25) further states that if learners are properly instructed, they should be capable of transferring to an entirely new word processor, spreadsheet or database program with relative ease. This therefore implies that, when a new version of a software package is released (for example MS Office 2013), learners should have no problem converting to the latest version of the software.

The main purpose of teaching is to enable learners to transfer what they learn in the classroom to new situations or new problems. Van Gog, Paas and Van Merriënboer (2004:83) claim that more often than not, learners are unable to apply the knowledge and skills they have acquired in doing exercises to new problems. To overcome this problem, and to aid transfer of learning Westwood (2004:14) states that teachers should first ensure that the learner is really fluent in applying the knowledge, skill or strategy in one context before introducing different problems or tasks. It is helpful to discuss openly with the learners the similarity between the demands of any new type of problem and the appropriate knowledge and skills previously acquired. By exposing learners to multiple problem examples, Van Gog *et al.,* (2004:83) are convinced that teachers can improve the transfer of learning rate.

Teachers should be aware that problem-solving abilities in learners often develop very slowly (Cai & Lester, 2010:4). It is therefore important that the CAT classroom must have a problem-solving culture and that problem solving must be a regular and consistent part of CAT activities.

3.8 IMPLICATIONS OF TEACHING PROBLEM-SOLVING FOR TEACHERS AND LEARNERS

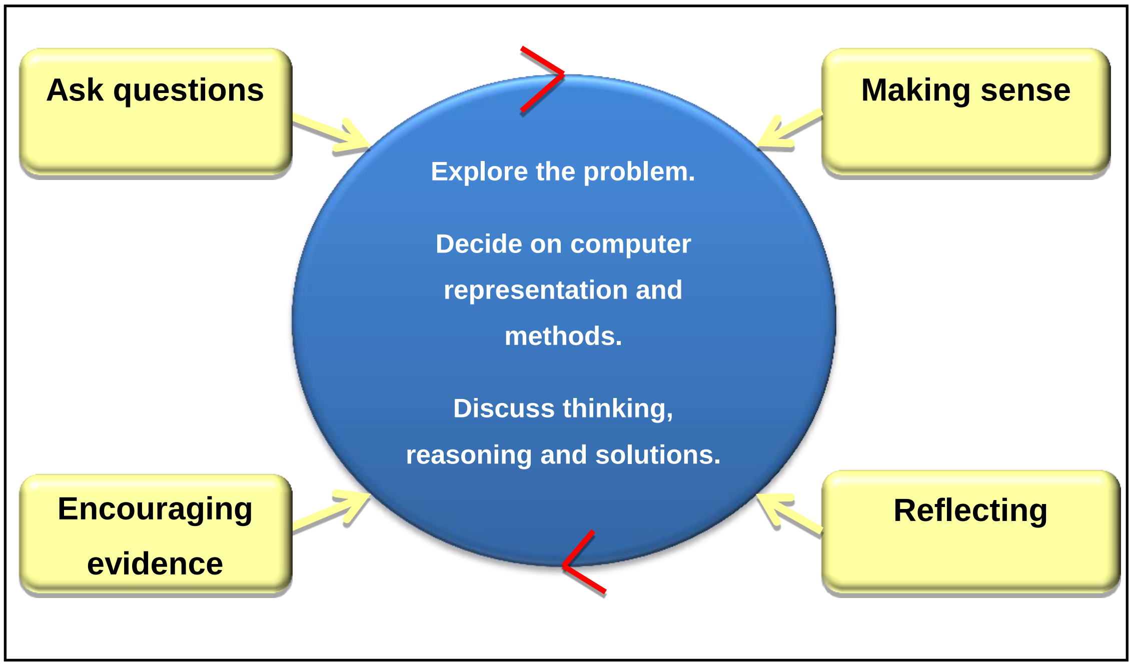
Developing CAT learners into effective and successful problem solvers is a long-term, continuous process that must be a fundamental part of the CAT instructional program. It is also important for learners to buy into the necessity of frequently engaging in thought provoking and interesting activities.

For a classroom to become one where problem solving is taught, Rigelman (2007:312) suggests that the roles of the teacher and the learner change. The teacher supports the learners to use a number of different methods/strategies/approaches to the problem, and allows for communication and reflection. By doing this, the teacher does not find the answer for the learners, but guides their observations and questions.

The role of the learner is also influenced by problem-solving instruction. As learners engage in problem solving to solve a problem in CAT, they engage in computational thinking. During the process, learners explore the problem, they decide which computer application (for example word processing, spreadsheet or word processing) will be the best suited and they foster different methods of thinking about the problem. In this process is it is also important that learners must be able to discuss their thinking, reasoning methods, thoughts and the proposed solution.

Rigelman (2007:313) uses *Figure 3.4,* on the next page*,* that shows a cyclical model applied to mathematics. The researcher will show how the same model could be applied to the computational thinking problem-solving process.

Figure 3.4: Cyclical model of the computational thinking problem-solving process



Adapted from: Rigelman (2007:313)

The model in *Figure 3.4* above is a circle, indicating that the problem-solving process does not start and end at a specific point. The process can be conducted consecutively, although one step may not be completed when the next step begins. Some actions or processes may take place at the same time, and not all learners will be at the same place in the process as they try to solve the problem. Learners must discuss their thinking while they develop their computer representations. For example, learners can discuss how they can use the computer to present data in a variety of graphic formats, such as a line graph, bar graph, etc. At the same time, teachers should become part of the problem-solving process. Teachers should encourage evidence, they must lead learners to use different approaches, and they must also assist learners in the reflection process to ensure that they make informed decisions. It is thus clear that, especially in

Grade 10, teachers should not withdraw when learners are doing the PAT; they must be involved throughout the process to ensure success.

The use of Bloom’s Revised Digital Taxonomy can be very useful for CAT teachers to lead learners through the problem-solving process.

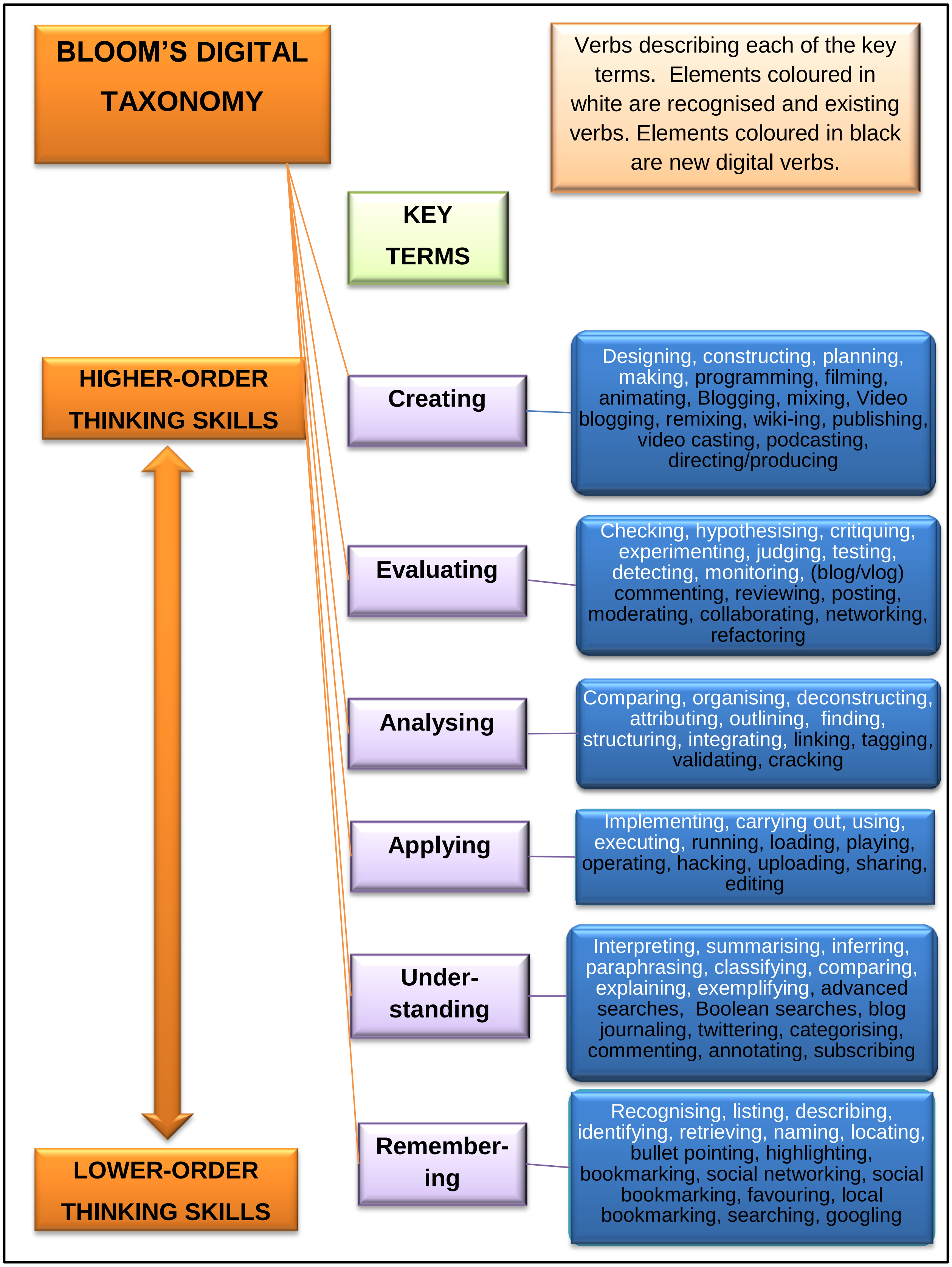
3.8.1 Bloom’s Revised Digital Taxonomy

Bloom's Taxonomy illustrates that when a teacher teaches a task or learners are assisting each other with a specific problem, this represents a higher-order level of thinking than simply performing the task oneself. Explaining requires not only *application* of the learned material, but also *analysis* and *evaluation,* as well as to ensure that the most important elements are being taught and in the correct sequence. A revised version, adds a new category, *Creating* and puts it at the top of the list. This category includes the following "higher-order thinking skills": *designing, constructing, planning, producing, inventing, devising, making*, all of which are common to the sorts of tasks used to teach CT.

Bloom’s Revised Taxonomy takes into account emerging technologies and show how instruction and assessment can be supported by using the varying levels of thinking skills (Hinrichs & Wankel, 2011:175). Implementation of these verbs (and their respective subcategories), as indicated in *Figure 3.5,* into learning goals and objectives ensures high-quality instruction that reaches all types of learners, while attaining levels where they can develop and grow their knowledge base.

In recognition that the educational world has changed since Bloom proposed his original taxonomy in 1956, a digital version of Bloom’s taxonomy as shown in *Figure 3.5*, on the next page, was developed by Churches in 2008 (Landrum & McCarthy, 2012:112-116). Churches added the notion of learners learning digital thinking skills within the traditional levels that Bloom proposed. To ensure that learners perform at the highest digital level, it is important that teachers keep this taxonomy in mind when developing learning objectives. Although all the verbs are not applicable to CAT, the researcher will discuss those verbs that are.

Figure 3.5: Bloom's Digital Taxonomy



Adapted from: Churches (2007:4)

Teachers must be familiar with the different key terms to assist learners' progress from lower-order thinking skills to higher-order thinking skills. The teaching goal behind any of the cognitive taxonomies is to equip learners to be able to transfer. For learners to be able to think means that they can apply knowledge and skills that they developed during their learning to new contexts. "New" means applications that the learners has not thought of before. Higher-order thinking is regarded as learners being able to relay their learning to other elements beyond those they were taught to associate with it (Brookhart, 2010:5).

Paragraphs 3.8.1.1 to 3.8.1.6 and *Tables 3.1* to *3.6* show how teachers can integrate Bloom's Digital Taxonomy in the classroom.

3.8.1.1 Remembering

For the lower-order thinking skill learners must have the required declarative/factual knowledge. For the theoretical part in CAT (cf. *Table 2.3*), instructions such as name, list and identify can be used. To develop this thinking skill in the practical part of CAT (cf. *Table 2.3*), teachers must include the following keywords as indicated by Churches (2007:5). The researcher discussed/explained how teachers can include these keywords in their CAT learning programme and sample instructions are given in italics.

Table 3.1: Remembering as a key term in Bloom's Revised Digital Taxonomy

Keyword	Discussion/Explanation of keyword and an example of keyword
Bullet pointing	In Grade 10 learners are expected to create a bulleted list (DBE, 2011a:12). Sample instruction: *Create a bulleted text with the following bullet: ♥.*
Highlighting	This is a key element of most productivity suites and is a skill technique that learners must have. Sample instruction: *Bold the heading and change the font colour to yellow.*

Keyword	Discussion/Explanation of keyword and example of keyword
Bookmarking or favorite-ing	This is where learners mark certain words, websites, resources and files for later use. This skill is only required from learners as part of the Grade 12 curriculum (DBE, 2011a:44). Sample instruction: *Locate the heading 'Internet' and add a bookmark called BOOKMARK to this text.*
Social networking	Social networking forms a key element of collaborating and networking. The CAPS document (DBE, 2011a:25) expects learners to have a factual knowledge as well as the practical knowledge of social networking. Example: *Teachers can create a page on a social network such as Facebook or use Twitter to communicate with learners.*
Social bookmarking	Churches (2007:5) describes this as an online version of local bookmarking or favourites. Although it is mostly the higher-order thinking skills like collaborating and sharing that apply this skill, this is the simplest form. Example: *Learners should know how to create a simple list of web sites saved to an online format rather than locally to the machine.*
Searching or "Googling"	Search engines are the key element in creating the PAT (DBE, 2011a:27,51). At its simplest, the learner just enters a key word or phrase into the basic entry pane of the search engine. This skill does not refine the search beyond the key word or term. *Sample instruction:* *Find the meaning of the expression "social networking".*

3.8.1.2 Understanding

Orlich, Harder, Callahan, Trevisan, Brown and Miller (2012:296) state that before learners can apply a concept or a fact, they must understand the concept or fact. Facts must be related to broader concepts before they have meaning to learners. This suggests that learners must be able to interpret, summarise and explain specific information. Roberts (2011) describes which applications can assist in understanding the different digital key verbs.

Table 3.2: Understanding as a key term in Bloom's Revised Digital Taxonomy

Keyword	**Discussion/Explanation of keyword and example of keyword**
Advanced and Boolean searching	This is progression from the lower thinking skill of remembering. Advanced search options in applications such as Google, Bing and Yahoo can be used to obtain information for their PATs (DBE, 2011a:25). Learners need a greater depth of understanding to create, modify and refine searches to suit their search needs. Example instructions: *Find information on technology development in China. Learners must know to use a capital "C" to exclude results of china dishes.* *The use of AND and OR between words can make a request more specific.*
Blog journaling	Although it is only required of learners to create a Facebook profile in Grade 12 (DBE, 2011a:44), learners in Grade 10 are already familiar with this concept (DBE, 2011a:25). Example: *This is a good example where learners must understand how a blog works before they can practically do blogging.*
Twittering	Although Twitter is only introduced in Grade 12 (DBE, 2011a:45), learners must understand in Grade 10 that Twitter is part of social networking. Bosman and Zagenczyk (2011:12) state that teachers can use Twitter in various ways to enhance learning: Examples: *Twitter can be used to focus on writing and presentation skills, as tweets are limited to 140 characters.*

Keyword	**Discussion/Explanation of keyword and example of keyword**
	Teachers can use Twitter to keep learners updated with information pertaining to upcoming examinations and tests. *Prior to an examination or a text, the teacher can host a recap quiz where the first learner to answer correctly can gain a bonus point.*
Categorising	Learners must be able to organise and classify different files, web sites and documents by using different folders and files (DBE, 2011a:19). Example instruction: *Create a folder structure to organise all your practical work into four different terms with subfolders for word processing, spreadsheets and database activities.*
Commenting and Annotating	In Grade 10 learners are expected to use comments in a word document (practical) (DBE, 2011a:25). They should also be able to explain certain concepts such as “green computing”. Example instructions: *Use a PowerPoint presentation to explain the findings of the research of your PAT project.* *Retrieve the word document and do the instructions as indicated in the comments. Make sure to delete each comment after you have completed the instruction.*
Subscribing	Discussion Boards, Newsletters and RSS Feeds. An RSS feed is to get the latest postings from a particular website (Gibbons, 2007:47). Example: *Teachers can encourage learners to subscribe to RSS feeds of CAT topics – rather than checking every website that relates to that topic, teachers and learners subscribe to the RSS feeds for those web sites.*

3.8.1.3 Applying

For learners to be able to apply concepts, teachers must ensure that activities given provide them with opportunities to meaningfully and reflectively apply procedures and processes to specific closed, logical and bounded tasks.

Table 3.3: Applying as a key term in Bloom's Revised Digital Taxonomy

Keyword	**Discussion/Explanation of keyword and example of keyword**
Running and operating	This is used when learners can initiate a program or an operation and manipulate hardware and applications to obtain a basic goal or objective.
Playing	Learners who successfully play or operate a game show an understanding of process and task and an application of skills (Churches, 2007:8).
Uploading and sharing	Allowing learners to upload material to a website and share material is a simple form of collaboration, a higher-order thinking skill.
Editing	With most media, Churches (2007:8) states that editing is a process or a procedure that every user should be able to do.

3.8.1.4 Analysing

Sousa (2009:54) claims that analysing takes place when learners can break up material into different components so that its structure may be more comprehensively understood. This ability allows learners to identify different parts, to examine the interrelationship of the different parts and the whole, and to recognise the organisational principles involved. Learners must be able to organise and reorganise information into categories.

Table 3.4: Analysing as a key term in Bloom's Revised Digital Taxonomy

Keyword	**Discussion/Explanation of keyword and example of keyword**
Validating	With the vast amount of available information, combined with the lack of authentication of data, learners must be able to validate the reliability of the relevant information sources that they use. It is therefore important that teachers should empower learners to analyse data sources and make judgements on them. This is also a specific aim of CAT (DBE, 2011a:10). Example: *Teachers can allow learners to create a form to collect data on a specific topic. After learners receive the information back, learners can analyse the data, graph what they have learnerd and draw the necessary conclusions (Clarke & Watts-Taffs, 2014:51). This skill is also needed in the PAT.*
Linking	This occurs when learners have to establish and build links within and beyond documents and web pages. Example instruction: *Locate the web address in the last sentence of the document. Insert a hyperlink that links to the website together with a screen tip that reads 'Linking a website'.*

3.8.1.5 Evaluating

Evaluating is defined as the process where a learner must make an evidence-based judgement by evaluating against specific criteria or normative standards (O'Donnell, Dobozy, Bartlett, Breyer, Reeve & Smith, 2012:50).

Table 3.5: Evaluating as a key term in Bloom's Revised Digital Taxonomy

Keyword	Discussion/Explanation of keyword and example of keyword
Blog/vlog commenting and reflecting	Learners must be taught how to comment and reply to postings made by others and they must also have the skill to evaluate the material in context and reply with an answer or comment. Example: *The teacher can leave a post on Facebook and learners must comment on the specific post. The teacher can then evaluate the commenting.*
Posting	Good postings are not simple one-line answers, but learners must learn how to structure and construct their answers in evaluating the topic or the concept. Example: *Teachers can ask learners to post comments to blogs and discussion boards. The class can then evaluate the posting to determine whether the post was relevant.*
Collaborating and networking	Learners must learn how to evaluate the team/group members' strengths and abilities and have the ability to evaluate the different contributions that members make. Example: *Most computers in a CAT lab are networked. This feature can be used by teachers to teach learners about group/team work, an increasing feature of education. A learner can save a document on the network, and the rest of the group can retrieve the document, work on the document, make corrections and re-save the document.*

3.8.1.6 Creating

Creating is defined as learners constructing new knowledge and ideas through the reconstruction of information into new concepts, patterns or structures (O'Donnell, Dobozy, Bartlett, Breyer, Reeve & Smith, 2012:50).

Table 3.6: Creating as a key term in Bloom's Revised Digital Taxonomy

Keyword	**Discussion/Explanation of keyword and example of keyword**
Programming	Whether it is creating their own applications, programming macros or developing games or multimedia applications within structured environments, learners must create their own programs to suit their needs and goals. In CAT programming is not part of the curriculum. However, learners can create their own websites.
Filming, animating, videocasting, podcasting, mixing and remixing	Learners often capture, create, mix and remix content to produce unique products. This does not form part of the CAT curriculum.
Publishing	Whether learners do this via the web or from home computers, publishing in text, media or digital formats is increasing in learners' daily school lives. For learners to be able to do this, requires that a huge overview of not only publishing the content, but there is also a process and a product involved. From Grades 10 - 12 (DBE, 2011a:12) learners require this skill. Example: *Learners can publish their PAT research and results in the form of a booklet (using desktop publishing software) or by means of a webpage that they create.*

If teachers keep these verbs in mind when they teach, it is possible that they (the learners) will be more successful in developing higher-order thinking skills to solve problems.

3.9 TEACHING PROBLEM-SOLVING AND USING PROBLEM-SOLVING AS A TEACHING-LEARNING STRATEGY

It is important for teachers to know the difference between teaching problem solving and using problem solving as a teaching strategy (Killan, 2010:208). To Killan teaching problem solving means teaching learners how to solve a problem. To do so learners must apply existing knowledge to the problem in order to solve the problem. According to the researcher, is what the focus should be for a CAT teacher. OECD (2013:121) states that for learners to acquire problem-solving competency they must receive high quality education. Teachers must therefore use progressive teaching methods (and/or) strategies, such as problem-based learning, project-based learning and inquiry-based learning, individual project work (such as the PAT) and group project work. These will all assist in fostering a deep understanding of knowledge and learners will be prepared to apply their knowledge to different situations/problems.

On the other hand, using problem solving as a teaching strategy is a technique for teaching through problem solving. It involves problem solving to help learners learn other things; learners will acquire new knowledge through solving a problem. Rigelman (2007:308) suggests that problem-solving teaching should enable learners to build new knowledge, solve problems that arise in CAT and beyond, apply and adapt a wide variety of strategies, and monitor and reflect on the process. Teachers' actions and decisions related to these expectations often vary and are influenced by the teachers' beliefs about CAT, problem solving and the learners' ability.

Three teaching strategies that teachers can employ to foster problem-solving competencies in the CAT classroom are discussed in the next section.

3.9.1 Problem-based Learning

Savery (2006:9) describes problem-based learning as an instructional (and curricular) learner-centred approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem. Microsoft (2014) mentions that this type of learning will ensure that assignments and activities are learner-centred and are focused on real-world problems and issues.

Hinrichs and Wankel (2011:50) claim that problem-based learning creates an opportunity for learners to identify a problem, suggest possible solutions, test solutions and monitor the outcomes. Problem-based learning allows learners to utilise Bloom's Revised Digital Taxonomy higher-order skills. This includes the ability to think critically, evaluate different solutions, effectively communicate the solution or alternative solutions and analyse the different options. It also encourages learners to work in groups and allows them to think about and analyse real-world problems, and to find, evaluate and use resources. This directly links to what the PAT expects from learners. However, Uden and Beaumont (2006:33) clearly state that the main aim in PBL is not the completion of the project, but the learning that accompanies the project. The project must not test certain skills; it must assist in the development of the skills.

Thorson (2009:4-5) agrees and states that problem-based learning is a good example of how teaching and learning can take place at a practical level. It focuses on the central concepts and principles of a specific discipline (such as CAT), it involves learners in problem solving and other meaningful activities and it allows them to work on their own to construct their learning. Problem-based learning not only provides for the acquisition of facts, but also stimulates learners' higher-order thinking skills (Snyder & Snyder, 2008:91). Problem-based learning can take place in many formats. Learners can work alone, in pairs, in small or medium sized groups and in large groups (although the researcher is convinced that this will seldom happen in the CAT classroom). The PAT is a fine example of how problem-based learning can assist learners' learning. Learners are faced with a problem that they do not know the answer to. Learners must do research, interpret and validate the data and come to a conclusion. Table 3.7 provides more examples of problem-based learning in a CAT classroom.

Table 3.7: Examples of problem-based learning in a CAT classroom

Individual	Conducting an Internet search. Word processing – preparing an advertisement for a specific occasion. Preparing a spreadsheet. Practical Assessment Task
Pairs	Peer critiques – learners assess each others work/activities and if there is a mistake, they explain the correct answer. Working together on a spreadsheet to enter information, solve a problem or answer a question.
Small Groups	Designing questions to collect data for a database. Preparing presentations.
Large Groups	Learn how to use a computer tool. Observe a presentation.

3.9.1.1 Benefits of problem-based Learning

For teachers to use problem-based learning it is important that they understand the benefits of this teaching method. Chan (2008:2), Microsoft (2014) and Uden and Beaumont (2006:34) concur that PBL has the following benefits when properly implemented in the classroom.

- Meaningful learning takes place in the classroom when learners are involved in the learning process through discussion and co-operative research. Learning is driven by challenging, open-ended problems.
- Learners take responsibility for their own learning and it activates prior knowledge.
- PBL encourages advanced thinking skills that traditional teaching methods do not always address. Often when learners are given a problem or project, learners will simply copy and paste information that they have found on the Internet. With project-based learning, such as the PAT, learners have the opportunity to explore concerns, solve problems and collaborate with peers in the classroom.

- Learners build confidence in information-seeking skills.
- It is related to real-life situations; these skills are highly transferable.
- Learners have an opportunity to develop confrontation and persuasive skills, promoted by group dynamics and peer evaluation.

To make sure that a good project adds value to teaching, according to Chan (2008:2), teachers must include the following elements:

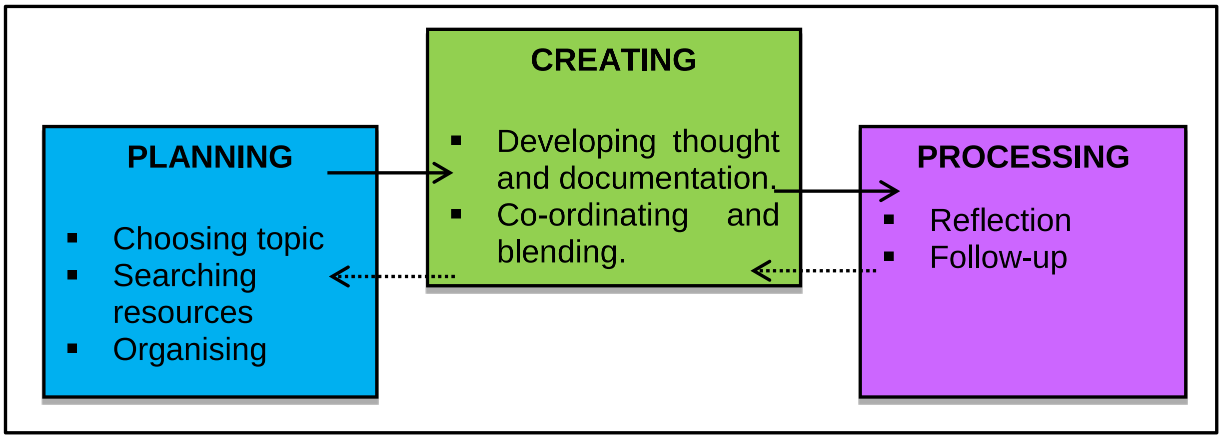
- Ensure that tasks or problems are related to real-world problems - learners will be more engaged and motivated to solve the tasks.
- Learners must explore – problems in PBL do not usually ask questions that learners can easily answer with prior input of knowledge.
- Problems in PBL are deliberately presented to learners at the beginning of the learning process.
- Problems should allow teamwork - the project should be large and effective enough for every team member to contribute to and benefit from the collaboration. It will produce a negative effect if the problem can be tackled as effectively (or more effectively) by an individual. Microsoft (2014) states that teamwork and co-operation are keys to success for learners in the information-rich, highly technical work force. Collaboration will allow learners to contact experts by using e-mail, the Internet and video conferencing.
- The teacher becomes a facilitator whose role can be a subject matter expert, resource guide and a task group consultant.

The next section focuses on project-based learning. Although the approaches of problem-based learning and project-based learning are similar, there are some differences. Fisher and Frey (2007:70) declare that problem-based learning is authentic to a specific situation; thus learners might be more limited in their ability to complete these complex assignments successfully. They therefore suggest project-based learning, where a multidimensional task is defined and supported, and state that it is more frequently used for high school learners.

3.9.2 Project-based Learning

Project-based learning is a teaching and learning approach that involves learners in complex activities (Han & Bhattacharya, 2001). It usually requires multiple stages and an extended duration - more than a few class periods and up to a full term or year. In CAT the PAT may also be regarded as a project-based learning product. Projects focus on the creation of a product or performance, and generally require learners to choose and organise their activities, conduct research and combine information (Barron & Darling-Hammond, 2008:1). For Han and Bhattacharya (2001) there are three main processes, as seen in *Figure 3.6*, in project-based learning, namely planning, creating and implementing and processing.

Figure 3.6: General framework of Project-Based Learning



Han and Bhattacharya (2001)

In the planning phase, learners choose the project (this is the PAT that the teacher gives the learner), locate the required resources (by making use of the Internet, books and others), and organise the collaborative work. Through these activities, they identify and represent a topic, gather relevant information and generate a potential solution.

The second phase is creating or implementing the project. This phase includes activities such as development and documentation, co-ordination of and blending member contributions, and presentation to class members (this may be done by presentation software). At this stage learners are expected to build a product that can be shared with others.

Activities for the third phase, processing the project, include reflection and follow-up on the projects (Bender, 2012:31-32). At this stage, learners share their project in a small group or with the entire class, they listen to the feedback from the class and then they reflect on the learning process. In the CAT classroom the teacher can allow some time for learners to share their PAT projects with other learners in the class. The class can provide feedback, and in this way learners can reflect on their learning. Learners share every group's or individual's project and exchange feedback. The CAT teacher or even the learners' peers may provide scaffolded assistance.

Project-based learning is rooted in the idea that a problem or question drives learning activities toward the construction of a concrete object in a reliable context (Bender, 2012:31; Papanikolaou & Boubouka, 2010:135). In this process, learners pursue solutions to open-ended problems by formulating questions for investigation; designing plans or proposals; collecting, analysing and integrating information; constructing explanations and models; and creating artefacts or products of their understanding. It is also essential that learners have the opportunity to control the learning process; make decisions on the pacing, sequencing and content of learning; and evaluate the outcome of their efforts and their own learning strategies. Teachers can use Internet inquiry as a vehicle to help learners think critically and to assist them in problem solving.

3.9.2.1 Benefits of Project-based Learning

It is stated that the majority of research literature on the topic highlights the degree to which this teaching method augments learner motivation. Project-based learning provides the opportunity for learners to work in the affective domain (the manner in which learners deal with content emotionally such as feelings, values, appreciation, enthusiasm, motivation and attitude). Diversity of issues that relate to the habits of mind such as flexibility, persistence, responsibility and creativity are addressed with project based learning (Welsh, 2006:17-18). There is a greater retention of learning and application to real-world problems, greater motivation among weaker learners and fewer disciplinary problems. The problem-solving ability of learners improve, as well as their research, communication and resource-management skills. These are all 21st century learning skills (cf. 2.2). Research has indicated that teachers who make use of project-based learning develop a greater meta-cognitive awareness, creativity and a critical reflection in their teaching (Yeong & Ng, 2008:111).

While project-based learning is a pedagogical approach that can involve the entire class, inquiry-based learning is a practical approach to learning where learners form their own questions about a topic and then their own answers. The next section focuses on how inquiry-based learning can assist in the problem-solving process.

3.9.3 Inquiry-based Learning

Inquiry-based learning (IBL) encompasses a number of teaching methods, such as problem-based learning, project-based learning, investigations and research (Whitton & Moseley, 2012:10). All these activities are centred around a process of meaningful investigation.

It is described as inquiry-based learning as a practical approach that involves learners constructing their own questions about a certain topic and then exploring their answers (Rushton, 2008:5). Question formation is part of the plan and problem solving is part of the outcome. When learners are engaged in inquiry-based learning, ownership and responsibility are encouraged as learners search and construct knowledge and its meaning through different research methods and resources. This can be a very useful teaching strategy especially with the theoretical content part of CAT.

Example of inquiry-based learning

The teacher pose a question related to theory (different kinds of computers – what kind of computer is used by NASA?) and learners must do an Internet search and create a mindmap of the information that they obtained.

Inquiry-based learning activities begin with a question, followed by investigating solutions, creating new knowledge as information is gathered and understood, discussing discoveries and experiences, and reflecting on new-found knowledge (Savery, 2006:16). Wolsey and Grisham (2012:128) point out that the act of inquiry transforms knowledge through encounters with essential questions, multiple sources of information representing many different perspectives. Alvarado and Herr (2003:30–36) outline that this entails learners being more involved, they reflect, ask questions, identify and formulate problems, and they form their own theories. They mention three types of questions that can be used. Initial questions (asked to get the lesson going), guiding questions (to keep learners focussed on the content) and follow-up questions (which reunite learners following the learner-centred, individual inquiry stage). These questions can be described as follows:

- Initial questions cannot simply have a yes or no answer. Initial questions explore higher-level thinking and they are flexible.

Example of System Technology: Types of computers

CompuSave Bank is a new emerging bank that needs to purchase computers. Do you think that they will need the same type of computer as what you are using at home? Give some characteristics that must be taken into account to determine the type of computers that the bank must purchase? (Answer: Characteristics of mainframe computers)

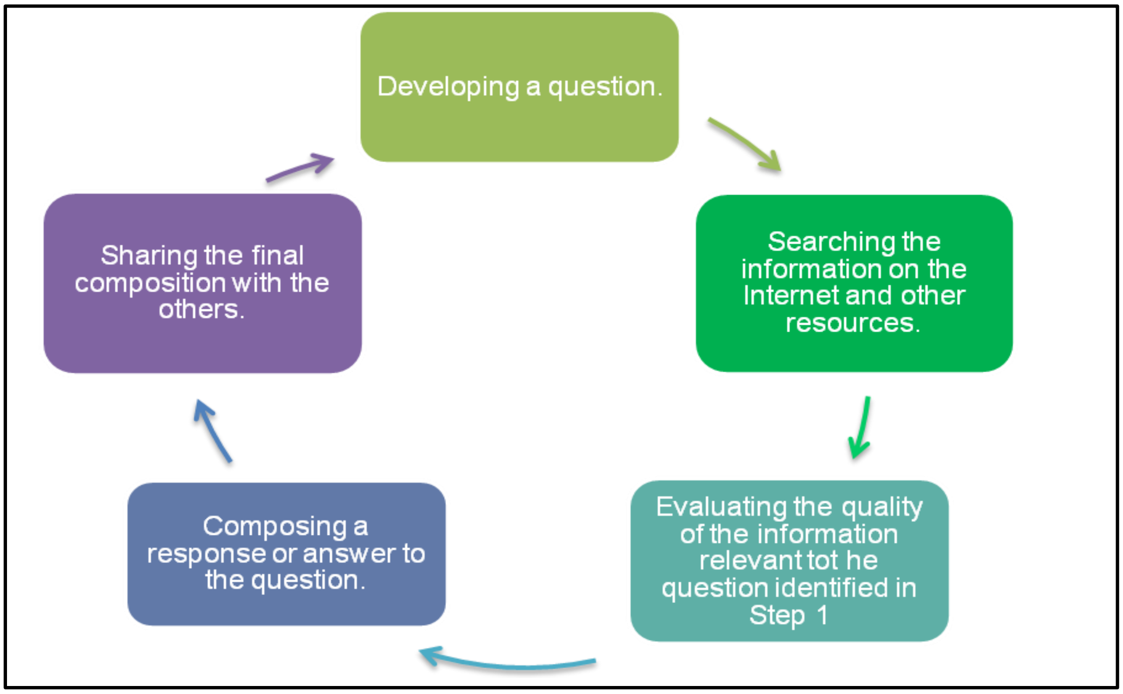
- Guiding and follow-up questions will keep learners focused on the content for their task.

Example of guiding and follow-up question

Do you think the characteristics of a mainframe computer is different from other types of computers? Can you explain how mainframe computers differ from other types of computers such as personal computer of super computers?

Teachers must be encouraged to give learners the opportunity to use Internet inquiry to explore content topics (Wolsey & Grisham, 2012:127-128). The possibility of exploring a topic in depth engages learners in content learning and knowledge transformation that result in enduring understanding. Internet inquiry consists of five phases as described by Leu (2004):

Figure 3.7: Internet Inquiry



Adapted from: Leu (2004)

The process of asking questions, determining appropriate sources to obtain the answers, evaluating the different sources, and synthesising ideas from them leads to the opportunity to transform that knowledge. Search engines such as Google and media sharing repositories such as YouTube can all be used to support IBL. Teachers must therefore provide the opportunity for learners to use the Internet (and have Internet available in the CAT classroom) and other digital sources. These sources can be used to explore the domain content, instead of just using a prescribed textbook (Conole, 2012a:275).

It is important for teachers to provide time in the lesson for learners; they must allow learners to have a certain amount of time for finding the relevant information. This can be very time-intensive. Teachers must also provide scaffolding assistance which may often be done by means of a guiding worksheet for leading learners through the inquiry process (Woolf, 2009:302).

3.9.3.1 Benefits of Inquiry-based Learning

Inquiry-based learning has many educational benefits for example it improve the learners' reasoning ability and the ability to acquire new knowledge as the increased interactivity increases learning. Inquiry-based learning also allows learners to plan, manage, analyse and communicate the results of their learning (Woolf, 2009:300).

Teachers can use the teaching strategies discussed in paragraphs 3.9.1, 3.9.2 and 3.9.3 to ensure that learners are involved in active problem solving in the CAT classroom. However, it is important for teachers to distinguish between an activity or exercise and a problem. The next section focuses on the difference between a problem and an exercise.

3.10 SOLVE AN EXERCISE OR SOLVE A PROBLEM?

Teachers must be aware that very often in classes learners are presented with information and examples and then learners must solve a problem to show their understanding of the information (Killan, 2010:207). Many of these so-called problems often have only one correct answer; Killan (2010:207) therefore refers to these activities as exercises and not real problems. It is thus important for teachers to understand that activities or exercises given to learners to reinforce knowledge and understanding must not be regarded as problems to be solved, but merely as exercises.

There is a definite difference between solving an exercise and solving a problem. (Crebert, Patrick, Cragnolini, Smith, Worsfold & Webb, 2011:5). When learners solve an exercise, they are expected to follow specific steps or they know which formula to use to reach a specific predetermined answer. To solve a problem means there is no definite answer; it is open-ended and not straightforward. The National Research Council

(2000:63) concurs by stating that learners who were trained on specific task components without being provided with the principles underlying the problems could do specific tasks well, but they could not apply their learning to new problems.

Teachers must to be able to differentiate between a problem and an exercise (Sutton, 2003). If a learner already knows the algorithm (steps) to get to the answer, or if the learner understands the conceptual structure of the task, then it is an exercise and not a problem. Although exercises are an important first step in bridging the gap between theory and application, Mourtos, De Jong Okamoto and Rhee (2004:1) assert that merely doing exercises from a textbook will not provide the complexity and depth necessary to master problem-solving skills. Teachers who only let learners learn from exercise solving, handicap their learners, as they rely heavily on solutions they have seen before. So a problem with a brand new context presents a formidable challenge to them.

In *Table 3.8*, on the next page, Mourtos *et al.,* (2004:10) try to distinguish between exercise solving and problem solving. It is also very important for teachers to make learners aware of the differences between exercise solving and problem solving.

Table 3.8: Differences between exercise solving and problem solving

Exercise solving	Problem solving
A process used to obtain the one and only right answer for the data given.	A process used to obtain a best answer to an unknown, subject to some constraints.
The learner has come across similar exercises in textbooks, in class or in homework.	The learner has not encountered this situation before; it is all new.
Learners are helped in a way that the exercise gives tips, rules to be used or even give prescriptions.	There is nothing in the problem statement that will guide the learner to what skill, knowledge or technique he or she must use to solve the problem.
The usual method is to recall familiar solutions from previously solved exercises.	The algorithm for solving the problem is unclear.
Communication skills are not essential.	To get to the result of the problem, the learner must have oral and/or communication skills.

Mourtas *et al*. (2004:10)

From the table above it is clear that a problem-solving task is one that engages the learners in thinking about and developing the important skills that they need to acquire competence in CAT. This is in contrast with the stereotypical approach to teaching where teachers explain a concept, skill or a function, provide an example and then drill the learners on similar examples.

It is therefore obvious that teachers should make an effort to ensure that activities are developed in such a way that they will assist learners to develop their problem-solving skills.

3.11 DESIGNING PROBLEMS FOR LEARNERS TO SOLVE

Guidelines are suggested for teachers to ensure that the activities or tasks they set develop learners' problems solving skills (Crebert *et al.,* 2011:9). The activities must be authentic, have real-world value and solvable. Activities should challenge learners' understanding and skills that are important in the subject's content domain. Through problem solving learners must become aware of other skills (such as teamwork, communication and analytical skills) that they need during the problem-solving process. The teacher must steer and support learners who are beginners (such as Grade 10 learners) in this process.

Arends and Kilcher (2010:330) agree with Crebert *et al.* (2011:9) and add these guidelines for teachers to ensure that all set activities are effective problems. Activities must be ill-structured and disorganised. This will lead to complex problems with many issues and sub-issues that have different solutions. Teachers must ensure that problems are relevant to the learners' lives and society. Activities should give learners the opportunity to think critically and creatively and to practise research, writing, problem solving, and decision-making and communication skills.

Once teachers have developed or designed an activity as a problem-solving activity, they must also consider different factors in the classroom that may influence problem solving in that classroom.

3.12 FACTORS INFLUENCING THE IMPLEMENTATION OF PROBLEM-SOLVING IN THE CLASSROOM

Learners need to develop the ability to apply problem-solving skills when faced with issues or problems that are new to them. The development and use of problem-solving skills also improve learning (Marquardt, 2012:140-141). In the paragraphs that follow the different factors that can influence problem solving in the classroom are discussed.

3.12.1 Roles of teachers and learners during problem solving

It is not always easy for teachers to implement problem solving in a CAT classroom. Cai and Lester (2010:4) mention that the implementation of meaningful and useful problems in the CAT classrooms may be hampered. One of the biggest issues to them is the amount of time that teachers allocate to solving and discussing the problem. Wolsey and Grisham (2012:19) are convinced that when teachers rush to “cover” the curriculum, learners are not provided with deeper learning and an application of the domain content knowledge.

It is not uncommon for learners to believe that problems are solvable with little or no thinking (Black, Harrison, Lee, Marshall & William, 2005:32-35). They observed that teachers prevent learners from taking part in discussions in the classroom. When teachers ask questions, they expect an immediate response. They stress that it is important for learners to be given enough time to answer a question. When answers cannot be given, teachers should ask more questions – thus leading the learners to engage in thinking and producing the correct answer.

Studies conducted in the USA show that teachers often take over the learners’ thinking and reasoning skills in challenging computing tasks by telling them how to solve the problem (The National Council of Teachers of Mathematics, 2010:4). The researcher knows from experience that this happens quite often in the CAT classroom. The NCTM further states that many teachers believe it is their calling to remove the challenge and the problem for learners. Instead of leading learners through different problem-solving strategies, teachers indicate how to solve the posed problems.

The researcher agrees with The national Council of Teachers of Mathematics that, for learners to learn problem solving, they must productively struggle with computing. Because of this, it is important that learners must know how to use technology. The next section discusses the role of technology in problem solving.

3.12.2 The role of technology in problem solving

Teachers must realise that if they want to improve the problem-solving skills of learners, the comprehensive use of new technologies in the classroom is essential. The process of learning in the classroom can become significantly richer; if learners have access to new and different types of information, they can manipulate information on the computer through graphic displays or controlled experiments in ways never before possible, and can communicate their results and conclusions in a variety of media to the teacher, learners in the next classroom or learners around the world (Moeller & Reitzes, 2011:9-11).

By introducing different technologies into the classroom, the teacher assists learners to become accomplished users, information explorers, problem solvers and decision makers. Voskoglou and Buckly (2012:35) point out that the use of suitable software packages, Smartboards, videos and so on increases learners' resourcefulness and encourages them to find solutions to posed problems. They mention, however, that the type of problem and learners' level of cognitive and physical development will prescribe the need for technology skills. The diverse learner population in classes challenges teachers to see how domain knowledge (especially theoretical CAT content) may be provided (Wolsley & Grisham, 2012:19).

The two criteria for technology in education that is needed to prepare lifelong learners and learners that are effective and successful in the workplace are:

(1) The teacher must ensure that communication, connectivity and collaboration are an integral part of the learning process.
(2) Along with this, teachers must keep in mind that, with the help of technology, learners can learn from any place at any time – not necessarily just in the classroom (Software and Information Industry Association, 2010:17).

It is thus clear that it is important for CAT learners to have access to technology. Besides the traditional computer lab, teachers must think innovatively to allow access to technology. Teachers must consider the degree to which learners are permitted to use school and personal technologies – this is especially of value in schools where there is no Internet access. Wolsey and Grisham (2012:4) assert that learners should be allowed to bring iPods, MP3 players and cell phones to class. Teachers must also explore how best to implement bring-your-own-technology (BYOT) – otherwise known as BYOD (Bring your own device), because learners might have more powerful computers in their cell phones, iPads and netbooks (Ullman, 2011:54-57). Teachers should permit these devices within reason and when these are combined with the school technology, these tools can be powerful learning devices when learners are taught how and when to use them.

3.12.3 The role of basic computer skills in problem solving

If teachers want to develop and improve problem-solving performance, Hartman (2002:51-53) suggests that teaching the basic skills is important. Every necessary skill must be taught to be mastered. When teachers start teaching a word processing program, they teach learners how to save and open a document, how to move the cursor, how to insert and delete text and so on. A demonstration of every skill is given by the teacher, and then the learners are asked to solve a problem or exercise requiring that skill. Through experience the researcher knows that this is how teaching occurs in the CAT classroom. The word processing package is broken down into skill components, and then the teacher teaches every skill methodically to mastery.

Research that was conducted shows that if a teacher wants learners to use databases effectively, the different skill components of database must be taught (Chen, 2010:180). The database package must be broken down into the different required skill components. For learners to master these database skills, they must understand and achieve representation of database computerisation at three levels.

- First level: Factual knowledge of how to perform database procedures. These are the steps required to complete a procedure. To create a record, there must be different fields. Every field has its own field properties.

- Second level: Procedural knowledge of the functionalities of a database application. Learners must know why and when to use a certain function (calculation) or a procedure (query).
- Third level: This is the problem-solving process.

It is crucial for learners to master the skills at all three levels if they want to succeed at problem solving. Hartman (2002:52) agrees with Chen that, even though teachers often succeed in teaching specific skills to mastery, every now and then they fail to support problem solving transfer. He warns teachers that the narrow focus on the mastery of particular skills can confine the way that learners apply what they have learnt to new situations.

It is thus clear that if teachers want learners to use software applications for problem-solving, learners must be skilled and experienced in applications as well as in problem solving.

3.13 PROBLEM-SOLVING IN COMPUTER APPLICATIONS TECHNOLOGY

It is stated in the CAPS document that learners must use appropriate applications packages such as word processing, spreadsheet and presentation application to solve a variety of problems (DBE, 2011a:10, 12, 51). The researcher is therefore of the opinion that it is important for teachers to know how to use these applications in fostering critical thinking and problem-solving skills.

3.13.1 Spreadsheets as a problem-solving tool

Nowadays electronic spreadsheets have replaced the need to rely on programming languages and have become the predominant method for application programming where learners as end-users have become spreadsheet programmers.

Teachers can use spreadsheets as a cognitive tool in the classroom to give learners the necessary competency to solve problems, to develop representations and to investigate data (Hoag, 2008:1). Hoag (2008:59) further reports that from a project that was designed by Rutledge and Rhea it was determined that the upper four levels of Bloom’s taxonomy were associated with spreadsheet activities:

- Application – enter data and print numerical and/or graphic report.
- Analysis – compute calculations, develop reports.
- Synthesis - analyse data, examine cause and effect, make predictions, discuss “what-if”.
- Evaluation – perform a simulation, modify parameters, experiment with different data, discuss impact of the parameters involved, reach conclusions, develop or refine a model, develop recommendations or guidelines, reach decisions.

Teachers can teach the development of spreadsheets in a variety of ways namely formal teaching where the teacher is the instructor, by making use of textbooks and other written material, tutorials or even from peers (Baker, Powell, Lawson & Foster-Johnson, 2006:214). Teachers must be aware that, according to Hoag (2008:3), the goal of spreadsheet teaching is first to develop the required spreadsheet skills (as set out in the CAPS document), and secondly to develop an understanding for the problems that they are solving, with the mathematical and spreadsheet concepts that are involved, and the development of the solution or answer. If spreadsheets are used as a cognitive tool, it supports the construction of knowledge within the applicable learning background (Lavidas, Komis & Gialamas, 2011:2). Thus, to them, the most effective learning properties of a spreadsheet are the interactive manipulation of data, the decision-making properties and the multiple representations of a problem; therefore spreadsheets are very effective in solving computable problems.

Teachers might find that learners have problems in translating situations (the PAT) or problems (spreadsheet exercise or spreadsheet examination) into a spreadsheet format or presentation. According to Hoag (2008:58), this is equivalent to decoding word problems into mathematical representations. A problem given to CAT learners must often be translated into a transitional mathematical representation prior to being implemented into a spreadsheet representation.

Owing to the flexibility of spreadsheet programs, they can be used in many different ways in the classroom. The Science Education Resource Centre (2012) mentions that teachers can construct spreadsheets in one of two ways:

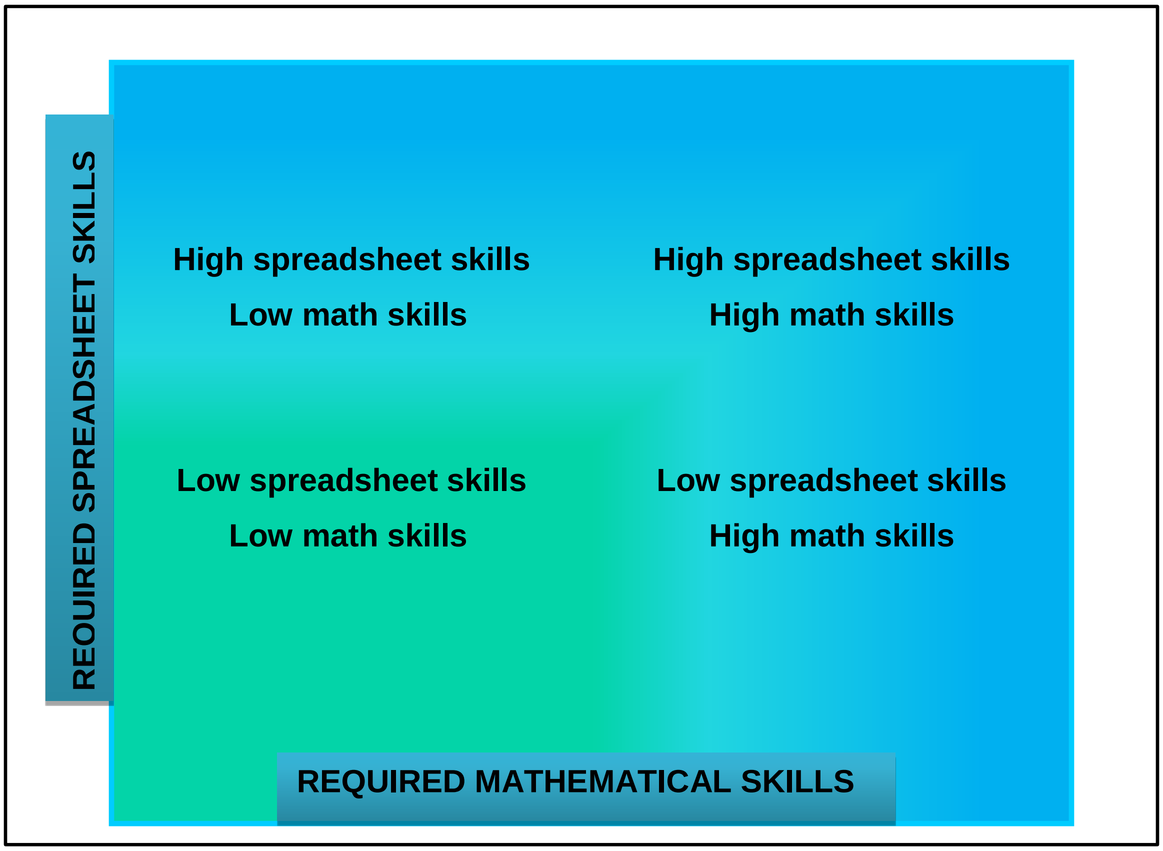
(1) Learners are required to understand and apply mathematical concepts or the mathematics can be hidden.
(2) Learners are required to learn and use sophisticated spreadsheet programming skills or the work may be done for them.

The discussion put forward by Cahill and Kosicki (2001:770-792) focuses on the aspect that spreadsheet exercises can be varied in two dimensions:

(1) the difficulty of spreadsheet programming skills that learners need; and
(2) the level of mathematics that learners need.

Figure 3.8, on the next page, shows how a teacher can create four different types of exercises or activities (Cahill & Kosicki, 2001:770-792).

Figure 3.8: Options for assignments along two dimensions in spreadsheets

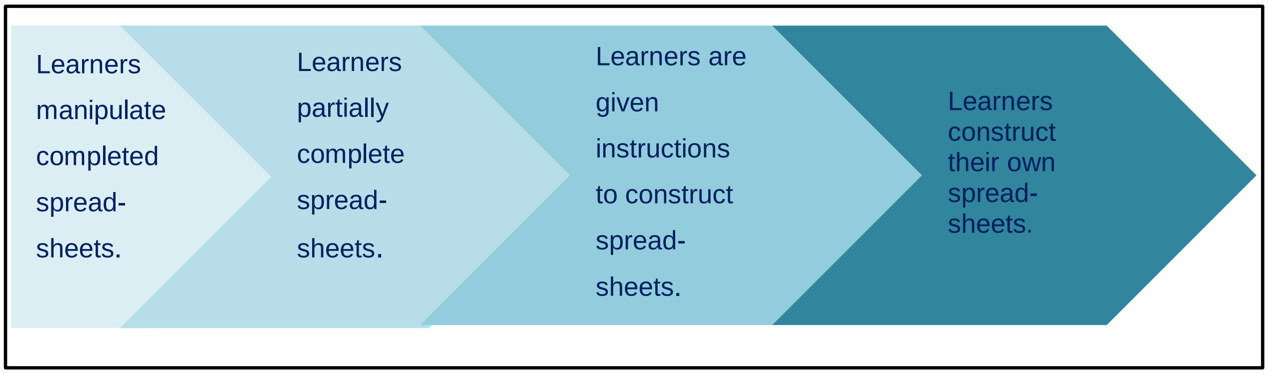


Adapted from: Cahill and Kosicki (2001:181)

Figure 3.8 portrays how the levels of transparency may be used at different levels of assistance. When a CAT teacher creates an exercise or activity, different levels of assistance may be given, from nothing (in other words, a blank file) to detailed instructions or incomplete or completed worksheets.

To save time, spreadsheets with detailed instructions or partially or fully completed files are very often given to learner. It is important for the researcher to mention that the learners who use spreadsheets are often referred to as end-user programmers. Spreadsheets are easier to code than many other standard programming languages. However, for learners to create a spreadsheet requires a level of know-how, careful analysis and persistence. It is therefore important that teachers teach these critical skills. Teachers must make sure that the given activities or exercises require a variety of spreadsheet and problem-solving skills. Cahill and Kosicki (2001:770-792) use the following diagram (*Figure 3.9*) to show teachers how the spreadsheet skills can be varied in activities or exercises.

Figure 3.9: Options for varying spreadsheet skills in assignments



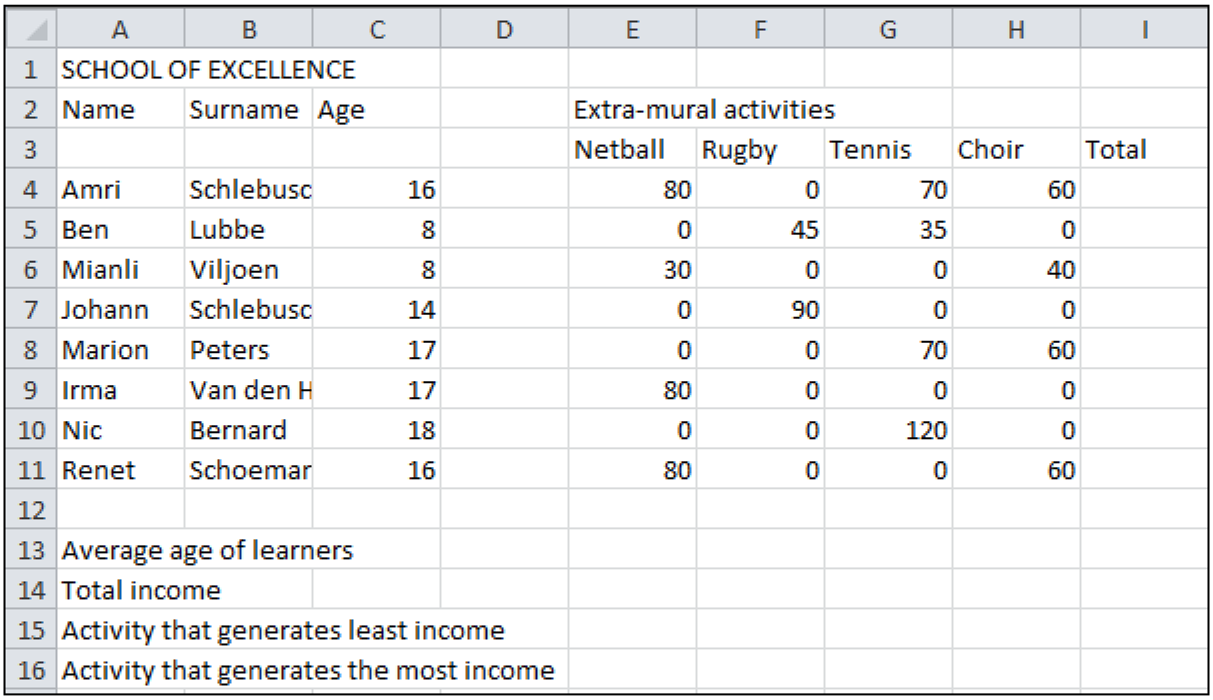
Adapted from: Cahill and Kosicki (2001:187)

Teachers should start off with a completed spreadsheet that learners must simply manipulate. This is an exercise/test/activity and not a problem. Learners need procedural knowledge to do this.

Example 1

The researcher designed a constructed spreadsheet activity/exercise that learners must manipulate to complete the spreadsheet. Learners retrieve the following file thatcontains the spreadsheet document as seen in *Figure 3.10* on the next page, and carry out the instructions given by the teacher.

Figure 3.10: Example of PBL spreadsheet activity



	A	B	C	D	E	F	G	H	I
1	SCHOOL OF EXCELLENCE								
2	Name	Surname	Age		Extra-mural activities				
3					Netball	Rugby	Tennis	Choir	Total
4	Amri	Schlebusc	16		80	0	70	60	
5	Ben	Lubbe	8		0	45	35	0	
6	Mianli	Viljoen	8		30	0	0	40	
7	Johann	Schlebusc	14		0	90	0	0	
8	Marion	Peters	17		0	0	70	60	
9	Irma	Van den H	17		80	0	0	0	
10	Nic	Bernard	18		0	0	120	0	
11	Renet	Schoemar	16		80	0	0	60	
12									
13	Average age of learners								
14	Total income								
15	Activity that generates least income								
16	Activity that generates the most income								

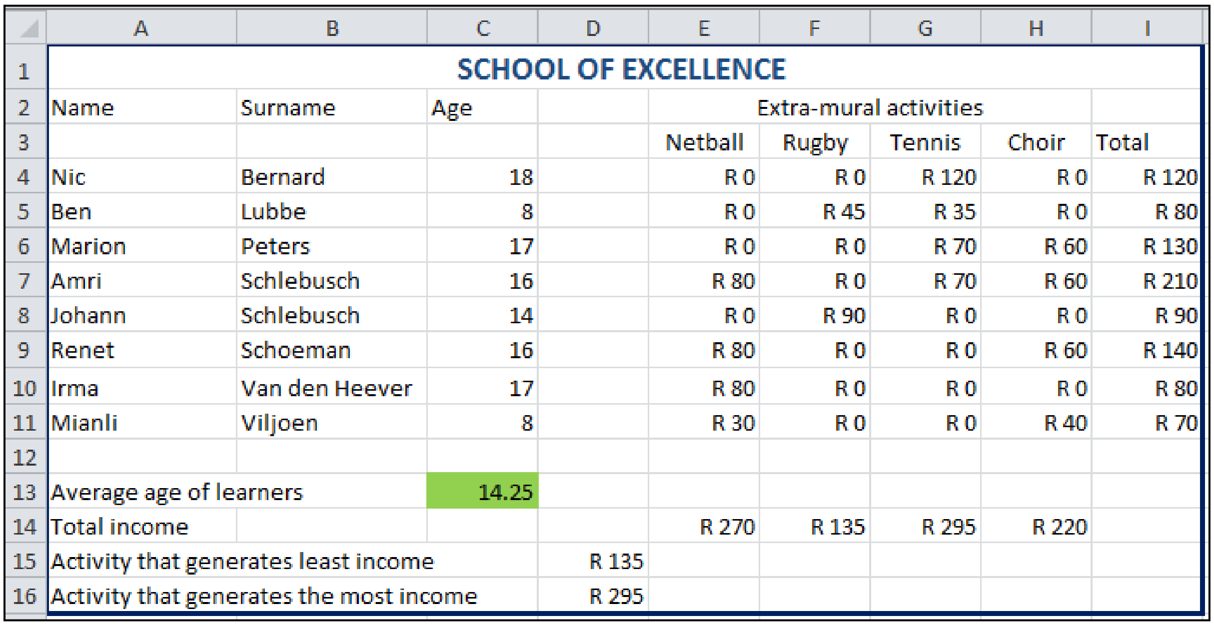
Instructions to learners

1. Merge cell A1:I1. Change the font to bold, 14 pt and a blue font colour.
2. Change the column width of column A:B to 15.
3. Merge cell E2:H2.
4. Centre the different activity names in cells E3:H3.
5. Sort the learners in alphabetical order according to their surnames.
6. In cell I4 calculate the total amount that Amri must pay for the term. Copy this formula down to all the other children.
7. In cell C13 calculate the average age of the learners. Format the answer to zero decimals. Fill this cell with a light green colour.
8. In cell E14 calculate the total income generated from netball. Copy this formula to all the other sports.
9. In cell D15 display the lowest amount that was generated by the different activities.
10. In cell D16 display the highest amount that was generated by the different activities.

11. Format all the amounts under Extra-mural activities to South African Rand with no decimal places.
12. Border the spreadsheet with a thick dark blue border.

The correct answer file or marking memorandum is given as *Figure 3.11*.

Figure 3.11: Solution for a PBL spreadsheet activity

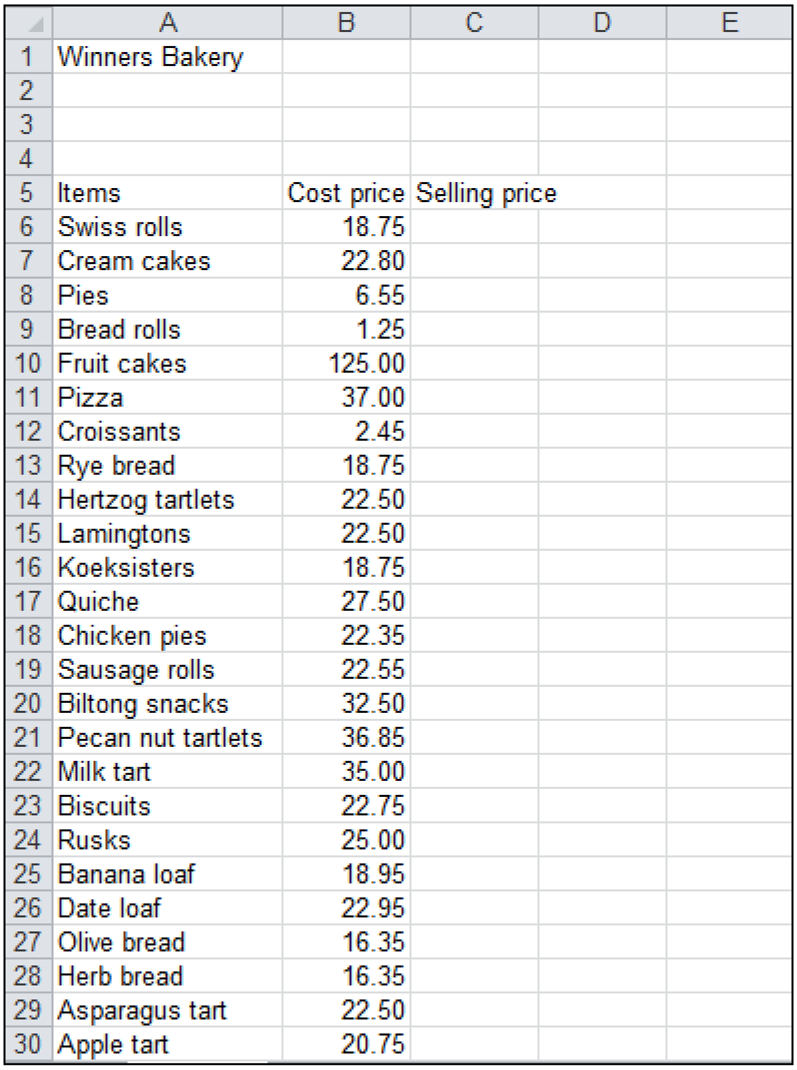


	A	B	C	D	E	F	G	H	I
1	SCHOOL OF EXCELLENCE								
2	Name	Surname	Age		Extra-mural activities				
3					Netball	Rugby	Tennis	Choir	Total
4	Nic	Bernard	18		R 0	R 0	R 120	R 0	R 120
5	Ben	Lubbe	8		R 0	R 45	R 35	R 0	R 80
6	Marion	Peters	17		R 0	R 0	R 70	R 60	R 130
7	Amri	Schlebusch	16		R 80	R 0	R 70	R 60	R 210
8	Johann	Schlebusch	14		R 0	R 90	R 0	R 0	R 90
9	Renet	Schoeman	16		R 80	R 0	R 0	R 60	R 140
10	Irma	Van den Heever	17		R 80	R 0	R 0	R 0	R 80
11	Mianli	Viljoen	8		R 30	R 0	R 0	R 40	R 70
12									
13	Average age of learners		14.25						
14	Total income				R 270	R 135	R 295	R 220	
15	Activity that generates least income			R 135					
16	Activity that generates the most income			R 295					

Example 2

Learners retrieve a file that contains a partially completed spreadsheet as seen in Figure 3.12 and follow instructions in completing the spreadsheet. Matthews and Loots (2010:27) designed such an activity. Below is a partial screen print of the file the learner must retrieve.

Figure 3.12: Example of PBL partially constructed spreadsheet activity



	A	B	C	D	E
1	Winners Bakery				
2					
3					
4					
5	Items	Cost price	Selling price		
6	Swiss rolls	18.75			
7	Cream cakes	22.80			
8	Pies	6.55			
9	Bread rolls	1.25			
10	Fruit cakes	125.00			
11	Pizza	37.00			
12	Croissants	2.45			
13	Rye bread	18.75			
14	Hertzog tartlets	22.50			
15	Lamingtons	22.50			
16	Koeksisters	18.75			
17	Quiche	27.50			
18	Chicken pies	22.35			
19	Sausage rolls	22.55			
20	Biltong snacks	32.50			
21	Pecan nut tartlets	36.85			
22	Milk tart	35.00			
23	Biscuits	22.75			
24	Rusks	25.00			
25	Banana loaf	18.95			
26	Date loaf	22.95			
27	Olive bread	16.35			
28	Herb bread	16.35			
29	Asparagus tart	22.50			
30	Apple tart	20.75			

Instructions to learners

1. The figures provided are actually the SELLING PRICE of the items, not the cost price. Move the figures to the Selling price columns and arrange the items in alphabetical order.
2. You need to calculate the actual cost price if the selling price has been calculated according to a 70% profit margin. TIP: Copy the list of prices to sheet 2 where you will find the factor (cell B2) to use for the calculation of the cost price. Use this cell as an absolute reference.

3. Return to the Cost price column on sheet 1 and use the ROUND function to round off the cost price figures to two decimals. You need to link these cells with the cost price column on sheet 2.

4. Add the following column headings:

4.1 Column D: Sale

4.2 Column E: Discount price

4.3 Column F: Expiry date

5. Formatting the spreadsheet:

5.1 All column headings must be bold and text wrapped.

5.2 Row 5 height: 30 and row heights of all others: 15

5.3 Columns B and C: right aligned

5.4 Columns D:F: centred

5.5 Left and right margins: 3 cm

5.6 Centre horizontally and vertically on page.

5.7 Main heading: Merge A1:F3 and change to decorative font, 24 pt, centre.

5.8 You should have an open row (row 4) before text begins, if you followed these instructions correctly.

5.9 Add borders around all cells in use (A5:F36).

6. This week there are certain items on sale – all items that cost R25 or more. These items must be identified by the appearance of the word SALE in column D, next to the selling price of the item. Use a logical function.

7. The sale items are all going to be sold at 20% discount. Show the discount price in column E next to the specific item. Use a logical function.

8. Another reason for the sale is that the shelf life of these items all expires in 4 days' time. Use column F and the IF function together with TODAY () to insert the expiry date (descending format) next to the applicable items.

9. Calculate the average cost price (B40) and the average selling price (C40) and see if the percentage mark-up is really 70% (D40).

10. How many items (B41) are available at Winners Bakery?

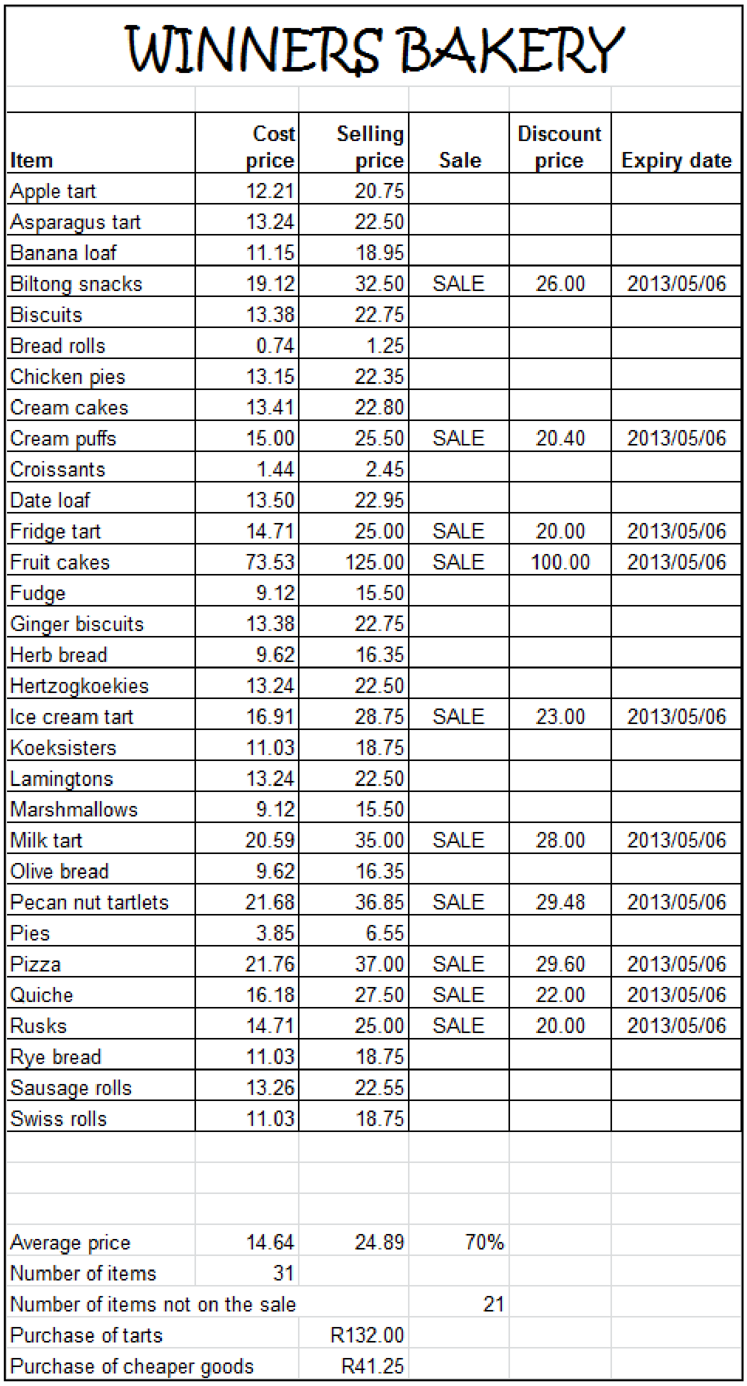
11. How many items (D42) are not on sale?

12. A customer comes into the bakery and enquires how much it would cost her to buy all tarts (excluding 'tartlets') available (one of each). Work it out for her, and

place your answer (in Rand) in cell C43. Use the selling prices, not the sale prices, in your calculation.

The correct answer file or marking memorandum is given as *Figure 3.13* on the next page.

Figure 3.13: Solution for a PBL spreadsheet activity



WINNERS BAKERY

Item	Cost price	Selling price	Sale	Discount price	Expiry date
Apple tart	12.21	20.75			
Asparagus tart	13.24	22.50			
Banana loaf	11.15	18.95			
Biltong snacks	19.12	32.50	SALE	26.00	2013/05/06
Biscuits	13.38	22.75			
Bread rolls	0.74	1.25			
Chicken pies	13.15	22.35			
Cream cakes	13.41	22.80			
Cream puffs	15.00	25.50	SALE	20.40	2013/05/06
Croissants	1.44	2.45			
Date loaf	13.50	22.95			
Fridge tart	14.71	25.00	SALE	20.00	2013/05/06
Fruit cakes	73.53	125.00	SALE	100.00	2013/05/06
Fudge	9.12	15.50			
Ginger biscuits	13.38	22.75			
Herb bread	9.62	16.35			
Hertzogkoekies	13.24	22.50			
Ice cream tart	16.91	28.75	SALE	23.00	2013/05/06
Koeksisters	11.03	18.75			
Lamingtons	13.24	22.50			
Marshmallows	9.12	15.50			
Milk tart	20.59	35.00	SALE	28.00	2013/05/06
Olive bread	9.62	16.35			
Pecan nut tartlets	21.68	36.85	SALE	29.48	2013/05/06
Pies	3.85	6.55			
Pizza	21.76	37.00	SALE	29.60	2013/05/06
Quiche	16.18	27.50	SALE	22.00	2013/05/06
Rusks	14.71	25.00	SALE	20.00	2013/05/06
Rye bread	11.03	18.75			
Sausage rolls	13.26	22.55			
Swiss rolls	11.03	18.75			
Average price	14.64	24.89	70%		
Number of items	31				
Number of items not on the sale			21		
Purchase of tarts		R132.00			
Purchase of cheaper goods		R41.25			

It is important for teachers to decide on the trade-offs between the time that learners must spend on the construction of the spreadsheet and the core content of the assignment (Cahill & Kosicki, 2001:770-792).

Examples 1 and 2 were typical exercises or activities that teachers can use in class to master skills. Example 3 is what a problem should look like. From a specific scenario (real-life), learners are requested to construct a word processing document and a spreadsheet.

Example 3

Learners are given instructions to construct a spreadsheet.

Scenario

The school will be hosting a Grade 10 Spring Dance. The principal decided that learners who have behaved well all year will be invited.

It will be at the Town Hall.

It will start at 18:30 on 4 September 2014.

Learners can book tickets on the bus to go to the venue.

The bus leaves at 17:50 from the school and returns to the school at 22:30.

Any dietary requirements must be specified.

Learners will receive a 15% discount if they have attended revision classes.

Problem 1: Data capture form

You need to create a data capture form with your word processor. This is to help you gather information for the spreadsheet and the database. It must include the learners':

- *Name*
- *Address*
- *Phone number*
- *E-mail address*
- *Dietary requirements*
- *Parent/guardian names and contact details*

Additional information required:

- *Will the learners book a seat on the bus?*
- *Did the learners attend revision classes?*
- *Have learners paid for the Spring Dance two weeks beforehand?*

Problem 2: Spreadsheet

You have been asked to create a spreadsheet which shows the cost of attending the Spring Dance for every learner. The cost per learner will differ depending on the following factors.

- *Learners can prepay for a cold drink package if they wish. This costs R25 per person, but means they do not have to pay for any further cold drinks. It is not compulsory for learners to purchase this if they do not want to.*
- *Learners can buy a bus ticket to get to the venue. This is R10 per person, but learners do not have to purchase this if they do not want to.*
- *If learners attend revision classes the school gives them a 15% discount.*
- *All other costs are fixed.*

COSTS (per learner)	
Ticket (includes DJ)	R50
Meal ticket	R30
Hiring of costume	R70
Cold drinks (optional)	R25
Bus ticket (optional)	R10
Revision class discount	15%

Your spreadsheet must:

- Include the learners' names, ticket cost, meal cost, and costume hire, bus ticket (optional), cold drinks (optional) and the 15% discount if the learner has attended the revision classes.
- Show how much attending the Spring Dance will cost a learner.
- Show whether the learner has received a discount for revision classes.

- Tell learners and the school if they have paid in full or have money left to pay.

3.13.2 Problems in problem solving with spreadsheets

The researcher is of the opinion that when learners construct a spreadsheet or complete a spreadsheet, they may have copycatted a worked out example without understanding the underlying concepts. Learners may think that they understand the problem and the solution, but they misinterpret either or both. Learners will often believe that their answers are correct, because the computer produced the answer.

When learners do not have sufficient domain knowledge, research conducted by Hoag (2008:34) shows that mistakes and misinterpretations may occur. The following mistakes are common when learners lack knowledge:

- Learners do not understand spreadsheet concepts; they do not understand the difference between a constant value and reference to a cell containing a constant value.
- Fragmentary knowledge of spreadsheet operations; the side-effect in inserting an area into a spreadsheet.
- Inability to develop an answer for a difficult cognitive problem.
- Errors in mathematical models underlying the spreadsheet implementation of formulae.

It is important for teachers to understand that when learners have to create a spreadsheet, they might experience a number of difficulties (Hoag; 2008:42):

- If the spreadsheet formulae closely match the requirements of the problem domain, creating cell formulae is easy for learners.
- If problems appear to be simple, but they cannot be easily solved as it requires a combination of functions.
- The solution to the problem may require specialised spreadsheet functions that may have no place in the learner's knowledge of how to solve the problem within the domain of work.

- When learners combine several cell referencing techniques, it gives them the opportunity for implementing computational structures.
- Very often learners use the wrong referencing technique and then obtain wrong answers, so teachers must make sure that learners are attentive to check cell referencing.
- Learners may also have trouble in spotting mistakes and debugging formulae.

Once a learner has completed a problem-solving activity as discussed, the teacher must assess the problem. The next section deals with assessment of problem solving in the CAT classroom.

3.14 ASSESSMENT OF PROBLEM-SOLVING IN COMPUTER APPLICATIONS TECHNOLOGY

Traditional school assessment has been severely controlled by rules and regulations that leave very little room for reflective problem solving (Deno, 2013:12). Assessment plays a critical role in all aspects of teaching and learning in CAT. Assessing a learner’s work in a problem-solving environment is quite different from traditional methods of assessing computational skills (Annenberg Foundation, 2013).

Formative assessment of problem solving begins in the CAT classroom where learner reasoning is opened and where the reasoning behind the problem solutions is a routine activity (Brookhart, 2010:122). It is suggested that for both formative and summative assessment, problem-solving rubrics may be useful for organising a learner’s thinking. Brookhart (2010:122) also states that the use of general problem-solving rubrics and not a task-specific rubric must be used. This will allow learners to internalise as their goal the general strategies of identifying the problem, defining and representing the problem, exploring possible strategies, acting on the strategies, and looking back and evaluating the effects of the strategies. By using the same rubrics, learners will focus on the qualities described in the rubrics as their goal for successful problem solving. A good example of such a rubric used in CAT is the rubric that teachers currently use for the assessment of the PAT.

When problem-solving skills are assessed, teachers must look for evidence such as interpretation of the problem and that the learner has thought creatively and laterally about the problem (Crebert *et al*., 2011:30). The learner must have considered a range of alternative solutions and evaluated their worth.

Through the use of open-ended problems (that is, problems that can be solved using a variety of approaches, or problems that have multiple solutions), we give learners the opportunity to make sense of the situation and the mathematics involved. Likewise, a rich problem-solving environment provides the teacher with a variety of assessment opportunities.

Although assessment is very important, it does not form part of the scope of this study. Problem-solving assessment is mentioned as a field of further study in Chapter 6. The next section concludes the discussion presented in this chapter.

3.15 CONCLUSION

This chapter discussed problem solving in CAT. Problem-solving is a skill that all learners should possess and it should be central to any school subject curriculum. CAT can be a vehicle to instill problem-solving skills in learners.

For a learner to become a competent problem solver, certain competencies must be developed. The chapter also investigated the problem-solving skills that would contribute to developing a good problem solver. From the literature it is also clear that problem solving requires critical thinking from learners – a skill that is important in computational thinking.

Problems may be defined as ill-defined or well-defined. It is therefore important that learners must make mental associations between what they know about the problem and their existing knowledge, skills and experiences. Cognitive strategies were explored together with the different types of knowledge that learners must have to be competent problem solvers. The problem-solving process which includes understanding the problem, representing the problem and learners' experience, was investigated. Transfer of learning was also discussed as part of the problem-solving process.

The chapter looked at the implication of teaching problem solving for teachers and learners. Bloom's revised digital taxonomy can be implemented by CAT teachers to ensure that they include digital thinking skills. If teachers are confident with the different key terms in the revised digital taxonomy, they can assist learners in developing from lower-order thinking skills to higher-order thinking skills. Examples of how the taxonomy can be integrated in the CAT classroom are provided.

Three teaching strategies (problem-based learning, project-based learning and inquiry-based learning) as problem-solving teaching strategies are investigated. It is important that teachers differentiate between an exercise and a problem when assignments/tasks are given in class, the literature review showing a distinct difference between the two. It is further important that teachers keep certain guidelines in mind when they prepare problems for learners to solve. Different factors in the classroom may influence the implementation of problem solving in the CAT classroom. Factors such as the role of learners and teachers during problem solving, the role of technology and the role of basic computer skills were investigated.

Finally the chapter investigated how spreadsheets could be implemented as problem-solving tools in the CAT classroom. Spreadsheets can be used as a cognitive tool in the classroom to give learners the necessary competency to solve problems.

The next chapter considers the research methods that were followed in undertaking the current study.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 INTRODUCTION

Research methodology is a way of logically and methodically answering a research problem (Bhattacharya, 2006:17-20). It is important for the researcher to choose his or her methodology and, in addition to the knowledge of methods and techniques, the methodology must also be applied.

It is essential for the researcher to know not only the research methods or techniques but also the methodology. The research methodology is a way of systematically solving the research problem (Kothari, 2006:8) and therefore deals with the different research methods while also considering the logic behind the methods employed.

Researchers need not only know how to develop certain indices or tests, how to compute the mean, the mode, the median or the standard deviation or Chi-square and how to apply particular research techniques, but they must also know which of these are relevant, what would they mean and indicate, and why (Kothari, 2006:8). Researchers must further understand the assumptions underlying various techniques and they must know the criteria by which they can decide that certain techniques and procedures will be relevant to certain problems and others not. All this means that it is necessary for the researcher to choose a methodology addressing the specific research problem, as this may differ from problem to problem (Jonker & Pennink, 2010:23).

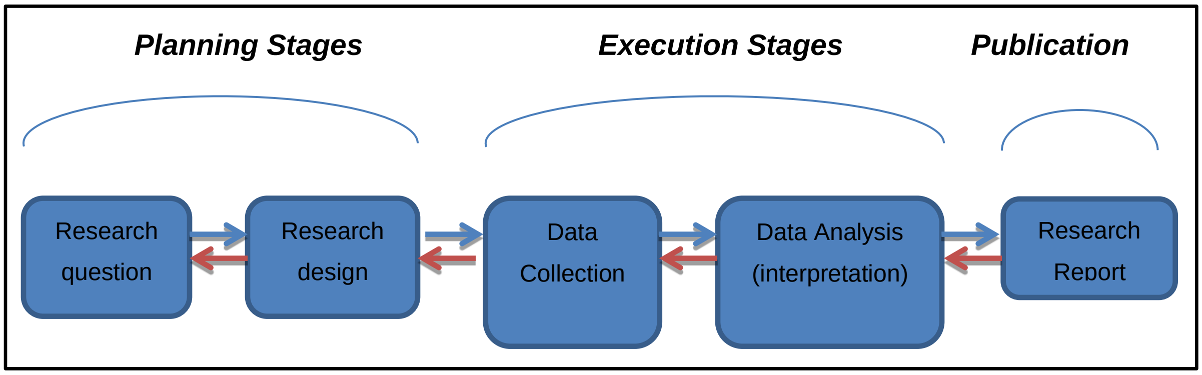
Chapter 4 deals with the research process, research design and methods. Data collection instruments, the sampling process and the analysis of data are highlighted. This chapter starts with the research process.

4.2 RESEARCH PROCESS

Research design is defined as a strategic framework for action that serves as a bridge between the research questions and the execution or implementation of the research (Durrheim, 2011:34). It may therefore be described as the plans that guide the arrangement of conditions for the collection and analysis of data in a manner that aims at combining relevance to the research purpose with economy in procedure.

Figure 4.1 shows the crucial role that the research design plays as a bridge between the research question and conducting the research.

Figure 4.1: The Research Process



Durrheim (2011:34)

For Durrheim (2011:34) the research process consists of five stages, namely:

- Stage 1: defining the research question;
- Stage 2: designing the research;
- Stage 3: data collection;
- Stage 4: data analysis; and
- Stage 5: writing the research report.

The bi-directional arrows in *Figure 4.1* indicate that the research process is constituted of a sequence of activities. The five different stages of the research process will be discussed in the rest of this chapter.

4.3 RESEARCH DESIGN AND METHODS

Research design is defined as the way in which the research is regarded and performed and how the findings are ultimately consolidated (Henning, Van Rensburg & Smit, 2004:30). Kothari (2006:7) outlines that the research method is considered as the techniques that a researcher employs for conducting the research.

To address the research questions, the researcher employed a mixed research design. To understand the mixed research design in full, the researcher deems it necessary to give a description of the three different research designs.

4.3.1 Qualitative research method

By employing qualitative research methods, Cant (2003:121) is of the opinion that the researcher focuses on an in-depth investigation, focussing on a relatively small number of individuals. Qualitative research is also called field research, critical research or interpretative research which expresses data verbally in a non-numerical form (Du Plooy, 2002:29). Hennink, Hutter and Bailey (2011:10) suggest that qualitative research is useful for exploring new topics or understanding complex issues.

Qualitative research is used to gain insight into people's attitudes, behaviour, value systems, concerns, motivations, aspirations, culture or lifestyles. Qualitative research is conducted in studies where the subject matter under investigation is new or underdeveloped and where qualitative methods can help to define terminology, concepts or subjects for investigation (Ritchie & Ormston, 2014:42).

4.3.2 Quantitative research method

Measurement and statistics are central to quantitative research because they are the connections between empirical observation and mathematical expressions of relations (Hoy, 2010:1). Furthermore, quantitative researchers are interested in understanding and exploring new ideas, and discovering patterns of behaviour.

Quantitative research is the collection and analysis of numerical data to describe, explain, predict, or control phenomena of interest (Gay *et al*., 2011:7). Leedy and Ormrod (2010:95) assert that quantitative researchers search for reasons and predictions that will generalise to other persons and places. This is done to establish, confirm or validate relationships and to develop generalisations that contribute to other theories.

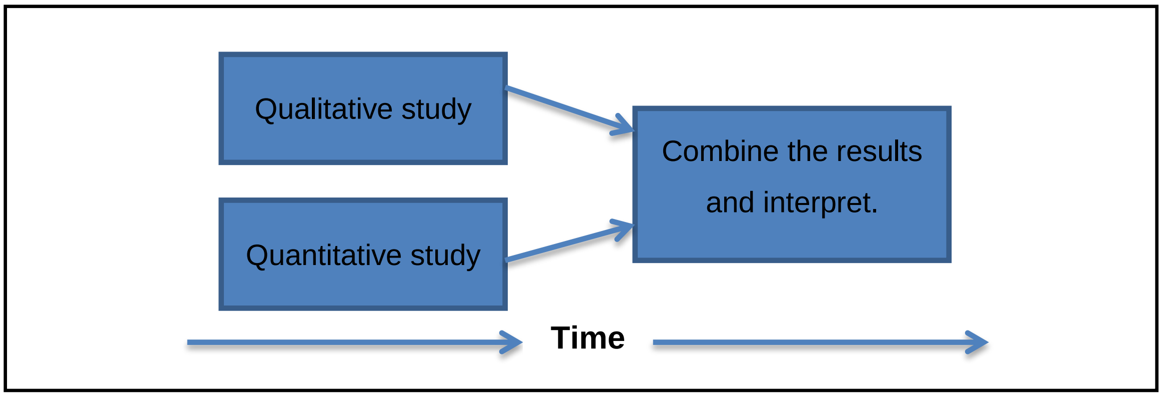
By employing the quantitative research design, deduction is usually used; that is, the research is carried out in relation to hypotheses drawn from the theory. A hypothesis is defined by Mustafa (2010:100) as a statement that is temporarily accepted as true in view of what is, at the time, known about a phenomenon, and it is employed as a basis for action in the search of new truth. He further states that it is important that the hypothesis must be stated before the researcher starts to gather data to ensure an unbiased investigation.

4.3.3 Mixed research design

There is a benefit to harnessing qualitative and statistical (quantitative) enquiry provided that the two methods and the data they provide can be clearly explained (Ritchie & Ormston, 2014:39-45). Hibberts and Johnson (2012:126) aver that this type of research, also called the QUAN-QUAL design, provides a structure for blending quantitative and qualitative research methods. For Gay *et al.* (2011:483) the purpose of a mixed research design is to build on the interaction and strength that subsists between quantitative and qualitative research methods to comprehend a phenomenon more fully than is possible when using either quantitative or qualitative methods only. By using a mixed research design, the researcher methodically use elements from both methods to collect, analyse, validate and interpret data, as proposed by Johnson and Christensen (2012:50).

Gay *et al.* (20011:486) and Fraenkel and Wallen (2010:561) refer to this method as the triangulation mixed research design. This implies that quantitative and qualitative data are weighted according to the specific research problem and are collected concurrently throughout the same study (cf. *Figure 4.2*). It is important to keep in mind that both quantitative and qualitative are given equal priority and all data is collected simultaneously.

Figure 4.2: Triangulation Design



Fraenkel and Wallen (2010:561)

The main advantage or underlying rationale for this method is that the strengths of the qualitative data (data of the context) offset the weaknesses of the quantitative data (ecological validity) and the strengths of the quantitative data (generalisability) counterbalance the weaknesses of the qualitative data (context dependence) (Denzin & Lincoln, 2011:292-294).

The researcher decided on the mixed research design based on the following rationale underwritten by McMillan (2012:318), Denscombe (2010:150) and Johnson and Christensen (2012:439):

- Triangulation is used when a researcher seeks merging and validation of results from different methods studying the same phenomenon. Triangulation also increases the credibility or trustworthiness of a research finding.

- For the purpose of expansion. The researcher attempted to expand the breadth and range of inquiry by using different methods for different inquiry components.
- A greater in-depth understanding of the research problem because of the opportunity to scrutinise multiple forms of data that are more wide-ranging than data having been collected via either quantitative or qualitative methods alone.
- The ability to answer complex research questions that cannot be addressed through the use of quantitative or qualitative methods only.
- A practical, problem-driven approach to research.

Quantitative research is used to quantify the research problem, to measure and count issues and then generalise these findings to the broader population (Hennink *et al*., 2011:17). In this study the quantitative method was used to gather data through a questionnaire relating to the education of teachers, in-service training received and answers to certain computational thinking skills and problem-solving skills. It was also used to test the relationship between problem solving and computational thinking skills. Qualitative research was used to understand or explain the behaviour and beliefs, to identify processes and understand the context of teachers' experiences (Hennink *et al*., 2011:17). This study partly employed the qualitative method with a semi-structured interview to gather data relating to problem solving and computational thinking skills.

The data collection in any research is of highly important. The different data collection instruments are discussed in the next section.

4.4 DATA COLLECTION METHODS

The sensible mixing of methods, procedures and other paradigm characteristics is an excellent way to conduct high-quality research. Tashakkori and Teddlie (2003:297) state that a method of data collection is simply a technique that a researcher employs to collect first-hand research data. Simply said, it is the way that researchers get their information.

The data collection component of research is common to all fields of study, including physical and social sciences, humanities and education. Regardless of the field of study or preference for defining data, accurate data collection is vital to sustaining the reliability of research. Both the selection of appropriate data collection instruments (existing, modified or newly developed) and clearly delineated instructions for their correct use reduce the probability of errors arising (National Academies of Sciences, 2009:33-35). A mixed research design uses a combination of quantitative and qualitative data collection methods (McMillan, 2012:146–147).

The data collection methods that the researcher used are literature review, questionnaires and interviews. The different methods are discussed in the next section.

4.4.1 Literature review

The literature review is a safety measure for the researcher from “re-inventing the wheel” (Hall, 2008:34). However, it also empowers the researcher to take benefit of the theoretical and academic development in the area in which the research is to be conducted. A literature review is the analysis of information and research-based information to create a complete, accurate depiction of the knowledge and research-based theory available on the particular topic (Dawidowics, 2010:5). The literature review is therefore used to make an evaluation of what is known about computational thinking and problem solving in the CAT subject field, ensuring then that knowledge is not assumed about relevant topics in the research.

The literature review forms a vital part of the research process as it comprises the evaluation and review of related research studies and other documents and policies, such as the CAPS document, and offers the researcher a sound knowledge of previous research work (Hartas, 2010:96-100). Diverse viewpoints and an enhanced research quality are linked to efficient literature reviews. The critical review of available literature encouraged the researcher to an open-minded paradigm shift that produced new viewpoints of the research topic, with more clarifying and analytical powers than those offered by existing perspectives. Elliger and Yang (2011:118-119) state that a critical literature review launches the theoretical and methodological fundamentals of research.

It provides a foundation for building knowledge, while clarifying the issues under deliberation. A new perspective on the subject is also developed, hence giving the subject a better investigative and predictive power.

In addition, literature reviews can aid the understanding of the problem researched (McLaughlin & Mertens, 2004:36). Without reviews of relevant literature, difficulties could be experienced when constructing a volume of approved knowledge on any education topic. A review of literature also provides the benefit of further insights to be gained from the purpose and results of a study. The literature review will assist in answering some of the research questions, such as:

- What are the essences of computational thinking and computational thinking skills with regard to CAT? (cf. 1.6)
- What are the essences of problem solving with regard to CAT? (cf. 1.6)

The following section describes the questionnaire as the data collection instrument used for collecting quantitative data in this study.

4.4.2 Questionnaires

In this study, the researcher employed a questionnaire (cf. Appendix D) as a primary source for data collection from a large group of teachers with diverse characteristics. A primary source according to Daniel and Sam (2011:104) is an original work that is based on individuals' thoughts. Adler and Clark (2011:212) define a questionnaire as a data collection instrument with questions and statements that are designed such that the research can solicit information from respondents. Bhattacharya (2006:55) points out that questionnaires are very effective for constructing data on attitudes, opinions and reasons.

A questionnaire is a written list of questions, given or posted to respondents who should complete it by themselves and can be useful (Laws, 2003:306-307) when:

- Information is needed from a larger number of respondents.

- The researcher knows what data is needed.
- The required information is straightforward and in a standardised format.
- The respondents will be comfortable in answering the questions.

Daniel and Sam (2011:105) describe a good questionnaire as follows:

- The respondent (teacher) recognises and believes that the topic is significant enough to spend adequate time and effort to complete it.
- The questionnaire attains information that cannot be obtained from anywhere else.
- It is attractive and well arranged.
- It is comprehensive enough to obtain the essential data.
- Questions should start from obtaining general to more specific responses.
- Questions must be worded as basically and clearly as possible. Every question should only address one idea.
- Questions should not be phrased to lead to a sought-after response.
- The responses of an effective questionnaire should be easy to interpret and to tabulate.

However, there might be certain limitations to this data collection method (Bhattacharya, 2006:55-56).

- Respondents (teachers) might be unwilling to provide information, so it is important that the researcher reassures the respondents that the information will be confidential.
    - Respondents might not be able to provide relevant information owing to a lack of understanding and the lack of ability to identify their motives and provide reasons for certain actions.

- Semantic difficulties – two different wordings of the same question will frequently generate quite different results; the researcher must therefore ensure that the questions are properly phrased.

In this study, questionnaire limitations were addressed by informing respondents that all personal data will be kept anonymous. The pilot study (cf. 4.6) clarified and corrected all questions and semantic difficulties that respondents could not understand.

The construction of the questionnaire ensures that the information gathered is correct, and therefore the next section discusses the construction of the questionnaire.

4.4.2.1 Construction of the questionnaire

The researcher developed a questionnaire to explore the computational thinking skills and the problem-solving skills of CAT teachers in the Free State province. These questionnaires were distributed to the teachers personally or sent by e-mail.

In this study, a four-part questionnaire was used to collect data to establish whether Grade 10-12 CAT teachers teach within the paradigm of computational thinking and within the framework of problem solving in the Free State province. This section describes the construction of the CAT teachers' questionnaire (cf. Appendix D).

- Part 1 of the teachers' questionnaire was designed to obtain personal data of the surveyed population and comprised five closed-ended questions to obtain information such as personal data, gender, CAT qualification, access to a home computer and access to home Internet. Babbie (2103:255) describes closed-ended (or "closed question") as a question for which the researcher provides a suitable list of responses. This information was needed for statistical purposes.

- Part 2 of the questionnaire was designed to obtain data on CAT teachers' experience in teaching CAT. This information was requested to determine teachers' experience in teaching the subject. Teachers were also requested to state the highest grade that they teach and whether they found teaching CAT easy. This information was used to determine whether CAT teachers have experience and whether they were enthusiastic about teaching the subject.

- Part 3 of the questionnaire was designed to obtain school details from the respondents. Teachers were requested to indicate whether their schools were in rural or urban areas. This information was needed for statistical purposes only. They were also asked to indicate whether their schools supported the upgrade and maintenance of the computers used for teaching CAT.

- Part 4 of the teachers' questionnaire was extracted from the theory in the literature review chapters (cf. Chapter 2 and Chapter 3). The researcher used a summated rating scale known as the Likert scale. As Kumar (2005:145) explains, this scale is based on the assumption that every statement on the scale has an equal 'attitudinal value', 'importance' or 'weight' in terms of reflecting an attitude to the issue in question. Mustafa (2010:208- 209) asserts that this procedure is simpler to construct, it provides for expression of intensity and it is a more reliable scale than other scales such as Thurston's differential scale.

The Likert scale also assisted the researcher to place the different respondents in relation to one another in terms of the intensity of their attitude to computational thinking and problem solving. The categorical scale used in this study was: *Always, Usually, About half the time, Seldom* and *Never*.

To ensure that the data is as accurate as possible, it is important to provide instructions to respondents on how to complete the questionnaire. The next section highlights this aspect.

4.4.2.2 Instructions for completing the questionnaire

Instructions were given to respondents (cf. Appendix E) to make sure that they know what was expected and how they could complete the questionnaire. The instructions were clear and concise and the information provided in the questionnaire was as follows:

- Respondents were informed that the study was attempting to explore the problem-solving skills and computational skills of Grade 10 - 12 CAT teachers in the Free

State province. Respondents were informed that the project would provide useful information that could be supportive to CAT teachers in general.

- Respondents were requested to make a cross (either manually or by electronic tick) over the shaded block that followed the questions in the questionnaire.
- Respondents were reassured that the name of the teacher and the school would not be made public.
- Respondents were given a due date when the questionnaires would either be collected or by when the questionnaires must be sent via e-mail.
- Respondents were informed that the Free State Department of Education gave permission for the study to be conducted (cf. Appendix C).
- Respondents were thanked in anticipation of their co-operation.

The following paragraphs highlight content validation of the questionnaire.

4.4.2.3 Content validation of the questionnaires

Part 4 of the questionnaire was designed to establish whether CAT teachers teach within the framework of computational thinking and within the framework of problem solving.

In items 14-28, 30, 32-36, 38-48, 50-58, 65-69, of the final questionnaire, teachers were requested to indicate the frequency that best described typical teaching and learning actions in their CAT classrooms. This was done with the aid of the numeric or Likert-type scale. Every statement was given a numerical value and the following scales were used to categorise each item.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

The items were designed to establish basic computational thinking skills and problem-solving skills that teachers applied in teaching CAT. These items were constructed to elicit information on whether teachers teach within the framework of computational thinking and problem solving.

Some questionnaire items speak to more than one aim. Items 19 stating “I allow learners to discuss work in class so that they can have a better understanding of the work”, and item 23 stating “I allow for team work in the CAT classroom”, both address the promotion of discussions within groups which relate directly to promoting higher-level cognitive processes (such as problem solving). With item 69 a definite link exists between promoting group work and how the teaching of CAT takes place. While teaching, the teacher allows for learners to engage in group work to solve problems.

- To ***promote higher-level cognitive processes*** that is needed in computational thinking (items 14, 17, 19, 20, 21, 23, 69).

  These items were included in the questionnaire to find out whether teachers engaged learners in activities that would enable them to foster higher-level cognitive processes (such as thinking, reasoning and abstraction) that are needed in computational thinking.

- To ***promote group work*** (items 18, 19, 23 and 68).

  For teachers to create a computational thinking culture in a classroom, they should make sure that team work and group work occurs.

- To ***identify*** whether ***basic computer skills*** are needed for problem solving (item 25).

  This item was included to determine whether teachers think that learners need basic computer skills to be competent problem solvers.

- To identify whether teachers ***use cognitive tools*** (Mindtools) (items 15, 24 and 34).

  Mindtools such as presentations, the Internet and mind maps are useful cognitive tools that teachers can use in CAT. These items were included in the questionnaire to determine whether teachers make use of these tools to enhance learners’ computational thinking skills.

- To determine whether ***high quality teaching*** takes place in the CAT classroom (items 16, 26, 27, 28, 30, 55, 56, 58).

  To lead learners through the problem-solving process and to determine how instruction and assessment can be supported by using the varying levels of thinking skills

- Using the ***Internet as a cognitive tool*** (items 32, 33 and 35).

  These items of the questionnaire were designed to determine whether CAT teachers use the Internet as a cognitive tool to teach computational thinking skills.

- The use of ***algorithms*** as an important part of ***computational thinking*** (item 36).

  This was to determine whether teachers teach learners the ability to develop a step-by-step strategy for a problem.

- The use of ***application software*** as a vehicle to ***promote problem solving*** in CAT (items 38–42).

  These questions were included in the questionnaire to determine whether teachers use the appropriate applications such as MS Word, MS Excel and MS Access to foster critical thinking and problem-solving skills.

- The use of ***electronic tools to foster teaching and learning*** (items 44–46).

  For CAT to be fully implemented it is important that technology must be available in the CAT classroom. If a classroom does not have the necessary tools that learners can choose from, computational thinking can be hampered. These items were included in the questionnaire to determine whether CAT can be successfully implemented and through successful implementation, learners could develop computational thinking- and problem-solving skills.

- If teachers are of the opinion that CAT learners are competent problem solvers and if CAT learners have computational thinking skills (items 47 and 48).

- The ***PAT*** forms an integral part of CAT as ***part of problem solving and computational thinking*** (items 49–54).

  The PAT is a problem that is given to the learners to promote their problem-solving skills and their computational thinking skills.

- To determine ***how teaching CAT takes place*** (items 57, 65, 66 and 67).

  These items were included in the questionnaire to determine whether teachers are just teaching to produce good results (item 57) and/or whether teachers have enough teaching time to just cover the curriculum (item 65) or if teachers have time to ensure learners have a deeper understanding of both practical work and theoretical work of the CAT curriculum (items 66 and 67).

- In items 29 and 30 teachers were requested to indicate whether they use any taxonomy when they set assignments or formal assessments to ensure that higher-order thinking skills are developed. These skills are important if teachers want to ensure that learners become competent problem solvers (cf. 3.8). Once again the researcher made use of a Likert-type scale.

Bloom's Taxonomy	1 ☐	Bloom's Revised Digital Taxonomy	2 ☐	Other	3 ☐	I do not use a taxonomy	4 ☐

- In item 37 the researcher wanted to establish whether teachers know what an algorithm is, as this is an important step in the problem-solving process. Teachers were requested to identify different algorithms by simply answering yes or no. In item

49 teachers were required to indicate whether they think that the PAT adds any educational value to the teaching of CAT. The PAT is one tool that teachers can use to teach problem solving.

Yes	1 ☐	No	2 ☐

- Items 59-64 were included in the questionnaire to determine whether teachers know the difference between a problem and an exercise. These items were constructed to ascertain whether teachers teach within the framework of problem solving. The respondents were requested to indicate whether certain attributes were a characteristic of a problem or of an exercise.

Exercise	1 ☐	Problem	2 ☐

- Items 70 and 71 were merely included for statistical purposes to determine how many respondents attended a workshop on either computational thinking or problem solving.

Yes	1 ☐	No	2 ☐

With the content validation completed, the distribution of the questionnaire to respondents need to occur.

4.4.2.4 Distribution of questionnaires

The researcher used two different methods to distribute the questionnaires to respondents. Where possible, the questionnaires were delivered to and collected from schools, but most of the questionnaires were e-mailed to respondents.

4.4.2.4.1 Electronic mail

Survey research where researchers make use of the Internet is becoming more common (Sapsford, 2006:130-131). It is further stated that e-mail presentation is the simplest means of delivery. An e-mail is sent to individuals asking them to fill in an attached questionnaire and to return the questionnaire as an attachment to the reply e-mail. However, this presents a problem for the user to remain anonymous. Dillman (2007:358) believes that e-mail surveys can exist in several forms: e-mail with a link point to web-questionnaires; e-mail with attached questionnaire; e-mail text without attachments or links. The researcher used an e-mail with the questionnaire attached. The researcher decided on this method because it is familiar to most of the population. Online questionnaires can offer distinct advantages, according to Dillman *et al.* (2009:1-18) and Denscombe (2010:159). While enabling the researcher to contact a geographically distributed population, it also saves the researcher costs and data can be obtained faster.

Some disadvantages of this method include the exclusion of people who do not have a computer or are unable to access a computer. These respondents received the questionnaires by direct delivery from the researcher.

4.4.2.5 Permission to conduct the research in the Free State province

Before any data could be collected, the researcher applied for and obtained the necessary permission from the Free State Department of Education. The researcher completed an application form (cf. Appendix A and Appendix C).

Data was also collected by means of a semi-structured interviews conducted.

4.4.3 Semi-structured interviews

There is very little difference between the questionnaire and the interview (Mitchell & Jolley, 2013:290). The most important difference is the physical contact between the interviewer and the participant[x]. For the purpose of this study, the researcher employed semi-structured interviews with open-ended questions to obtain information-rich qualitative data that would enrich the quantitative data collected with the questionnaires.

A semi-structured interview is described by Hesse-Biber and Leavy (2011:102) and Myers (2013:122) as the researcher relying on a set of pre-formulated questions and guiding the conversation to remain on those questions. Although the researcher asks the participants a certain set of questions, semi-structured interviews allows a researcher to ask for clarity or even follow new paths if the data gathered in this way is relevant to the study. The nature of qualitative research reflects the in-depth perspective of interviews, which include establishing a relationship between the interviewer and the interviewee, asking open, empathetic questions and encouraging the interviewees to answer in detail (Hennik *et al.,* 2001:109; Myers, 2013:122).

4.4.3.1 Construction of semi-structured interview

The following questions were derived from the research questions (cf. 1.6) and prepared before the semi-structured interviews.

- *What problem-solving activities do you give to your learners to do in CAT?*
- *What computational thinking skills are developed by the problem-solving activities that you give to your learners?*
- *Why do some teachers only teach application without the framework of computational thinking and not within the framework of problem solving?*
- *How best would you integrate computational thinking with teaching CAT concepts?*
- *In your opinion, what are the effective ways of teaching computational thinking to learners?*

The next section describes how the population and sample were selected.

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[x] For qualitative research the word “participant” is substituted for the word “respondent”.

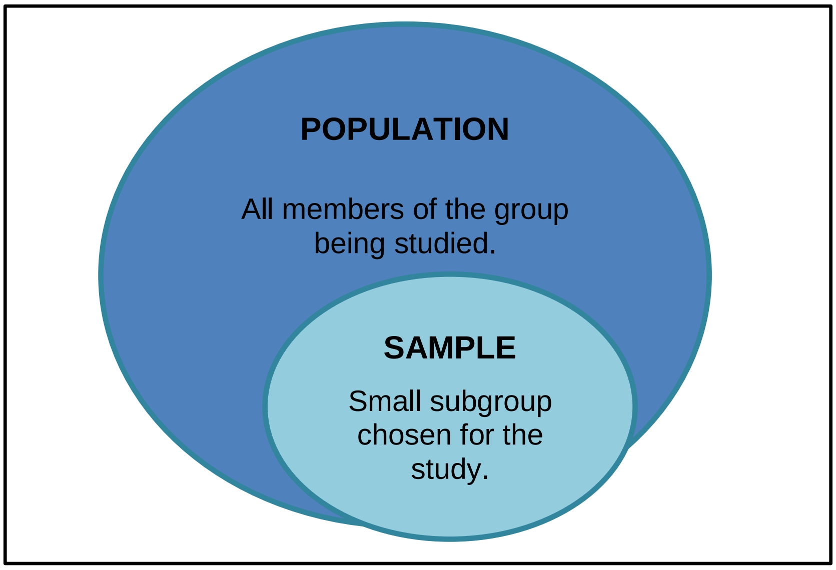
4.5 POPULATION AND RESEARCH SAMPLE

This section provides the population and the sample for this study. Clarification follows below.

4.5.1 Population

As shown in *Figure 4.3*, Denscombe (2010:23) refers to the population as all the items in the category of things that are being researched.

Figure 4.3: Population and sample



Denscombe (2010:23)

It is not the size that defines a population, but the presence of a specific characteristic (Hartas, 2010:67; Walliman, 2006:274). Gray (2004:82) defines a population as the total number of possible individuals that can be included in a study. Since the population is the group from whom a sample will be drawn, it is important for Gorard (2013:78-79) that the population should be defined in advance as the target of the research.

The population of this study consists of FET phase (Grades 10-12) CAT teachers. In 2014, the year in which the data for this study was gathered, there were 188 secondary schools in the Free State province offering the subject CAT (cf. Appendix G).

Sampling is the study of characteristics of a subset (called the sample) selected from a larger group (called the population) to understand the characteristics of the larger group (Johnson & Christensen, 2012:216). Once the characteristics of the sample have been determined, these characteristics are generalised from the sample to the population; thus the researcher will make statements about the population based on the sample study.

The researcher used probability sampling for the quantitative part of this study. Daniel (2012:6,33) and Bhattacharya (2006:83) mention that probability sampling gives every teacher in the population a known and non-zero chance of being selected. They further aver that probability sampling ensures that every single individual (teacher) in the population has an equal chance of being selected as a subject for the research. The selection of the specific individual depends entirely on chance. This method guarantees that the selection process of teachers is completely randomised and without bias by the researcher. McMillan and Schumacher (2010:129) agree with this by stating that with probability sampling the individuals are drawn from a larger population in such a way that the probability of selecting every member of the population is known. It is also their opinion that if this sampling is piloted efficiently it will provide approximations of what is true for a population from a smaller group of respondents.

Probability sampling can either be unrestricted (simple random sampling) or restricted (complex probability sampling). It is Gorard's (2013:79-80) view that when a researcher selects a sample from a known population, the best approach is to select the samples (teachers) randomly. This will ensure that the sampling is free of systematic prejudgment that may stem from choices by the researcher. For this study, simple random sampling was used to collect quantitative data. This ensured that every individual in the population under study has an equal chance of being selected and that the probability of an individual of the population being selected is unaffected by the selection of other individuals in the population (Cohen *et al*., 2005:100).

The sampling procedures for the quantitative data from questionnaires and the qualitative data from semi-structured interviews occur independently. The next section describes the sampling process.

4.5.2 Sample

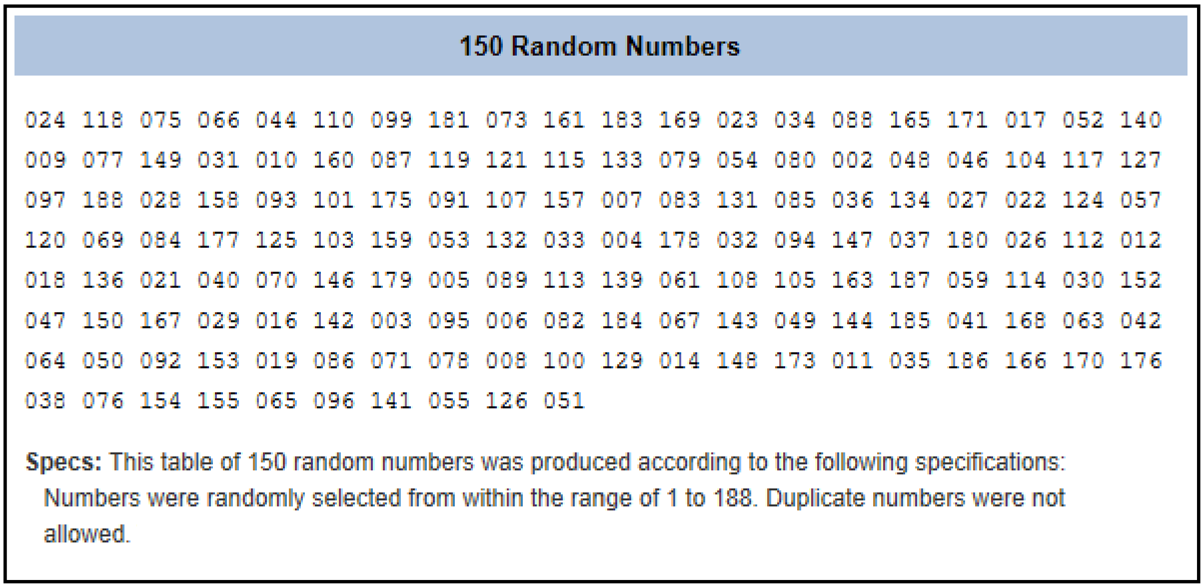
This section provides the sample for this study. Clarification follows below.

4.5.2.1 CAT teacher sample for questionnaire

The researcher could not determine the accurate number of secondary school CAT teachers because in three districts there were no Learning Facilitators (also called Subject Advisors) to assist in providing such information. It was subsequently assumed that there could be one CAT teacher per school which totalled 188 (cf. Appendix G) practising CAT teachers in the province.

As previously mentioned, simple random sampling was conducted to select the sample for the CAT teachers. Simple random sampling is described by Hartas (2010:67) as the unsystematic selection of the individuals or units from the population with the intent that the sample is representative of this population. Any bias in the population is then equally distributed among the sample. This process ensured that every teacher that taught CAT had an equal and independent chance of being selected. In this study a Table of Uniform Random Numbers was used to select the 150/188 CAT teachers who were included in the population of 188 schools offering CAT in 2014. The researcher created a Table of Uniform Random Numbers (*Table 4.1*) with the help of Stat Trek: Teach yourself Statistics that is available on the Internet. (http://stattrek.com/statistics/random-number-generator.aspx).

Table 4.1: Table of Uniform Random Numbers



150 Random Numbers

```
024 118 075 066 044 110 099 181 073 161 183 169 023 034 088 165 171 017 052 140
009 077 149 031 010 160 087 119 121 115 133 079 054 080 002 048 046 104 117 127
097 188 028 158 093 101 175 091 107 157 007 083 131 085 036 134 027 022 124 057
120 069 084 177 125 103 159 053 132 033 004 178 032 094 147 037 180 026 112 012
018 136 021 040 070 146 179 005 089 113 139 061 108 105 163 187 059 114 030 152
047 150 167 029 016 142 003 095 006 082 184 067 143 049 144 185 041 168 063 042
064 050 092 153 019 086 071 078 008 100 129 014 148 173 011 035 186 166 170 176
038 076 154 155 065 096 141 055 126 051
```

Specs: This table of 150 random numbers was produced according to the following specifications: Numbers were randomly selected from within the range of 1 to 188. Duplicate numbers were not allowed.

(http://stattrek.com/statistics/random-number-generator.aspx)

The first school (first teacher) was identified as 1, the second school (second teacher) as 2 and school (teacher) number 105 as 105 and so on (horizontal line). The numbers that were created randomly were then used to select the relevant schools to send the e-mails or deliver the questionnaire to.

The rationale for these numbers is that the researcher believed that data collected from the samples would provide the necessary information to answer the research questions.

4.5.2.2 CAT teacher sample for semi-structured interviews

For the semi-structured interviews the researcher conducted purposive sampling within the category of non-random sampling. Adler and Clark (2008:121) and Brikci and Green (2007:9) suggest that for much of qualitative research, purposive sampling is desirable. This sampling provides a focused effort in gathering information-rich data to answer research questions. In purposive sampling, people or other units are chosen, as the name implies, for a particular purpose (Leedy & Ormrod, 2010:206). Members of a population are chosen with the purpose to ensure that all key characteristics of relevance to the data needed are covered. McMillan and Schumacher (2010:138) state that in purposeful sampling, the researcher selects particular elements from the population that will be representative or informative about the topic of interest. On the basis of the researcher's knowledge of the population, a judgement is made about which participants should be selected to provide the best information to address the purpose of the research (Johnson & Christensen; 2012:231).

The researcher selected 8 participants (who are specialists teachers in the field of CAT) to conduct semi-structured interviews with. Semi-structured interviews were selected for a number of reasons. The face-to-face interviews were conducted because the researcher wanted to gain insight in and understanding of the data obtained from the questionnaires. It was also a way for the researcher to attend to lived experiences. The semi-structured interview served a comparative and representative purpose – it was to compare responses and to put these responses in the context of common group beliefs and themes (Galetta, 2013:72; Fetterman, 2009:554)

The next section discusses the pilot study that was conducted before data collection occurred.

4.6 PILOT STUDY

Piloting the study is an important component of the data collection process. Before the researcher prepared the final format of the questionnaire, the items were tested by conducting a pilot study.

The aim of a pilot study is to try out the research approach to identify potential problems that may affect the quality and validity of the results (Basit, 2010:71; Blessing & Chakrabarti, 2009:114). The pilot study should thus be representative of the sample of the main study, and the approach, methodology and methods that are used in the pilot study should be reflected on the actual study that occurs later.

A pilot study is a prelude to the main study (Basit, 2010:71). The pilot study will reveal whether several changes are required if the study is to be effective and efficient. Cargan (2007:117) concurs with this by stating that a pilot study is a means of checking whether the questionnaire can be administered and whether accurate data can be provided.

Respondents in a pilot study should be asked to be particularly critical and they should be requested for feedback on their experiences (Blessing & Chakrabarti, 2009:114). Hall (2008:79), Cargan (2007:116) and Basit (2010:70-72) point out that the advantages of using a pilot study can be summarised as follows:

- To verify that the questions asked are appropriate for the respondents.
- Verify the reliability of the pilot study in general.
- To make sure that the information obtained is consistent.
- To make sure that adequate directions are given for the questionnaire to be conducted.
- To standardise procedures to be used.
- To ensure that all topics are covered and that the data will therefore be valid.

The researcher must ensure that the respondents that took part in the pilot study must not be included in the actual study (Basit, 2010:73). Because they have answered the questionnaire before, it may cause them to provide ready-made answers.

The section below indicates how the pilot study was conducted and used as an instrument to maximise the validly and reliability of this research (Hall, 2008:78).

4.6.1 Pilot study conducted

The researcher decided to test the items by e-mailing the questionnaire as an attachment to ten Grade 10 - 12 CAT teachers in the Lejweleputswa and Motheo Education Districts. Respondents were requested to answer the questionnaire and then comment on the items contained in the questionnaire.

The questionnaire was also handed to a statistician (a lecturer in the Department of Mathematics, Science and Technology Education, at the Central University of

Technology, Free State (Welkom Campus)). The researcher was advised on a suitable layout of the questionnaire to ensure its compatibility with the statistical programme used to analyse the data. As a result of all these processes, the questionnaire was revised and modified, and the final draft was prepared and e-mailed to the respondents. The statistician suggested that items 28 and 30 be removed from the original questionnaire, (these items asked the respondents to name other taxonomies that they use when setting assignments and formal assessments).

Accordingly, based on the responses and the information obtained from the 10 teachers during the pilot study, the questionnaire was modified by revising a few questions. In the pilot study questionnaire, the wording of items 37, 59, 60, 61, 62, 63 and 64 were stated to be vague for some pilot responses. These questions were edited and corrected to increase the validity and the reliability of the study. Gray (2004:90) states that the validity of an instrument refers to the extent to which the instrument measures what it is intended to measure.

After all corrections were made to the questionnaire, it was then e-mailed and handed to respondents. Respondents were requested to return the completed questionnaire by e-mail attachment within one week. The respondents to whom questionnaires were hand delivered, the same period were given. A total number of 125/150 questionnaires were received, which results in a 83% return rate. Once all the questionnaires had been received back from the respondents, the data was analysed with the Statistical Package for the Social Sciences (SPSS).

On the basis of the pilot study, a number of items with below 0.25 item-total correlations and those with above 0.8 item-total correlations were eliminated. Items with below 0.25 item-total correlations do not contribute to validity by discriminating the same as the total scores discriminates. Items with 0.8 item-total correlations were eliminated because they measured what other items measure. 5 items were eliminated. Besides validity, the reliabilities were computed by using Cronbach Alpha. Accordingly, the reliability of the items of the questionnaire was found to be valid, indicating the instrument was reliable (cf. 4.5.2).

The next section discusses the analysis of the questionnaire data.

4.7 PROCEDURE FOR THE ANALYSIS OF QUESTIONNAIRE AND INTERVIEW DATA

Once the data has been collected, the researcher must apply the required strategies to analyse the collected data.

4.7.1 Analysis of quantitative data

To analyse data means that the researcher must organise, account for and explain the collected data (Cohen *et al*., 2005:147). It is also stated that it includes making sense of the data in terms of the respondents' definitions of situations, noting patterns, themes, categories and regularities.

Quantitative data was provided by the questionnaires, and to analyse the data, the researcher employed a variety of strategies. In this study the SPSS (Statistical Programme for the Social Sciences) was used to calculate the Chi-square, summarise and create appropriate tables, examine the relationship between variables and to perform tests of statistical significance on the hypotheses.

The researcher applied descriptive statistics (cf. 4.7.1.1) for all the items in the questionnaire. The Pearson's Chi-Square Test was used to analyse the inferential statistics as it is a statistical test testing for the existence of a relationship between two variables.

The next section provides a deeper examination of descriptive and inferential statistics.

4.7.1.1 Descriptive Statistics

Descriptive statistics can be relevant in two instances (Healy, 2009:15-16):

When a researcher wants to summarise or describe the distribution of a single variable (univariate descriptive statistics), the values of that variable will be arranged such that the relevant information can be quickly understood and appreciated. Percentages and graphs may be used to describe a single variable. The goal of univariate descriptive statistical procedure is thus the process of data reduction.

When the researcher wishes to describe a relationship between two or more variables, these statistics, also called measures of association, will assist the researcher to quantify the strength and direction of a relationship.

In this study certain items of the questionnaire were grouped together to describe the:

- Biographical data (cf. 5.2.1.1);
- Technology in the classroom (cf. 5.2.1.2);
- Promotion of higher-level cognitive processes (cf. 5.2.1.3);
- Group work (cf. 5.2.1.4);
- Use of taxonomies (cf. 5.2.1.5);
- Use of algorithms (cf. 5.2.1.6);
- Problems vs. exercises (cf. 5.2.1.7);
- Sufficient teaching time (cf. 5.2.1.8);
- Practical Assessment Task (cf. 5.2.1.9);
- Teachers' perception of their learners' problem-solving skills and computational thinking skills (cf. 5.2.1.11); and
- Language and teaching methods (cf. 5.2.1.12).

The major types of descriptive statistics are measures of central tendency, and measures of dispersion and variability. Measures of central tendency are numerical summaries used to summarise a data set with a single representative number. The three most common measures of central tendency are mean (average), median (midpoint in the distribution; half of the respondents are below the median and half of the respondents are above the median) and mode (most commonly occurring value) (Tullis & Albert, 2008:24). According to Walker and Maddan (2014:37-39), measures of dispersion and variability determine whether a group of scores are spread out over a broad range or whether the scores are concentrated in a relatively narrow band.

Knowing how the values are spread above and below the middle of the distribution can be just as informative as knowing the mean or the median value. The range (the difference between the highest and the lowest score), the variance, the standard deviation and the coefficient of variation are most commonly used in education research. In this study the mean was used as the measure of central tendency. Measures of central tendency were computed to summarise the data for the following data variables:

- Internet use in the CAT classroom (cf*. Table 5.5*);
- Promotion of higher-level cognitive processes (cf*. Table 5.7*);
- Group work (cf*. Table 5.8*);
- Problems vs. exercises (cf*. Table 5.13*);
- Sufficient teaching time (cf*. Table 5.15*).

The descriptive statistics in this study was used to describe the findings and the inferential statistics used to test the hypotheses and draw conclusions from the statistics. The following section elaborates on the inferential statistics.

4.7.1.2 Inferential Statistics

Inferential statistics becomes relevant when a researcher wants to generalise the findings of the study from a sample to a population (Healy, 2009:17). Durrheim (2011:208) states that inferential statistics permits the researcher to make an educated guess on how much the random variance will be; it therefore allows the researcher to estimate the amount of change involved in drawing conclusions. He further states that the two main reasons for using inferential statistics are to estimate the population parameter (population value) and to test the research hypotheses (educated guess or expectations about differences among groups in the population or about relationships among variables).

4.7.1.2.1 Pearson Correlation Coefficient

There are various statistical procedures available for the expression of relationships.

The researcher used the Pearson Correlation Coefficient and the Spearman Correlation Coefficient to test the hypothesis (cf. 1.8) that is set in this study.

Adler and Clark (2011:430) describe the Pearson r as follows: negative values of Pearson's r (less than 0 to -1) indicate that the two variables are negatively or indirectly related. This means that as one variable increases in value, the other variable decreases. Positive values of Pearson's r (greater than 0 to 1) indicate that the two variables are directly related. This means that as one variable increases, the other variable will also increase. In both cases Adler and Clark argue that r's "distance" from 0 indicates the strength of the relationship; the farther from 0, the stronger the relationship. Correlation can range from -1.00 to +1.00 (McMillan & Schumacher, 2010:168). A coefficient near 0.00 will imply that problem solving and computational skills are not related.

The Spearman correlation coefficient is a standardised measure of strength of the relationship between two variables that does not rely on the assumptions of a parametric test (Field, 2013:794). A Pearson correlation coefficient was indeed performed on data that had been converted into ranked scores.

The level of significance (p-value) calculated by the Pearson's correlation coefficient and Spearman's correlation coefficient will be used either to except or reject the null hypothesis (cf. 1.8). If the p-value is less or better than 0.05 or less than 0.01, a conclusion can be drawn that the null hypothesis should be rejected (Antonius, 2013:199).

A cross-tabulation using chi-square was computed to determine influential relationships among all the different variables (items) in the questionnaire as set out below:

- I find CAT easy to teach * The location of my school (cf. *Table 5.21*).
- I find CAT easy to teach * I have access to a computer at home (cf. *Table 5.22*).
- I find CAT easy to teach * I have access to Internet at home (cf. *Table 5.23*).
- I give learners pre-constructed worksheets and expect them only to follow the instructions and do calculations as required by instructions * When learners do

activities (exercises) in class, I consider that as problem solving (cf*. Table 5.24*).

- When I talk, I “question”, I do not “tell” * My lessons present problems that develop learners’ thinking skills (cf*. Table 5.25*).
- When I talk, I “question”, I do not “tell” * I redirect learners’ questions in such a way that learners are encouraged to arrive at their own answers (cf*. Table 5.26*).
- I prefer it when it is quiet in my class during practical lessons * I allow learners to discuss work in class so that they can have a better understanding of the work (cf*. Table 5.27*).
- I set my own CAT assignments * When I set assignments, I set the assignments according to a specific taxonomy (cf*. Table 5.28*).
- I set my own CAT assignments * I use the following taxonomy when I set assignments (cf*. Table 5.29*).
- I set my own CAT assessments’ * When I set assessments, I set the assessments according to a specific taxonomy (cf*. Table 5.30*).
- I set my own CAT assessment * I use the following taxonomy when I set an assessment (cf*. Table 5.31*).
- I use the Internet in my class to actively engage learners in the learning process * My learners have Internet access in the CAT classroom/My learners have access to electronic mail in the CAT classroom (cf*. Table 5.32*).
- I use algorithms * I think the following are examples of different algorithms (cf*. Table 5.33*).
- I use concept maps to help learners master content * Use of presentation tools to help learners to create a mental picture of content (cf*. Table 5.34*).
- I use open-ended questions/problems that can be solved in different ways * With MS Access 2010/2013 I give the learners the opportunity to create their own database from scratch (cf*. Table 5.35*).
- Majority of CAT learners in my class are competent problem solvers * I think that the PAT adds educational value to the CAT learners (cf*. Table 5.36*).
- I can cover the curriculum with the teaching time that I have * I have enough teaching time to provide learners with a deeper understanding of theory and practical work (cf*. Table 5.37*).
- I have enough teaching time to provide learners with a deeper understanding of

practical work * I phrase my questions in such a way as to encourage critical thinking skills (cf. *Table 5.38*).

4.7.1.2.2 Factor Analysis

Dewberry (2004:304) declares that factor analysis can be used to reduce a large number of correlated variables to a smaller number of variables. This strategy was employed in this study.

Kaiser-Meyer-Olkin (KMO) and Bartlett's Test (cf. *Table 5.39*) were used to measure the strength of the relationship among variables. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) is a statistic that indicates the proportion of variance in the variables that might be caused by underlying factors (Rasli, 2006:14). The KMO measures the sampling adequacy which should be greater than 0.5 for a satisfactory factor analysis to proceed. These tests were conducted in this study.

4.7.2 Analysing qualitative data

Data was collected from the participants by employing semi-structured interviews (cf. 4.4.3). To analyse the data, the researcher employed no software packages such as, Atlas.ti, but analysed the data manually. Thematic analysis was used to analyse the original data obtained from the semi-structured interviews. Thematic analysis aims to identify themes within the data. It is a greater inductive way of analysis because the categories into which the themes will be sorted are not decided prior to coding the data (Ezzy, 2002:86-88).

The first stage of thematic coding is called descriptive coding (or sometimes called open coding), a process of highlighting an important theme or word in every individual interview to identify relevant categories or themes (Rivas, 2012:370). Grouping together words under descriptive codes that share a common meaning to create an interpretative code is the second stage of thematic coding. Thereafter the researcher defines an all-embracing (overarching) theme that epitomises the key concepts in the analysis – “What must the teacher develop in learners” and “The role of the teacher”. The researcher decided on two themes, namely “Learners” and “Teahcers” (cf. 5.3). Thematic coding does not necessarily take place in a sequential manner – the researcher may move back and forth between different stages (King & Horrocks, 2010:152-158). In this study, qualitative data was themed and reported on as such. The qualitative analysis process for this study is explained in paragraph 5.3.

For any research to be meaningful and useful, it is very important to test the validity and the reliability of the data used for the study. These two concepts are discussed in the next section.

4.8 VALIDITY AND RELIABILITY OF QUANTITATIVE DATA

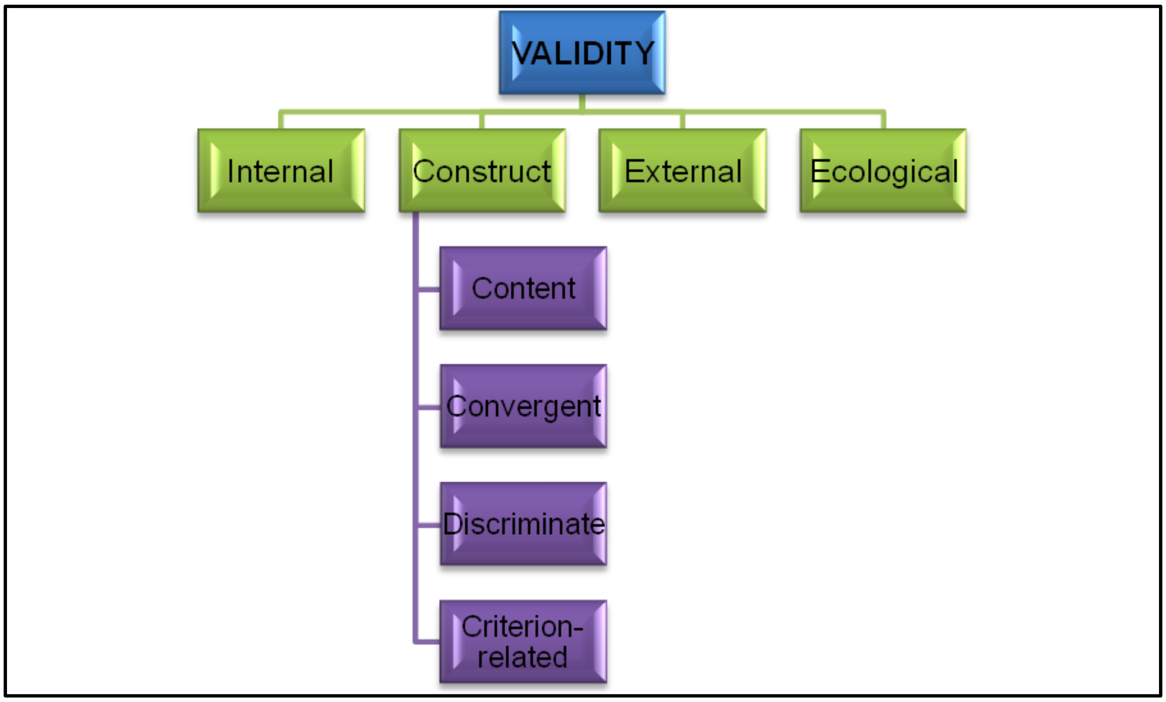
The two most important and fundamental characteristics of any research procedure are reliability and validity. These two principles are discussed next.

4.8.1 Validity

The validity of the study measures how meaningful the results and the overall value of research are. Hartas (2010:74) is of the opinion that establishing validity is more important than achieving reliability, in that the results of a study may be reliable but not valid, making the entire research exercise worthless.

Hartas (2010:75) distinguishes between four types of validity as shown in *Figure 4.4*. Each of these are discussed below *Figure 4.4* on the next page.

Figure 4.4: Validity



Hartas (2010:75)

The validities above are defined as follows (McBurney & White, 2010:174-179):

- Internal validity: is the most central type of validity as it concerns the relation between the independent and dependent variables. An experiment or research has internal validy if there are sound reasons to believe that a cause-effect relation really exists between the independent and dependant variable (Johnson & Christensen, 2012:276). To ensure that the study is reliable, the researcher used random samples whenever possible and sample sizes were appropriate. The researcher did so to avoid the influence of these extraneous or third variables in the results.
- Construct validity: whether the results support the theory behind the research. The study should test a hypothesis. The validty was ensured through using the literature review's content when the items of the questionnaire and the questions in the semi-structured interview were constructed.
- External validity: can the results of the research be generalised to another situation: different subjects, settings and times? In this study this was achieved by simple random sampling.

- Ecological validity: refers to the ability to generalize the results of the study across settings (Johnson & Christensen, 2012:294). The results of this study can be transferred to other schools offering CAT as a subject. The ecological validity was ensured by random sampling of schools.

4.8.2 Reliability

Reliability is the degree to which the finding is independent of accidental circumstances of the research (Silverman, 2004:285). Hartas (2010:71) mentions that the consistency and the stability of a measurement will determine whether the results of a study are repeatable. The reliability of the quantitative data in this study was ensured by conducting a pilot study (cf. 4.6.1) and determining the Cronbach-Alpha (cf. 4.6.1). The discussion of validity and reliability leads to the trustworthiness in qualitative research discussed next.

4.9 TRUSTWORTHINESS IN QUALITATIVE RESEARCH

The trustworthiness of qualitative research is often queried by positivists, perhaps because their notions of validity and reliability cannot be addressed in the same way in naturalistic work. Numerous naturalistic researchers have, however, opted to employ different terminologies to detach themselves from the positivist paradigm. One such author is Guba (1981:75-91), who recommends four criteria to be used by qualitative researchers in pursuit of a trustworthy study. By addressing related issues, Guba’s ideas relate to the criteria used by the positivist investigator:

- Credibility (in preference to internal validity);
- Transferability (in preference to external validity/generalisability);
- Dependability (in preference to reliability);
- Confirmability (in preference to objectivity).

4.9.1 Credibility

Savin-Baden and Major (2013:475) state that credibility relates to the notion that the study should be convincing and therefore be believable to other researchers. Credibility infers that the study characterises some reality, which is the reality from the participants' point of view. Certain provisions can be made by researchers to ensure the credibility of their studies. One such provision is triangulation (which was used in this study). Guion, Diehl and McDonald (2011:1-2) state that triangulation may involve the use of different methods, such as individual interviews and open-ended interviews, which normally form the major data collection approaches for qualitative research. According to Kennedy (2009), the use of diverse methods compensates for their individual restrictions and exploits their particular advantages. This study employed both interviews and questionnaires to gather data from various groups of people.

4.9.2 Transferability

Transferability denotes the degree to which the results of qualitative research can be generalized or transferred to other contexts or settings (Shenton, 2004:69). Qualitative transferability is principally the concern of the person who wishes to perform the generalising. The qualitative researcher can enrich transferability by systematically defining the research context, the problem and the objectives that were central to the research. The person who desires to "transfer" the results to a different context is then responsible for making the decision of how practical the transfer is. In this study, trustworthiness is aimed for by stating the research context, problem and objectives.

4.9.3 Dependability

Brown (2005:32) asserts that the traditional quantitative opinion of reliability is based on the postulation of replicability or repeatability. It is apprehensive with whether researchers would obtain similar results if the same entity could be observed twice. The statement is made that researchers are unable to measure the same entity twice - by definition if something is measured twice, two different things are actually measured. In order to appraise reliability, quantitative researchers construct various hypothetical notions (e.g., true score theory) to try to circumvent this fact.

Shenton (2004:72-73) states that the awareness of dependability, on the other hand, emphasises the need for the researcher to pronounce the ever-changing context within which research takes place. In order to report the dependability question more directly, the developments within the study should be described in detail, in order for a future researcher to repeat similar research, if not necessarily to attain similar results. Such in-depth writing also permits the reader to measure the degree to which appropriate research practices have been followed. In order for readers of the research report to develop a systematic understanding of the methods and their value, the text should comprise sections devoted to:

- The research design and its implementation, describing what was planned and executed on a strategic level;
- The operational detail of data gathering, addressing the minutiae of what was done in the field.

This study provides in-depth reporting grounded in a clear explanation of the research design and data gathering methods.

4.9.4 Confirmability

According to Brown (2005:32), qualitative research is inclined to agree that each researcher brings a unique stance to the study. Confirmability mentions the degree to which the results could be confirmed or substantiated by others. There are a number of methods for improving confirmability. The researcher can document the developments followed by checking and rechecking the data during the study. Maxwell (2004:134) states that the researcher can actively look for and voice negative occurrences that challenge prior observations. Also, after the study, one can conduct a data audit, or audit trail that reviews the data collection and analysis techniques and make judgements regarding the probability for bias or distortion. In this study a data audit was undertaken to ensure minimum influence through bias.

4.10 ETHICAL ISSUES

The researcher considered the following ethical issues as described by Hennink *et al.* (2011:66-68) and Duncombe and Jessop (2012:109-112) during the selection and recruitment of respondents in the research:

- Permission for the research was obtained from the Free State Department of Education (cf. Appendix C).
- Adequate information was given to all respondents to ensure that they may consider whether they are willing to participate in the study.
- The researcher resolved to cause no harm to any of the respondents. This included refraining from any mental harm in the form of humiliation or discomfiture, or social harm in terms of how the individual was treated by others in the community.
- The names of the respondents/participants were kept confidential and anonymous at all times.
- The researcher ensured the ethical use of the data and the process of analysis and interpretation by reporting on both the positive and negative aspects of the data.
- The researcher made sure that a trustworthy environment is set for the semi-structured interviews.

4.11 CONCLUSION

This chapter emphasised the methodology for the study. The study was QUAN-QUAL by design as both quantitative data and qualitative data were collected. In quantitative research the researcher sought to gather numerical data that could be analysed by using mathematically based methods (statistics in particular). In qualitative research the researcher intended to gather data from participants in their own words. This would enable the participants to provide explanations and descriptions of their experiences.

This chapter also outlined the methods of data collection. For quantitative data a questionnaire and for qualitative data semi-structured interviews were used to collect data. The approaches to these two methods of data collection were presented.

The selection of the population and sample for this study was explained in this chapter. The sample for this study was selected for the purpose of representing the population. The chapter also gave a detailed description of how the data was to be analysed. The issue of reliability and validity of quantitative and qualitative methods were also elaborated on in this chapter.

The next chapter deals with the presentation, analysis and interpretation of the research results.

CHAPTER 5

RESULTS OF THE EMPIRICAL INVESTIGATION

5.1 INTRODUCTION

This chapter deals with the analysis, presentation and interpretation of results of an investigation into the computational thinking skills and problem-solving skills of Grades 10 - 12 CAT teachers in the Free State province.

This chapter is divided into two sections, the first section dealing with the quantitative data analysis. Descriptive statistics, inferential statistics and factor analysis were used to analyse the quantitative data. Inferential statistics reports the results of the Chi-square Tests computed to determine with there were significances between variables. The objective of this was to draw conclusions about the characteristics of the population from the information contained in the sample. In the second section, the qualitative data was analysed with a thematic analysis.

The next section describes the analysis of the quantitative and qualitative data. The following research question is addressed through the empirical data:

- How do teachers integrate computational thinking and problem solving in the CAT classroom?

The inferential analysis data tests the hypothesis as set out in Chapter 1 (cf. 1.8).

H_1: There is a statistically significant relationship between problem-solving skills and computational thinking skills of Grades 10 - 12 CAT teachers.

H_0: There is no statistically significant relationship between problem-solving skills and computational thinking skills of Grades 10 – 12 CAT teachers.

5.2 QUANTITATIVE DATA ANALYSIS

Quantitative data analyses were employed to analyse the data collected via the questionnaire (cf. Appendix D).

5.2.1 Descriptive Statistics

The section provides statistical descriptions that arise from responses to items that measured biographical data, technology in the CAT classroom, critical thinking, taxonomy, algorithms, problems *vs.* exercises, teaching time, PAT, workshops, teacher perceptions, language and teaching methods, problem relation and computer skills.

5.2.1.1 Biographical Data Analysis

CAT teachers' questionnaires were delivered and e-mailed to 150 CAT teachers across the Free State province of which 125 completed CAT teacher questionnaires were collected or returned via e-mail. This is a representation of 83.3%. These 125 teachers were then included in the study and the following information was derived from a descriptive analysis of the participants.

- **Personal data for CAT teachers**

Table 5.1: Summary of personal data: education district, gender, CAT qualification, access to home computer and access to home Internet

N = 125

PART 1

PERSONAL DATA ITEMS		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
1	Education District	**Fezile Dabi**		**Thabo Mofutsanyane**		**Motheo**		**Lejweleputswa**		**Xhariep**		
		25	20%	37	29.60%	30	24.00%	21	16.80%	12	9.60%	100
2	Gender	**Male**		**Female**								100
		52	41.60%	73	58.40%							
3	CAT Qualification	**Tertiary**		**In-service**								100
		70	56.00%	55	44.00%							
		Never		**Seldom**		**About half the time**		**Usually**		**Always**		
4	Access to home computer	2	1.60%	1	0.80%	7	5.60%	12	9.60%	103	82.40%	100
5	Acces to home Internet	14	11.20%	10	8%	16	12.80%	25	20%	60	48%	100

In *Table 5.1* the descriptive analysis of the 125 completed questionnaires revealed that 20.0% of the teachers were from the Fezile Dabi district, 29.6% were from the Thabo Mofutsanyane district, 24.0% were from the Motheo district, 20.0% were from the Lejweleputswa district and 6.4% were from Xhariep. In the secondary schools that offered CAT, 41.6% of the teachers were males and 58.4% were females. Just more than half of the teachers (56.0%) have a tertiary qualification and 44.0% of the teachers received in-service training. Furthermore, the majority of the teachers (82.4%) has access to a home computer. It is interesting to note that only 48.0% of the teachers have continuous (*"always"*) access to the Internet at home. It is also interesting to note that 19.0% of teachers identified that they *"seldom"* or *"never"* have Internet access at home.

- **Experience in teaching CAT**

Table 5.2: Summary of experience in teaching CAT

N = 125

PART 2

EXPERIENCE IN TEACHING CAT		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
6	Years of teaching experience in CAT	**0 - 2 years**		**3 - 4 years**		**5 - 8 years**						
		19	15.20%	23	18.40%	83	66.40%					100
7	Highest Grade in teaching CAT	**Grade 10**		**Grade 11**		**Grade 12**						100
		6	4.80%	17	13.60%	102	81.60%					
		Never		**Seldom**		**About half the time**		**Usually**		**Always**		
8	Find it easy to teach CAT	2	1.60%	2	1.60%	13	10.40%	46	36.80%	62	49.60%	100

Since CAT was only introduced in 2006 as part of the new curriculum, the maximum teaching experience that teachers can have in CAT (at the time when the questionnaire was administered) is 8 years. In *Table 5.2* it was noted that 66.4% of teachers have been teaching CAT since the beginning of 2006, whereas 33.6% of teachers are new appointments or have fewer than 5 years' teaching experience in CAT.

The statistics show that 36.8% (*"usually"*) and 49.6% (*"always"*) find it easy to teach CAT. Hence, 81.6% of teachers are teaching Grade 12 as their highest grade, while 13.6% of teachers teach up to grade 11 and only 4.8% of teachers teach only Grade 10. From this it is evident that most teachers in this study (81.6%) teach Grade 10, Grade 11 and Grade 12.

- **School details**

Table 5.3: Summary of school details

N = 125

PART 3

SCHOOL DETAILS		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
9	Location of School	**Urban**		**Rural**								
		80	64.00%	45	36.00%							100
		Never		**Seldom**		**About half the time**		**Usually**		**Always**		
10	School supports the upgrade of computers used for CAT.	4	3.20%	7	5.60%	31	24.80%	39	31.20%	44	35.20%	100
11	School supports the maintenance of computers used for CAT.	2	1.60%	6	4.80%	26	20.80%	29	23.20%	62	49.60%	100

From the schools that participated in the study, 64% were located in towns, while 36% of schools that offer CAT are located in the rural areas.

It is notable that of the participating schools 31.2% (*"usually"*) and 35.2% (*"always"*) upgrade their computers used for CAT. The majority of schools stated that they always (49.6%) and 23.2% (*"usually"*) maintain the computers used for CAT. The upgrade and maintaining of computers can have a significant influence on the teaching and learning of CAT.

To enhance the descriptive analysis for items 12 – 71, the researcher grouped the relevant variables together and reported on the relevant variables as a unit.

5.2.1.2 Technology in the CAT classroom

For effective teaching and learning to occur in the CAT classroom, the integration of different visual and Internet-based technologies are essential.

- **Visual technology**

Table 5.4: Summary of visual technology

N = 125

PART 4		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
		Never		Seldom		About half the time		Usually		Always		
15	I make use of video clips to explain difficult content to my learners.	7	5.60%	14	11.20%	41	32.80%	42	33.60%	21	16.80%	100
24	I make use of concept maps (mind maps) to help learners to master content.	25	20.00%	41	32.80%	20	16.00%	33	26.40%	6	4.80%	100
43	I make use of presentation tools druing my lessons to assist the learners in creating a mental picture.	6	4.80%	14	11.20%	25	20.00%	65	52.00%	15	12.00%	100
44	I have electronic resources such as a whiteboard in my class.	52	41.60%	6	4.80%	5	4.00%	11	40.80%	51	50.80%	100

The researcher defines visual technology as visual aids such as a whiteboard for presenting video clips and concept maps. The responses to the questions on the use of visual technology indicated that 50.4% of all teachers "*always" or "usually*" use video clips to explain these concepts to the learners. Presentation tools (such as PowerPoint) are *"always"* used by only 12.0% of teachers, although the majority of teachers *"usually"* (52.0%) use presentation tools. The majority of teachers (52.8%) *"never"* or *"seldom"* use concept maps to assist learners.

- **Internet technology**

Teacher responses to items 32, 33, 34, 45 and 46 of the questionnaire enabled the researcher to apply *The Means Procedure* to establish whether CAT teachers use Internet in the CAT classrooms.

Table 5.5: The Means Procedure for establishing how CAT teachers use the Internet in the CAT classroom

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Items 32, 33, 34, 45 and 46	125	1	5	3	1

Table 5.5 indicates the mean value computed for the use of the Internet in the CAT classroom. The standard deviation represents the average amount of variability in a set of scores, or the average distance from the mean. The larger the standard deviation, the larger the average distance each data point is from the mean of distribution. As the calculated mean for the use of Internet in the CAT classroom is 3, it consequently implies that teachers are using the Internet *"About half of the time"* in the CAT *classroom. Table 5.5* thus implies that teachers use the Internet as a technology tool in computational thinking and problem solving on an average of 50.0%.

5.2.1.3 Promotion of higher level cognitive processes (critical thinking)

Items 14, 16, 17, 21, 56, 58 and 69 in Part 4 was formulated to establish how teachers use their typical teaching and learning actions to promote higher-level cognitive processes. *Table 5.6* indicates how teachers use questions and answers to promote critical thinking.

Table 5.6: Summary for the promotion of higher-order thinking skills

N = 125

PART 4		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
		Never		Seldom		About half the time		Usually		Always		
14	When I talk, I "question", I do not "tell".	1	0.80%	6	4.80%	57	45.60%	50	40.00%	11	8.80%	100
16	My lessons present problems that develop learners' thinking skills.	0	0.00%	6	4.80%	44	35.20%	57	45.60%	18	14.40%	100
17	I redirect learners' questions in such a way that learners are encouraged to arrive at their own answers.	0	0.00%	1	0.80%	40	32.00%	59	47.20%	25	20.00%	100
21	If a learner cannot find an answer to a question, I will give the learner the answer.	6	4.80%	11	8.80%	35	28.00%	40	32.00%	33	26.40%	100
56	I phrase my questions in such a way as to encourage critical thinking skills in my CAT learners.	0	0.00%	4	3.20%	30	24.00%	60	48.00%	31	24.80%	100
58	If a learner cannot find an answer to a question, I ask more questions.	10	8.00%	9	7.20%	37	29.60%	50	40.00%	19	15.20%	100
69	If a learner does not know what to do (for example which function to use in Excel) I will tell the learner which function to use.	0	0.00%	9	7.20%	44	35.20%	41	32.80%	31	24.80%	100

From *Table 5.6* it is clear that only 8% of teachers *"always"* use questions in class. 40% *"usually"* use questions. The majority of teachers will *"always"* or *"usually"* or *"about half the time"* give learners the answers to questions if learners cannot answer a question. Responses to data items 21 and 69 also shows that 58.4% and 57.6% of teachers *"usually"* or *"always"* tells learners what to do if the learners cannot proceed or find an answer to a problem. By telling the answer to learners, it is an indication that teachers do not promote higher-order thinking skills.

Responses to items 14, 16, 17, 21, 56, 58 and 69 also enabled the researcher to apply *The Means Procedure* to establish whether teachers do encourage critical thinking or higher-order thinking skills in the CAT classroom.

Table 5.7: The Means Procedure for the promotion of higher-order thinking skills

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Item 14, 16, 17, 21, 56, 58, 69	125	1	5	1.63	0.96

Table 5.7 (where 1 = Never and 5 = Always) indicates The Means Procedure for the CAT teachers' teaching and learning actions in the CAT classroom to encourage critical thinking. In *Table 5.7* the arithmetic mean for how teachers encourage critical thinking is 1.63. *This implies that teachers in the CAT classroom "Seldom" encourage critical thinking that is needed for computational thinking.*

5.2.1.4 Group work

Items 19, 23 and 68 were analysed to determine whether teachers allow group work in the CAT classroom, as this is part of the problem-solving process. Item 18 (I prefer it when it is quiet in my class during practical lesson) was included in this battery of questions to indicate that when a teacher prefers a quiet classroom, there is no room for discussions or group work. It is then assumed that learners must do their own work, without discussing work with other learners.

Table 5.8: The Means Procedure for group work in the CAT class

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Item 18, 19, 23 and 68	125	1	5	3.91	0.93

The mean score for the questions asked to establish the extent of teachers allowing group work in the CAT classroom is 3.91 (where 1 = Never and 5 = Always). *This mean implies that teachers are allowing learners "usually" to be involved in group work in the CAT classroom.*

5.2.1.5 The use of taxonomy in setting assignments or assessments

Items 26, 27, 28, 29, 30 and 31 were included to determine whether teachers set their own assignments and assessments and whether these are set as problems and not just as mere exercises.

Table 5.9: Summary for setting of assignments and formal assessments and the use of a taxonomy

N = 125

PART 4		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
		Never		**Seldom**		**About half the time**		**Usually**		**Always**		
26	I set my own CAT assignments.	23	18.40%	23	18.40%	36	28.80%	37	29.60%	6	4.80%	100
27	I set my own CAT formal assessments.	19	15.20%	27	21.60%	31	24.80%	36	28.80%	12	9.60%	100
28	When I set assignments, I set the assignment according to a specific taxonomy.	15	12.00%	6	4.80%	8	6.40%	51	40.80%	45	36.00%	100
		Bloom's Taxonomy		**Bloom's Revised Taxonomy**		**Other taxonomy**		**I do not use a taxonomy**				
29	I use the following taxonomy when I set assignments.	82	65.60%	20	16.00%	10	8.00%	13	10.40%			100
		Never		**Seldom**		**About half the time**		**Usually**		**Always**		
30	When I set formal assessments, I set the assessments according to a specific taxonomy.	16	12.80%	6	4.80%	9	7.20%	56	44.80%	38	30.40%	100
		Bloom's Taxonomy		**Bloom's Revised Taxonomy**		**Other taxonomy**		**I do not use a taxonomy**				
31	I use the following taxonomy when I set formal assessments.	79	63.20%	17	13.60%	12	9.60%	17	13.60%			100

Table 5.9 reflects that only 34.4% of teachers (*"usually"* and *"always"*) set their own

assignments and only 38.4% of teachers (*"usually"* and *"always"*) set their own formal assessments. Most of the teachers indicated that they use Bloom's Taxonomy when they set their own assignments (65.6%) or assessments (63.2%). It is interesting to note that Bloom's Revised Taxonomy is only used between 13.6% and 16.0% of the time. Between 10.4% and 13.6% of teachers *"never"* use a known taxonomy when setting own assignments or assessments.

5.2.1.6 The use of algorithms to teach CAT

Items 36 and 37 were included to determine whether teachers do use algorithms to teach CAT and whether they understand what an algorithm is.

Table 5.10: Summary setting assignments and formal assessments and the use of a taxonomy

N = 125

PART 4		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
		Never		Seldom		About half the time		Usually		Always		
36	I use algorithms when I teach	4	3.20%	5	4.00%	11	8.80%	55	44.00%	50	40.00%	100
		Yes		No								
37.1	The recipe to bake a cake.	107	85.60%	18	14.40%							100
37.2	To save a document	101	80.80%	24	19.20%							100
37.3	To create a mail merged letter.	113	90.40%	12	9.60%							100
37.4	To find the maximum in a range.	101	80.80%	24	19.20%							100

Item 36 in the questionnaire was included to determine whether teachers do use algorithms when they teach. *Table 5.10* shows that the majority of teachers claims to use algorithms in their teaching. Item 37 in the questionnaire was included to determine whether teachers can provide a clear indication of their understanding of an algorithm. All four examples given were algorithms. Almost 20% of teachers do not have a clear understanding of an algorithm. Teachers that chose answers that indicated that they do understand algorithms also indicated that they include algorithmic thinking in their teaching and learning.

5.2.1.7 Problems versus Exercises

Items that dealt with the difference between doing an exercise to reinforce contents and doing a problem to reinforce problem solving were included in the questionnaire. The items that dealt with these concepts were items 35, 38, 39, 40, 41 and 42.

Table 5.11: Are activities (exercises) given in class problem solving?
N = 125

PART 4		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
		Never		Seldom		About half the time		Usually		Always		
35	When learners do activities (exercises) in class, I consider that as problem solving.	2	1.60%	8	6.40%	15	12.00%	43	34.40%	57	45.60%	100

Table 5.11 illustrates that, from the response of teachers to this item, it is clear that the majority of teachers believes that a normal activity from (for example) a textbook equates with problem solving.

Table 5.12: The use of spreadsheet and database activities as exercises or problems

N = 125

PART 4		**% PARTICIPANTS ACCORDING TO CATEGORY**										**% TOTAL**
		Never		**Seldom**		**About half the time**		**Usually**		**Always**		
38	I give the learners pre-constructed spreadsheets and expect them to follow the instructions and do calculations as required by instructions.	4	3.20%	3	2.40%	29	23.20%	66	52.80%	23	18.40%	100
39	When I teach a spreadsheet application, such as MS Excel 2010 or 2013, I give the learners the opportunity to create their own spreadsheets from scratch.	6	4.80%	24	19.20%	32	25.60%	30	24.00%	33	26.40%	100
40	I give the learners a “story problem” and they have to construct (design) a spreadsheet from the given information.	17	13.60%	21	16.80%	29	23.20%	43	34.40%	15	12.00%	100
41	When I teach a database application such as MS Access 2010 or 2013 my learners work with pre-created databases.	3	2.40%	9	7.20%	39	31.20%	57	45.60%	17	13.60%	100
42	When I teach a database application, such as MS Access 2010 or 2013, I give the learners the opportunity to create their own database from scratch.	6	4.80%	17	13.60%	38	30.40%	43	34.40%	21	16.80%	100

From the descriptive analysis in *Table 5.12* it is clear that the majority of teachers uses pre-constructed spreadsheets (71.2%) and databases (59.2%) with given instructions. 50.4% of teachers allow learners *“usually”* or *“always”* to create a spreadsheet from scratch. 51.2% of teachers *“usually”* or *“always”* allow learners to create a database from scratch. However, 46.4% of teachers use “story problems” to design a spreadsheet from given information. It is therefore clear that teachers mostly use pre-constructed spreadsheets and databases when giving instructions. It can thus be assumed that exercises are mostly used for teaching and learning in the class room.

To determine whether teachers know the difference between a problem and an exercise, items 55 and 59–64 were included in the questionnaire. *Table 5.13* indicates The Means Procedure for the difference between a problem and an exercise.

Table 5.13: The Means Procedure for teachers' understanding of an exercise and a problem

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Item 55, 59 - 64	125	1	2	1.47	0.48

The arithmetic mean is 1.47. This indicates that teachers perceived the statements as problems. This further shows that teachers cannot make a clear distinction between an exercise and an activity.

5.2.1.8 Teaching time and teaching quality

Items 57, 65, 66 and 67 were included to determine whether teachers teach only with the emphasis on assessment and to determine whether the allocated time and content are adequate to give learners a deeper understanding of CAT with regard to computational thinking skills and problem-solving skills.

Table 5.14: Teaching time and quality of teaching

N = 125

PART 4		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
		Never		Seldom		About half the time		Usually		Always		
57	I only teach with the emphasis on assessment.	13	10.40%	16	12.80%	39	31.20%	38	30.40%	19	15.20%	100
65	I can cover the curriculum with the teaching time that I have.	3	2.40%	9	7.20%	33	26.40%	53	42.40%	27	21.60%	100
66	I have enough teaching time to provide learners with a deeper learning of theory.	1	0.80%	24	19.20%	38	30.40%	42	33.60%	20	16.00%	100
67	I have enough teaching time to provide learners with a deeper learning of practical work.	3	2.40%	16	12.80%	43	34.40%	39	31.20%	24	19.20%	100

From *Table 5.14* it is evident that only 23.2% of the teachers (*"never"* or *"seldom"*) try not to only teach with the emphasis on assessment. The majority of teachers (64%) also have "*Always"* or "*Usually*" enough teaching time to cover the curriculum. The emphasis on assessment also relates to the total amount of time that is available for completing the curriculum and providing learners with a deeper understanding. This is displayed in *Table 5.15*. In *Table 5.15* the arithmetic mean for enough teaching time to give learners a deeper understanding of CAT theory and CAT practice is 3.57. This implies that teachers "*usually*" have enough teaching time.

Table 5.15: The Means Procedure for sufficient teaching time

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Items 65, 66 and 67	125	1	5	3.57	0.99

5.2.1.9 The Practical Assessment Task

Items 49–54 were included to establish teachers' perception of the PAT with regard to educational value and learners' perception of the PAT.

Table 5.16: Teachers' perception of the PAT
N = 125

PART 4		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
		Yes		No								
49	I think that the PAT adds educational value to the CAT learners	105	84.00%	20	16.00%							100
		Never		Seldom		About half the time		Usually		Always		
50	I allow enough time in class for my learners to do the PAT thoroughly.	0	0.00%	23	18.40%	13	10.40%	43	34.40%	46	36.80%	100
51	I think that the learners develop their problems solving skills by doing the PAT.	6	4.80%	5	4.00%	23	18.40%	41	32.80%	50	40.00%	100
52	I think that the learners actually learn by doing the PAT.	5	4.00%	9	7.20%	18	14.40%	47	37.60%	46	36.80%	100
53	I think my learners understand the reason behind doing the PAT.	8	6.40%	7	5.60%	44	32.20%	39	31.20%	27	21.60%	100
54	I think my learners enjoy doing the PAT.	8	6.4	24	19.20%	53	42.40%	28	22.40%	12	9.60%	100

Table 5.16 shows that teachers think that the PAT adds educational value to learners' education. It is encouraging to the researcher that the majority of teachers do realise that

- the PAT can develop learners' problem-solving skills (72.8%); and
- that learners do learn by doing the PAT (74.4%).

However, it is a concern that the majority of learners does not enjoy doing the PAT (68.0%) and that 52.8% of learners do understand what the reason behind the PAT is.

5.2.1.10 Attendance of relevant workshops

Items 70 and 71 were included to establish whether teachers have attended any workshops on computational thinking and problem solving. 64.0% of all teachers did attend a problem-solving workshop, while only 52.0% of teachers attended a workshop on computational thinking.

5.2.1.11 Teachers' perception of their learners' problem-solving skills and computational thinking skills

Table 5.17: Teachers' perception of learners' problem-solving skills and computational thinking skills

N = 125

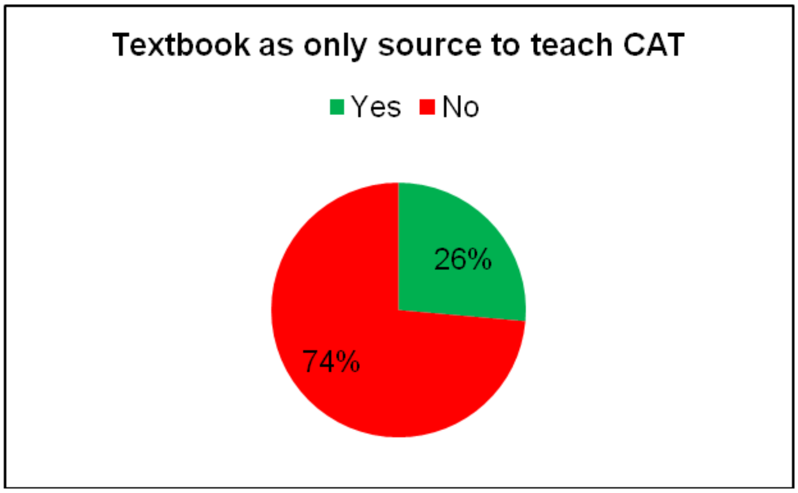
PART 4		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
		Never		Seldom		About half the time		Usually		Always		
47	I think that the majority of learners in my class are competent problem solvers.	3	2.40%	19	15.20%	71	56.80%	24	19.20%	8	6.40%	100
48	I think that the majority of learners in my CAT class have computational thinking skills.	5	4.00%	26	20.80%	59	47.20%	29	23.20%	6	4.80%	100

Items 47 and 48 were included to determine teachers' perception of learners' problem-solving skills and computational thinking skills. *Table 5.17* clearly indicates that teachers believe that only 25.6% of learners are *"usually*" or *"always"* competent problem solvers and that only 28.0% of the learners "*usually"* or "*always"* have computational thinking skills. This implies that CAT is failing as a vehicle to develop computational thinking skills and problem-solving skills among CAT learners.

5.2.1.12 Language and teaching methods

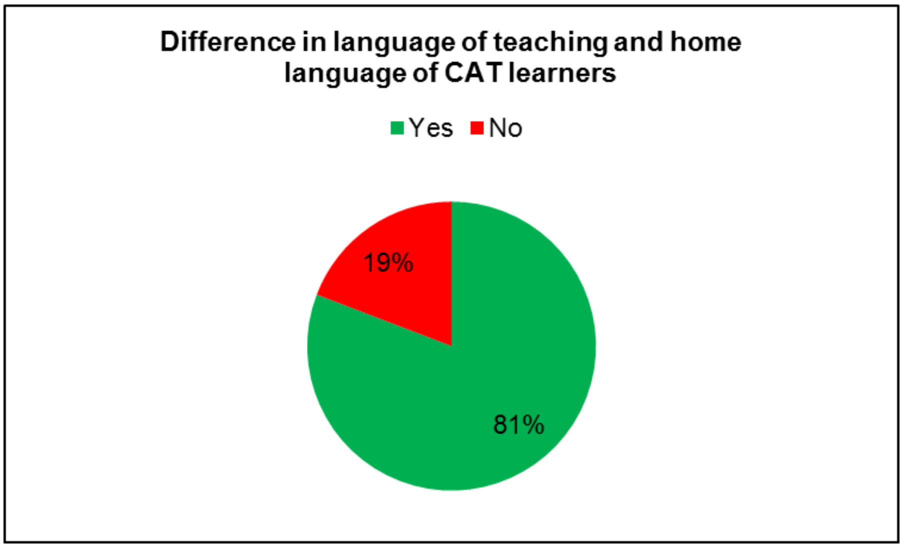
Items 12, 13 and 20 were included in the questionnaire to determine the teachers' teaching methods.

Graph 5.1: The use of only a textbook in teaching CAT



Graph 5.1 indicates that only 26.0% of teachers use only a textbook to teach CAT learners.

Graph 5.2: Difference in language of teaching and home language



Graph 5.2 shows that in 81.0% of learners there is a difference in the language of teaching at school and the home language of the learner.

Table 5.18: Allowing class discussions in home language
N = 125

PART 4		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
		Never		Seldom		About half the time		Usually		Always		
20	I allow learners to have class discussions in their home language.	36	28.80%	32	25.60%	19	13.60%	17	13.60%	21	16.80%	100

Table 5.18 however shows that only 30.4% of teachers *"usually"* or *"always"* allow learners to have class discussion in their home language.

5.2.1.13 Learners' relation to given problems

Table 5.19: Learners can relate to the problem that they must solve
N = 125

PART 4		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
		Never		Seldom		About half the time		Usually		Always		
22	When I give a problem to my learners to solve, the learners can relate to the problem.			21	16.80%	22	17.60%	74	59.20%	8	6.40%	100

Item 22 was included in the questionnaire to determine whether learners can relate to the problems that CAT teachers set them. *Table 5.19* shows that learners can relate only 6.4% of the time to the problem that they must solve; 34.4% of learners can *"seldom"* or *"about half of the time"* relate to the given problem; and 59.2% of learners can *"usually"* relate to the problem. When learners relate to a problem, it will be easier for them to find the solution to the problem.

5.2.1.14 Basic computer skills are important

Table 5.20: Basic computer skills are important in CAT

N = 125

PART 4		% PARTICIPANTS ACCORDING TO CATEGORY										% TOTAL
		Never		Seldom		About half the time		Usually		Always		
25	I think that basic computer skills are important in CAT.			1	0.80%	4	3.20%	23	18.40%	97	77.60%	100

Item 25 was included in the questionnaire to determine whether teachers think that learners need to have the basic computer skills to be successful in CAT. *Table 5.20* shows that the majority of teachers (77.6%) think that basic computer skills are *"always"* important in CAT.

5.2.2 Inferential Statistics

This section analyses the question items according to the Pearson Chi-square test (cf. 4.7.1.2.1).

5.2.2.1 Pearson Coefficient Chi-Square Test

The researcher applied Pearson's Chi-square test to analyse the inferential data. This is a statistical test testing for the existence of a relationship between two variables. If the p-value is less than 0.05, then there is a statistical significance between the two variables. This means that the researcher can be 95% confident that the relationship between the two variables is not due to chance.

After analysis of the data, all the variables that had no significance between the variables (i.e. the p-value > 0.05) were grouped together.

Below is a discussion of the variables for which the Chi-square value (p-value) was less than 0.05.

The Chi-square method was used because it is most suited for discreet data values. A cross-tabulation using Chi-square was computed to determine influential relationships between all the different variables. A few significant relationships were identified and are discussed below.

Table 5.21: Cross tabulation: I find CAT easy to teach * The location of my school.

		I find CAT easy to teach.				
		Never	Seldom	About half the time	Usually	Always
Location of school	Urban	0.00%	0.80%	9.60%	20.80%	32.80%
	Rural	1.60%	0.80%	0.80%	16.00%	16.80%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	9.486	4	0.050

The results of *Table 5.21* show that the Chi-square (4) = 9.486; p = 0.050 ∴ p = 0.05 which indicates that there is a statistically significant relationship between the location of the school and whether teachers find it easy to teach CAT.

Table 5.22: Cross tabulation: I find CAT easy to teach * I have access to a computer at home.

		I find CAT easy to teach.				
		Never	Seldom	About half the time	Usually	Always
I have access to a computer at home.	Never	1.60%	0.00%	0.00%	0.00%	0.00%
	Seldom	0.00%	0.80%	0.00%	0.00%	0.80%
	About half the time	0.00%	0.00%	0.00%	2.40%	8.00%
	Usually	0.00%	0.00%	2.40%	6.40%	28.00%
	Always	0.00%	0.00%	3.20%	0.80%	45.60%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	198.331	16	0.000

The results of *Table 5.22* indicate the Chi-square (16) = 198.331; $p = 0.000 \therefore p < 0.05$ indicating a statistically significant association between the two variables.

Table 5.23: Cross tabulation: I find CAT easy to teach * I have access to Internet at home.

		I find CAT easy to teach.				
		Never	Seldom	About half the time	Usually	Always
I have access to Internet at home.	Never	1.60%	0.00%	0.00%	0.00%	0.00%
	Seldom	0.00%	0.80%	0.00%	0.00%	0.80%
	About half the time	0.00%	2.40%	0.00%	3.20%	4.80%
	Usually	4.80%	3.20%	3.20%	10.40%	15.20%
	Always	4.80%	1.60%	9.60%	6.40%	27.20%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	37.639	16	0.002

The results of *Table 5.23* indicate the Chi-square (16) = 198.331; $p = 0.002 \therefore p < 0.05$ indicating a statistically significant association between the two variables.

Table 5.24: Cross tabulation: I give learners pre-constructed worksheets and expect them only to follow the instructions and do calculations as required by instructions * When learners do activities (exercises) in class, I consider that as problem solving.

		When learners do activities (exercises) in class, I consider that as problem solving.				
		Never	Seldom	About half the time	Usually	Always
When learners do activities (exercises) in class, I consider that as problem solving.	Never	0.00%	0.00%	0.80%	0.80%	0.00%
	Seldom	1.60%	0.80%	0.80%	2.40%	0.80%
	About half the time	0.00%	0.00%	4.00%	4.80%	3.20%
	Usually	1.60%	1.60%	11.20%	16.80%	3.20%
	Always	0.00%	0.00%	6.40%	28.00%	11.20%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	31.918	16	0.010

The Chi-square for *Table 5.24* variables is (16) = 31.918; p = 0.010 ∴ p < 0.050. This indicates that the test is statistically significant at the 5% level. There is thus a statistical significance between the two variables.

Table 5.25: Cross tabulation: When I talk, I “question”, I do not “tell” * My lessons present problems that develop learners’ thinking skills.

		When I talk, I "question", I do not "tell".				
		Never	Seldom	About half the time	Usually	Always
My lessons present problems that develop learners' thinking skills.	Never	0.00%	0.00%	0.00%	0.80%	0.00%
	Seldom	0.00%	0.80%	2.40%	0.80%	0.80%
	About half the time	0.00%	0.80%	24.80%	17.60%	2.40%
	Usually	0.00%	1.60%	8.00%	24.00%	6.40%
	Always	0.00%	1.60%	0.00%	2.40%	4.80%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	42.238	12	0.000

This table shows the results of the Pearson Chi-square test: the Chi-square statistic (42.238), degrees of freedom (12) and the associated p-value (0.000) are given. The p-value from the test is 0.000 which means that the test statistic is significant at the 5% level, thus indicating a statistical significant relationship between the two variables.

Table 5.26: Cross tabulation: When I talk, I “question”, I do not “tell” * I redirect learners’ questions in such a way that learners are encouraged to arrive at own answers.

		When I talk, I "question", I do not "tell".				
		Never	Seldom	About half the time	Usually	Always
I redirect learners' questions in such a way that learners are encouraged to arrive at their own answers.	Never	0.00%	0.00%	0.00%	0.80%	0.00%
	Seldom	0.00%	0.80%	0.80%	0.80%	2.40%
	About half the time	0.00%	0.00%	20.80%	20.00%	4.80%
	Usually	0.00%	0.00%	8.80%	23.20%	8.00%
	Always	0.00%	0.00%	1.60%	2.40%	4.80%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	42.207	12	0.000

This table shows the results of the Pearson Chi-square test: the Chi-square statistic (42.207), degrees of freedom (12) and the associated p-value (0.000) are given. The p-value from the test is 0.000 which means that the test statistic is significant at the 5% level, indicating the significant relationship between the two variables.

Table 5.27: Cross tabulation: I prefer it when it is quiet in my class during practical lessons * I allow learners to discuss work in class so that they can have a better understanding of the work.

		I prefer it when it is quiet in my class during practical lesson.				
		Never	Seldom	About half the time	Usually	Always
I allow learners to discuss work in class so that they can have a better understanding of the work.	Never	0.00%	0.00%	0.00%	0.80%	0.00%
	Seldom	0.00%	0.00%	1.60%	1.60%	5.60%
	About half the time	0.00%	0.00%	0.80%	8.80%	9.60%
	Usually	0.00%	0.80%	5.60%	32.80%	15.20%
	Always	0.00%	3.20%	4.80%	5.60%	3.20%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	33.245.	12	0.001

The results of *Table 5.27* indicate the Chi-square (12) = 33.245; $p = 0.001 \therefore p < 0.05$ that indicates a statistically significant association between the two variables.

Table 5.28: Cross tabulation: I set my own CAT assignments * When I set assignments, I set the assignments according to a specific taxonomy.

		I set my own CAT assignments.				
		Never	Seldom	About half the time	Usually	Always
When I set assignments, I set the assignment according to a specific taxonomy.	Never	8.00%	0.80%	0.00%	4.80%	4.80%
	Seldom	2.40%	0.80%	1.60%	8.80%	4.80%
	About half the time	1.60%	2.40%	4.80%	7.20%	12.80%
	Usually	0.00%	0.00%	0.00%	16.80%	12.80%
	Always	0.00%	0.80%	0.00%	3.20%	0.80%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	50.378	16	0.000

Table 5.28 shows the results of the Pearson Chi-square test: the Chi-square statistic (50.378), degrees of freedom (16) and the associated p-value (0.000) are given. The p-value from the test is 0.000 which means that the test statistic is significant at the 5% level, indicating a statistically significant association between the two variables.

Table 5.29: Cross tabulation: I set my own CAT assignments * I use the following taxonomy when I set assignments.

		I set my own CAT assignments.			
		Blooms' Taxonomy	Blooms' Revised Taxonomy	Other	I do not use a Taxonomy
I use the following taxonomy when I set assignments.	Never	5.60%	4.00%	3.20%	5.60%
	Seldom	15.20%	0.00%	2.40%	0.80%
	About half the time	21.60%	3.20%	0.80%	3.20%
	Usually	20.80%	8.00%	0.00%	0.80%
	Always	2.40%	0.80%	1.60%	0.00%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	38.389	12	0.000

Table 5.29 shows the results of the Pearson Chi-square test: the Chi-square statistic (38.389), degrees of freedom (12) and the associated p-value (0.000) are given. The p-value from the test is 0.000 which means that the test statistic is significant at the 5% level; therefore there is a statistically significant relationship between the two variables.

Table 5.30: Cross tabulation: I set my own CAT assessments' * When I set assessments, I set the assessments according to a specific taxonomy.

		I set my own CAT formal assessments.				
		Never	Seldom	About half the time	Usually	Always
When I set assessments, I set the assessment according to a specific taxonomy.	Never	8.00%	1.60%	0.00%	4.80%	0.80%
	Seldom	0.80%	1.60%	0.00%	11.20%	8.00%
	About half the time	2.40%	1.60%	2.40%	10.40%	8.00%
	Usually	1.60%	0.00%	3.20%	14.40%	9.60%
	Always	0.00%	0.00%	1.60%	4.00%	4.00%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	44.859	16	0.000

Table 5.30 shows the results of the Pearson Chi-square test: the Chi-square statistic (44.859), degrees of freedom (16) and the associated p-value (0.000) are given. The p-value from the test is 0.000 which means that the test statistic is significant at the 5% level, indicating a statistically significant association between the two variables.

Table 5.31: Cross tabulation: I set my own CAT assessment * I use the following taxonomy when I set an assessment.

		I set my own CAT formal assessments.			
		Blooms' Taxonomy	Blooms' Revised Taxonomy	Other	I do not use a Taxonomy
I use the following taxonomy when I set assessments.	Never	5.60%	1.60%	1.60%	6.40%
	Seldom	18.40%	0.00%	3.20%	0.00%
	About half the time	12.80%	4.80%	2.40%	4.80%
	Usually	20.80%	4.80%	0.80%	2.40%
	Always	5.60%	2.40%	1.60%	0.00%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	32.572	12	0.001

Table 5.31 shows the results of the Pearson Chi-square test: the Chi-square statistic (35.572), degrees of freedom (12) and the associated p-value (0.001) are given. The p-value from the test is 0.000 which means that the test statistic is significant at the 5% level, indicating a statistically significant association between the two variables.

Table 5.32: Cross tabulation: I use the Internet in my class to actively engage learners in the learning process * My learners have Internet access in the CAT classroom/My learners have access to electronic mail in the CAT classroom.

			I use the Internet in my class to actively engage learners in the learning process.				
			Never	Seldom	About half the time	Usually	Always
1	*My learners have Internet access in the CAT class.*	Never	11.20%	0.00%	0.80%	0.00%	0.00%
		Seldom	2.40%	7.20%	7.20%	4.00%	3.20%
		About half the time	10.40%	4.00%	3.20%	2.40%	6.40%
		Usually	2.40%	3.20%	2.40%	5.60%	7.20%
		Always	0.00%	0.00%	1.60%	0.00%	15.20%
2	*My learners have access to electronic mail in the CAT class.*	Never	11.20%	0.00%	0.80%	0.00%	0.00%
		Seldom	9.60%	11.20%	2.40%	0.00%	0.80%
		About half the time	11.20%	3.20%	4.00%	4.80%	3.20%
		Usually	8.80%	4.80%	2.40%	4.00%	0.80%
		Always	4.00%	0.00%	1.60%	0.80%	10.40%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square (1)	95.653	16	0.000
Pearson Chi-Square (2)	78.26	16	0.000

The Chi-square for *Table 5.32 (1)* variables are (16) = 95.653; p = 0.000 $\therefore$ $p < 0.050$. This indicates that the test is statistically significant at the 5% level.

The Chi-square for *Table 5.32 (2)* variables are (16) = 78.26; p = 0.000 $\therefore$ $p < 0.050$. This indicates that the test statistic is significant at the 5% level. These values indicate a statistically significant association between the two variables for both of the tables.

Table 5.33: Cross tabulation: I use algorithms * I think the following are examples of different algorithms.

			I use algorithms (steps/procedures) when I teach.				
			Never	Seldom	About half the time	Usually	Always
1	*Example: The recipe to bake a cake.*	Yes	2.40%	2.40%	6.40%	39.20%	35.20%
		No	0.80%	1.60%	2.40%	4.80%	4.80%
2	*Example: To save a document.*	Yes	2.40%	1.60%	5.60%	35.20%	36.00%
		No	0.80%	2.40%	3.20%	8.80%	4.00%
3	*Example: To create a mail merged letter.*	Yes	2.40%	0.80%	8.00%	40.80%	38.40%
		No	0.80%	3.20%	0.80%	3.20%	1.60%
4	*Example: To find the maximum in a range.*	Yes	2.40%	1.60%	7.20%	36.80%	32.80%
		No	0.80%	2.40%	1.60%	7.20%	7.20%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square (1)	5.279	4	0.260
Pearson Chi-Square (2)	10.291	4	0.036
Pearson Chi-Square (3)	31.801	4	0.000
Pearson Chi-Square (4)	5.791	4	0.215

In *Table 5.33* the only two variables that test statistically as significant at 5% is the Pearson Chi-square (2) where the variables are (4) = 10.291; p = 0.000 ∴ p < 0.050, and Pearson Chi-square (3) where the variables are (4) = 31.801; p = 0.000 ∴ p < 0.050, indicating a statistically significant association between the two variables.

Table 5.34: Cross tabulation: I use concept maps to help learners master content * I use presentation tools to help learners create a mental picture of content.

		I make use of presentation tools during my lessons to assist the learners in creating a mental picture of the content.				
		Never	Seldom	About half the time	Usually	Always
I make use of concept maps (mind maps) to help learners to master content.	Never	0.80%	6.40%	0.00%	12.80%	0.00%
	Seldom	0.80%	4.00%	12.00%	15.20%	0.80%
	About half the time	0.00%	0.80%	4.80%	8.00%	2.40%
	Usually	2.40%	0.00%	2.40%	14.40%	7.20%
	Always	0.80%	0.00%	0.80%	1.60%	1.60%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	49.246	16	0.000

Table 5.34 shows the results of the Pearson Chi-square test: the Chi-square statistic (49.246), degrees of freedom (16) and the associated p-value (0.000) are given. The p-value from the test is 0.000 which means that the test statistic is significant at the 5% level. This means that there is a statistically significant association between the two variables.

Table 5.35: Cross tabulation: I use open-ended questions/problems that can be solved in different ways * With MS Access 2010/2013 I give the learners the opportunity to create their own database from scratch.

		I make use of open-ended questions/problems that can be solved in different ways.				
		Never	Seldom	About half the time	Usually	Always
When I teach a database application, such as MS Access 2010 or 2013, I give the learners the opportunity to create their own database from scratch.	Never	0.00%	0.00%	0.80%	3.20%	0.80%
	Seldom	0.00%	3.20%	6.40%	4.00%	0.00%
	About half the time	0.00%	0.80%	17.60%	11.20%	0.80%
	Usually	0.00%	4.00%	15.20%	11.20%	4.00%
	Always	0.00%	0.00%	1.60%	12.00%	3.20%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	31.582	12	0.002

The results of *Table 5.35* indicate the Chi-square (12) = 31.582; p = 0.002 ∴ $p < 0.05$ indicating a statistically significant association between the two variables.

Table 5.36: Cross tabulation: Majority of CAT learners in my class are competent problem solvers * I think that the PAT adds educational value to the CAT learners.

		I think that the PAT adds educational value to the CAT learners.	
		Yes	No
I think that the majority of learners in my class are competent problem solvers.	Never	0.00%	2.40%
	Seldom	9.60%	5.60%
	About half the time	48.80%	8.00%
	Usually	19.20%	0.00%
	Always	6.40%	0.00%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	28.18	4	0.000

The results of *Table 5.36* indicate the Chi-square (4) = 28.18; p = 0.000 ∴ $p < 0.05$ indicating a statistically significant association between the two variables.

Table 5.37: Cross tabulation: I can cover the curriculum with the teaching time that I have * I have enough teaching time to provide learners with a deeper understanding of theory and practical work.

			I can cover the curriculum with the teaching time that I have.				
			Never	Seldom	About half the time	Usually	Always
1	*I have enough teaching time to provide learners with a deeper learning of theory.*	Never	0.00%	0.00%	2.40%	0.00%	0.00%
		Seldom	0.00%	4.00%	2.40%	0.00%	0.80%
		About half the time	0.00%	2.40%	12.00%	12.00%	0.00%
		Usually	0.00%	8.80%	13.60%	16.80%	3.20%
		Always	0.80%	4.00%	0.00%	4.80%	12.00%
2	*I have enough teaching time to provide learners with a deeper understanding of practical work.*	Never	0.00%	0.00%	2.40%	0.00%	0.00%
		Seldom	0.00%	4.80%	0.80%	0.80%	0.80%
		About half the time	1.60%	0.80%	18.40%	4.80%	0.80%
		Usually	0.00%	5.60%	12.00%	20.00%	4.80%
		Always	0.80%	1.60%	0.80%	5.60%	12.80%

Chi-Square Tests			
	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square (1)	69.443	16	0.000
Pearson Chi-Square (2)	90.676	16	0.000

The results of *Table 5.37* indicate the Chi-square (1) (16) = 69.443, p = 0.000 ∴ $p < 0.05$ and that the Chi-square (2) (16) = 90.676; p = 0.000 ∴ $p < 0.05$ thus indicating a statistically significant association between the variables.

Table 5.38: Cross tabulation: I have enough teaching time to provide learners with a deeper understanding of practical work * I phrase my questions in such a way as to encourage critical thinking skills.

		I have enough teaching time to provide learners with a deeper understanding of practical work.				
		Never	Seldom	About half the time	Usually	Always
I phrase my questions in such a way as to encourage critical thinking skills in my CAT learners.	Never	0.00%	0.00%	0.00%	0.00%	0.00%
	Seldom	0.00%	0.00%	1.60%	0.80%	0.80%
	About half the time	1.60%	8.00%	9.60%	4.80%	0.00%
	Usually	0.80%	4.80%	15.20%	20.00%	7.20%
	Always	0.00%	0.00%	8.00%	5.60%	11.20%

Chi-Square Tests

	Value	df	Asymp Sig. (2-sided)
Pearson Chi-Square	40.071	12	0.000

The results of *Table 5.38* indicate the Chi-square (12) = 40.071, p = 0.001 ∴ p < 0.05 indicating a statistically significant association between the two variables.

Factor analysis was used to establish the different factors among observed variables.

5.2.2.2 Factor Analysis

The aim of factor analysis is to reduce a set of variables into a smaller set of dimensions. It was used to determine whether certain items in the questionnaire have something in common with some of the variables used in the research (Field; 2013:655).

As seen in *Table 5.39,* on the next page, the KMO (cf. 4.7.1.2.2) for this study is 0.512.

Table 5.39: KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling		.512
Bartlett's Test of Sphericity	Approx. Chi-Square	5727.834
	df	2080
	Sig.	0.000

In *Table 5.39* the value of 0.512 for the KMO measure of sampling adequacy allows for the application of factor analysis. This is supported by the Bartlett's test of sphericity value of 0.000 that is less than 0.05; thus it proves that the analysis is significant.

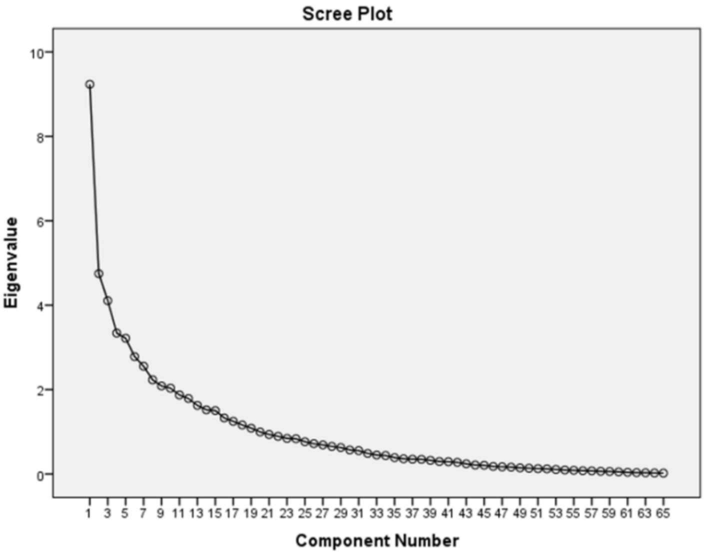
The table of communalities shows how much of the variance in the variables has been accounted for by the extracted factors. Small values indicate variables that do not fit well with the factor solution, and that these factors should possibly be dropped from the analysis. The extraction communalities for this study are acceptable, as there are no small values.

Table 5.40: Eigenvalues of the Correlation Matrix

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	9.233	14.205	14.205
2	4.747	7.303	21.508
3	4.107	6.318	27.827
4	3.340	5.138	32.965
5	3.216	4.948	37.913
6	2.782	4.279	42.192
7	2.553	3.928	46.120
8	2.232	3.433	49.553
9	2.086	3.209	52.762
10	2.034	3.130	55.892
11	1.873	2.881	58.773
12	1.788	2.751	61.524
13	1.626	2.502	64.026
14	1.520	2.339	66.366
15	1.502	2.311	68.677
16	1.328	2.042	70.719
17	1.248	1.920	72.639
18	1.163	1.788	74.428
19	1.086	1.671	76.098

With the aid of eigenvalues of the correlation matrix, the principal components were determined that had to be singled out. *Table 5.40*, on the previous page, shows the principal components that have eigenvalues greater than 1.

Graph 5.3: Scree Plot of Eigenvalues



In *Graph 5.3,* the scree plot graphs the eigenvalue against the factor number. As observed in the graph, from the 9th factor onward, the line is almost flat, meaning that every successive factor accounts for smaller and smaller amounts of the total variance. The researcher will only consider the nine factors which have been screed.

Table 5.41: Rotated Component Matrix

Rotated Component Matrix

	Component								
	1	2	3	4	5	6	7	8	9
I think that the learners actually learn by doing the PAT.	.908								
I think that the learners develop their problems solving skills by doing the PAT.	.848								
I think my learners understand the reason behind doing the PAT.	.846								
I think my learners enjoy doing the PAT.	.791								
I think that the PAT adds educational value to the CAT learners.	-.759								
I think that the majority of learners in my class are competent problem solvers.	.531								
I have enough teaching time to provide learners with a deeper learning of theory.		.801							
I have enough teaching time to provide learners with a deeper understanding of practical work.		.796							
I redirect learners' questions in such a way that learners are encouraged to arrive at their own answers.		.625							
I phrase my questions in such a way as to encourage critical thinking skills in my CAT learners.		.589							
I make use of open-ended questions/problems that can be solved in different ways.		.572							
My lessons present problems that develop learners' thinking skills.		.487							
I do allow learners to help one another with practical problems that they may experience in Word or Excel.			.740						
I allow learners to discuss work in class so that they can have a better understanding of the work			.698						
I allow for team work in the CAT class			.691						
I allow enough time in class for my learners to do the PAT thoroughly.			.630						
I make use of presentation tools during my lessons to assist the learners in creating a mental picture of the content.			.476						
I prefer it when it is quiet in my class during practical lesson.			-.466						
I use the following taxonomy when I set formal assessments.				-.875					
When I set formal assessments, I set the assessments according to a specific taxonomy.				.800					
I use the following taxonomy when I set assignments.				-.793					
When I set assignments, I set the assignment according to a specific taxonomy.				.673					

Table 5.41: Rotated Component Matrix (*continued*)

Rotated Component Matrix

	Component								
	1	2	3	4	5	6	7	8	9
Assumptions need to be made.					-.674				
When I talk, I "question", I do not "tell".					.653				
When teaching the learners how to do an Internet search, I only use Google as a search engine.					-.624				
I make use of concept maps (mind maps) to help learners to master content.					.453				
I think that the following are examples of different algorithms (procedures):To save a document.						-.768			
I think that the following are examples of different algorithms (procedures):To find the maximum in a range.						-.712			
I think that the following are examples of different algorithms (procedures):To create a mail merged letter.						-.554			
When learners do activities (exercises) in class, I consider that as problem solving.						.514			
I think that basic computer skills are important in CAT.						.502			
Communication skills are necessary.						.420			
My learners have Internet access in the CAT class.							.833		
My learners have access to electronic mail in the CAT class.							.740		
I use the Internet in my class to actively engage learners in the learning process							.642		
I make use of video clips to explain difficult content to my learners.							.432		
When I teach a spreadsheet application, such as MS Excel 2010 or 2013, I give the learners the opportunity to create their own spreadsheets from scratch.								.771	
When I teach a database application, such as MS Access 2010 or 2013, I give the learners the opportunity to create their own database from scratch.								.754	
I only use a textbook to teach CAT.								-.472	
When I teach a database application such as MS Access 2010 or 2013 my learners work with pre-created databases.					.401			.436	
When I give a problem to my learners to solve, the learners can relate to the problem.									.805
I give the learners a “story problem” and they have to construct (design) a spreadsheet from the given information.								.423	.485
Learner can only follow one approach.									-.442
I give the learners pre-constructed spreadsheets and expect them to do follow the instructions and do calculations as required by instructions.									.419

The Rotated Component Matrix displays the loadings for every item on each rotated component, clearly showing which items make up each component. The researcher then compared the questions that load onto the same factor to identify common themes. The questions that loaded highly on factor 1 (as seen in *Table 5.41*) all relate to the PAT and problem solving; the researcher will therefore label this factor *problem solving*. The questions that load highly on factor 2 all seem to relate to different aspects of teaching and questioning; this factor will therefore be labelled *teaching and questioning*. The questions that load highly on factor 3 all seem to relate to class discussions and group work; this factor will be labelled *collaboration*. The questions that load highly on factor 4 all seem to relate to taxonomy and the setting of assignments and assessments, so this factor will be labelled *taxonomy*. The questions that load highly on factor 5 all seem to be related to thinking, so this factor will be labelled *thinking.* Most of the questions that load highly on factor 6 all deal with algorithms; hence this factor will be labelled *algorithms.* Electronic resource questions load highly on factor 7; this factor will be labelled *resources*. The questions that load highly on factor 8 all seem to be related to exercises and problems, so this factor will be labelled *exercises vs problems*. Finally, the questions that load highly on factor 9 all relate to representation of information; thus this factor will be labelled *representation.*

This analysis apparently reveals that the questionnaire is, in reality, composed of nine factors. There may be two possibilities for this. It may firstly be due to the statistical analysis failing to measure what is set out to (namely computational thinking and problem solving), but does measure some related constructs, namely computational thinking and problem solving. Secondly this may be due to all nine constructs being sub-components of computational thinking and problem solving. However, the factor analysis does not indicate which of these possibilities is true.

5.2.2.3 Hypothesis testing

The researcher used the Pearson's coefficient correlation and Spearman's coefficient correlation test to test the hypothesis and null hypothesis (cf. 1.8) as stated in Chapter 1.

H_1: There is a statistically significant relationship between problem solving and computational thinking skills in the subject CAT.

H_0: There is no statistically significant relationship between problem solving and computational thinking skills in the subject CAT.

All items that related to problem solving were grouped together; likewise all items that related to computational thinking were grouped together. Tables 5.42 and 5.43 display the results of the hypothesis testing.

Table 5.42: Chi-square test

N=125

	Value	Df	Asymp. Sig. (2-sided
Pearson Chi-Square	1406.778	1216	.000

Table 5.43: Spearman's correlation coefficient

N=125

		Value	Asymp. Std. Error	Approx. T	Approx. Sig
Ordinal by Ordinal	Kendall's tau-b	.452	0.52	8.682	0.000
	Spearman Correlation	0.604	0.064	8.405	0.000

After the Pearson correlation and Spearman's rank-order correlation were used to determine the relationship between computational thinking and problem solving, the following may be concluded: the results indicate a value of 0.00, thus $p < 0.01$; the correlation is therefore statistically significant and the null hypothesis is rejected. The H_1 hypothesis could be proved and according to these calculations a statistically significant relationship between problem solving and computational thinking in the subject CAT does excist.

The next section analyses the qualitative data that was collected via semi-structured interviews.

5.3 QUALITATIVE DATA ANALYSIS

The following section portrays the thematic analyses of the transcribed qualitative data collected by the researcher by means of semi-structured interviews. The interviews allowed sufficient time for the participants to elaborate to collect in-depth data about problem solving and computational thinking; all the interviews were concluded in less than 30 minutes. The participants' discussions during the semi-structured interviews were recorded on a reliable cell phone recorder and later transcribed into textual data.

The processs of thematic coding (cf. 4.7.2) followed the following steps:

Qualitative analysis is a process of interim discovery, and aims at developing coded topics and categories (McMillan & Schumacher, 2010:351). The researcher attempted to bring order, structure and meaning to the responses of the collected data. The researcher searched through the data for regularities, patterns, topics, words and phrases to represent the topics and patterns. The data were continuously divided into manageable topics or categories. The emergent patterns or categories were colour-coded. Emic categories were emphasised and preferred when the data were collected. (McMillan & Schumacher, 2010:244). Similar colour-coded themes were then grouped together from all the responses of all the participants. Two all-embracing themes, namely "What must learners know" and "What is the role of the teacher" came forth. In this study these themes are portrayed as "Learners" and "Teachers". These topics and categories may initially come from the data or may be predetermined to seek a pattern for a plausible explanation. The transcripts were read intensively to gain familiarity with them.

A phenomenological analysis approach and representational approach were followed to gain clarity. Creswell (2012:193-194) makes mention of specific attributes which were adhered to:

- The significant statements of the participants were listed.
- These statements were grouped into larger information units or themes.
- The experiences of the participants with the phenomenon were described by including verbatim examples, and this is called a textural description.
- The researcher reflected on the setting and context in which the phenomenon was experienced.
- The textual and structural descriptions of the phenomenon that were incorporated in

culminating aspects cristalised.

Once the themes were established, the different colour coded words/sentences were grouped together into sub-themes underneath the two main themes, as tabled in *Table 5.44*.

Table 5.44: Themes and sub-themes

THEMES	**SUB-THEMES**
Learners	*Life skills* *Computer skills* *Thinking skills*
Teachers	*Scenario's/real-life activities* *Teaching time* *Professional qualification*

5.3.1 Theme 1: Learners

5.3.1.1 Sub-theme 1: Life skills

The teachers felt that for learners to be able to comprehend CAT, they should have certain life skills. They also added that with effective teaching and learning in the CAT class, it is possible for a teacher to inculcate these skills in learners.

A number of participants specifically expressed that learners need life skills such as working independently and being self-directed. Teachers must not provide correct answers to learners. Learners must be allowed the opportunity to find answers on their own. Some of the views of the participants are:

One must always realise that teaching is not always about conveying knowledge from a textbook to a learner. You must also try and convey life skills to a learner, and we all know that acquiring life skills is accompanied by problem solving. Life has never been a smooth ride. Don't spoon-feed learners [Participant 5]. Lead learners by certain clues to *develop their skills. Encourage learners to explore on their own* [Participant 2]. *Allow the child to do self-investigation* [Participant 4].

Teachers also mentioned that when teachers give certain problems/activities to learners, they must ensure that the problem is at the correct cognitive level. In other words, learners must be able to solve specific cognitive problems. This will allow for confidence building and the belief that they can do CAT. Responses to substantiate this are:

Teachers need to get learners to believe in themselves, i.e. build confidence, so do not give learners problems that are so difficult to solve that they give up almost before they start [Participant 3]. *Learners should be able to persevere in order to get an answer to a problem* [Participant 8].

When learners do activities/problems they must be able to articulate thoughts, listen effectively and communicate with others verbally and electronically.

Learners need to have effective communication skills, i.e. to ask when they do not understand something or to be able to go to 'experts' to look for answers to a problem [Participant 8]. *Learners need to have effective communication skills* [Participant 2].

Teachers felt that learners must also exhibit the ability to work effectively and respectfully with diverse groups in the CAT class owing to the fact that a CAT classroom consists of a diverse group of learners. Learners must also be willing to learn from one another. Learners must assume a shared responsibility for collaborative work, and value their peers’ contribution when they work in a group, as the main aim of group work is to learn from one another. Some of the responses that concluded this are:

Yes, it is not always possible to give individual attention to learners, and that is why if one experiences a problem that he cannot solve, we will solve the problem as a group because be rest assured there are other learners experiencing the same problem [Participant 5]. *Although there is not much time in the CAT curriculum, teachers should* *use group work or group activities from time to time, where appropriate - learners need to be able to operate in a team and be able to work together with others at times in order to solve a problem* [Participant 3].

5.3.1.2 Sub-theme 2: Computer skills

Some of the participants felt that it is very important for learners to have basic computer skills in CAT. Basic computer skills may be defined as computer literacy (cf. 2.5.4) which includes the use of a spreadsheet application with certain required mathematical skills to do some calculations (very well). Learners must also be able to transfer skills learnt in one application or version to another application or version. Some of the responses from the participants were:

In spreadsheets learners are required to use mathematical skills in order to solve problems via the use of formulae and functions [Participant 2]. *Some calculation skills in spreadsheets. This means that learners must be able to think mathematical in spreadsheets. They must be able to recognise certain functions* [Participant 7]. *Learning can only start when the basic skills are mastered* [Participant 1]. *Know the basics* [Participant 8]. *Transfer skills to solve other problems, i.e. if learners manage to do something in one application/version of software those skills can be transferred to another application/version of software* [Respondent 4].

Teachers felt that learners must be taught that a computer can be used outside the CAT classroom. It is important that learners realise that what they learn in the CAT classroom can be transferred to the external working environment. A computer inside the CAT classroom is the same as a computer outside the CAT classroom. They must therefore be able to transfer the skills that they have learnt in the CAT classroom to the world of work outside the school classroom.

Applications should be taught keeping in mind what the learners will need to be able to do a proper job one day. They must be able to learn a new program easily because they are used to using a computer and solving problems or making changes in programs if *they explore them further* [Participant 2].

A few teachers mentioned that there is not enough time in class for learners to become skilled in the computer applications programs. Time is limited and many learners do not have access to a computer at home to practise the skills learnt in class. A response from one teacher gives a clear picture:

In our school, and in most of the other schools in our district, learners do not have access to computers after school hours. Extra classes must be administered just to complete the syllabus. There is no time available for learners in these schools to just explore and get to know a computer [Participant 8].

Besides the fact that learners do not get enough time to practise the practical skills or problem-solving skills in the classroom, it was also mentioned by some participants that the textbooks they use in their schools do not provide for problem-solving skills or computational thinking skills. Many of the activities set in the textbooks are merely where data is given to learners and they have to complete calculations according to instructions. The textbook activity very seldom requires learners to design or start an activity from scratch; in other words, learners are given a word document/spreadsheet document and they must only complete the instructions given.

Practical data is given to the learners; they only have to add to the given exercise. Few exercises ask the learners to design from scratch [Participant 7].

5.3.1.3 Sub-theme 3: Thinking skills

For effective teaching and learning to take place in CAT classes, teachers must “unlock” learners’ thinking skills. When asked what teachers understand under thinking skills, the general response was that learners must be able to explain text and manipulate data into useful information. Learners must be able to relate content to questions. They must just think logically. A number of participants stated that they want to instill logical and critical thinking through the activities or problems that they give learners in class. Participants also mentioned that learners must learn to think for themselves and that they must have the ability to productively analyse and assess data and information. Learners must be able to make connections between information and from there be able to draw a conclusion to the problem. Teachers want learners to be able to identify and ask significant questions that explain various points of view and to find the best solution to the problem. Teachers want learners to use a variety of reasoning types when trying to solve a problem. Some of the participants' thoughts on this sub-theme are:

For me, I want to instill logical thinking skills with the learners; how to logically follow a process and apply the knowledge identifying a problem, gather information around the problem, look at solutions, test the solutions and apply the solution. Also to critically look at things and not just accept outcomes, but to work out solutions by the learner himself [Participant 1].

They learn to think for themselves using the knowledge that you have given them. They think out of the box exploring more options on the program that is not always found in the textbook [Participant 2].

Learners are posed with a problem and are expected to find a solution, break new ground or where they are required to give suggestions/recommendations as to how to improve a situation [Participant 3].

A learner must be able to think on his feet. A person runs into certain problems that the textbooks do not give the answers to; in as to how to solve a problem and this is where a learner must think wider than the "script". This is where a learner starts using life skills that he has acquired in the classroom [Participant 5].

Teachers felt that because CAT is categorised as a 'non-designated' subject, it is often wrongfully 'labelled' as a non-academic subject. The perception is thus that the subject does not challenge the academically strong learners and that CAT should be offered to only those learners who are able to cope with lower cognitive abilities.

Some learners (and teachers) only operate on lower and middle order cognitive levels and do not know how to operate on a higher-order cognitive level [Participant 4].

5.3.2 Theme 2: Teachers

5.3.2.1 Sub-theme 1: Scenarios/real-life activities

Teachers believe that scenarios or real-life situations must be used when teaching or assessing learners in problem solving and computational thinking. The problems that teachers set must have real-world value and use. This means the problem must be authentic and relevant to the learner's world of reference.

I like to do this within a scenario or context… so that learners apply the knowledge to solve problems in a context… that means they will have a stimulus to trigger their thoughts. Some learners find this difficult as their knowledge framework does not always include critical thinking [Participant 1].

Use contexts. Make these contexts relevant to the daily framework of the learners. Choose contexts that they can relate to. Choose problems in their daily lives that they in any case will have to solve… such as how many marks are needed to pass a subject, or qualify for a Bachelor's pass, or what cell phone contract is the best to choose, etc. Issues that are within the learners' realm of existence [Participant 2].

The problem-solving activities that I give my learners are mostly related to real-life issues. Where they must apply the knowledge they get in CAT to solve problems; such as the use of Excel functions to calculate cost of items, or the use of word-processing to design posters for other subjects [Participant 6].

The teachers explained that activities given to learners in class to teach problem-solving skills and computational thinking must be more than mere textbook activities. These textbook activities can be used to master skills, but it is important for teachers to expose learners to more than just textbook activities. The teachers felt strongly that as CAT teachers they must offer learners the opportunity to apply the knowledge that they learn in CAT (practically and theoretically) to solve problems. Teachers must go beyond the prescribed textbook and use alternative sources to foster computational thinking and problem-solving skills in learners. Examples of such sources are: open-book problems, CAT Olympiad type questions and research tasks. Responses from participants that support this view are:

Open-book tests are intended to encourage problem solving, where learners are given questions and they have to search for answers in given text or where they are allowed to find answers by other means, i.e. searching the Internet [Participant 2].

Include open-ended questions in teaching and learning [Participant 3].

Computer Applications Olympiad type questions where learners are expected to answer a question without being given instructions on what application skills (i.e. use filtering) to use on how to solve that problem [Participant 7].

Some of the participants also stated that it is sometimes necessary for learners to be given the solution and they must work in reverse to arrive at the question. This will help learners to see how the real-world relates to what is taught in the CAT class. Another option mentioned by more than one teacher is that teachers must give learners a badly formatted document or a screenshot of a completed document, without any instructions for the learners to follow. Learners are then expected to format/replicate the document correctly. For example, if a heading was in WordArt, the learner must know how to format a heading to a WordArt without any instructions being given.

Another idea is to present learners with the suggested answers (memorandum) of questions and then ask learners to pose problems to arrive at that suggested answer [Participant 2].

In the applications such as Word Processing and HTML, learners are given a screenshot and asked to replicate it without being given specific instructions on how to do it. Learners can be given a document that is badly formatted and be asked for suggestions on how to improve its appearance [Participant 3].

5.3.2.2 Sub-theme 2: Teaching time

A sub-theme that presented itself very prominently in most of the participants' responses was time management/sufficient time to teach the relevant skills to learners as prescribed in the CAPS document.

Teachers are under pressure to complete a packed syllabus, and so the thinking could be to get through the work and make sure that basic skills are covered [Participant 2].

The syllabus is so packed there is little or no time for revision [Participant 8].

It is the general feeling of teachers that a considerable amount of time must be spent on teaching problem-solving skills, a skill that must be continuously practised. Another problem that teachers mentioned was that to set a problem-solving task or a computational thinking task adds to teachers' current demanding workload.

Learners must routinely and repeatedly be given problem-solving activities, and the activities should be progressively more difficult - this takes time [Participant 3].
Some (teachers) view problem solving as time consuming on the learners' part and find that they do not have that time. Some teachers may also find it difficult to formulate problems or that it take too much time [Participant 4].

Teachers find this less demanding in terms of workload (referring to the setting of problem solving or computational thinking activities.) *They also feel it will save some time. An easy way out. Less marking and assessment of tasks for teachers. Not much assessment to review* [Participant 6].

5.3.2.3 Sub-theme 3: Professional qualification

As technology is an ever evolving field, it becomes clear from participants' responses that teachers sometimes feel inferior to learners and that they are afraid that their lack of knowledge may show. Teachers must be confident in content to be effective. Some teachers are still stuck in the old school concept of teaching where teachers “teach” and learners “listen”. The responses from two participants:

We tend to teach content and methodology that we are comfortable with, confident in. Problem-solving is not always easy to teach, or to include in a lesson methodology [Participant 1].

Some teachers still teach in the old paradigm of the teacher is the holder of the knowledge base and they will be the ones that instill that knowledge rather than allowing learners to explore and tap into the learners' knowledge base. Some teachers are afraid that their lack of knowledge will be shown up by the learners, instead of being willing to learn from their learners [Participant 3].

Many of the participants felt that teachers do not have the necessary qualifications to teach CAT as it should be taught, with computational thinking skills. One of the prominent reasons is that most of the ‘older’ teachers come from a Typing, Computyping or Computer Studies SG background. So although teachers have a formal teaching qualification, it does not stem from CAT. Most of these teachers received ‘in-service’ training since CAT was introduced. This ‘in-service’ training was mainly focused on teaching and learning the application programmes.

Many teachers are not qualified [Participant 4]. *First of all I honestly think that some teachers have not acquired the necessary life skills to teach learners how to solve certain problems. It is a question of how can one blind man lead another? [*Participant 5].

Many CAT teachers have not received formal pedagogical/methodology in respect of computational thinking/problem solving. There are very few higher education institutions in our country where teachers are able to get a formal qualification for CAT or are trained to teach CAT. Currently many CAT teachers come with various backgrounds as far as subject knowledge is concerned. There are still some teachers in the system that have translated from Computer Studies/Computyping to CAT. Others have completed *various short courses in computer training. Most have received support and training through DBE workshops and contact sessions. Perhaps in all of this there has not been a focus on computational thinking within the framework of problem solving* [Participant 3].

5.4 CONCLUSION

In this chapter quantitative and qualitative data were analysed and presented to establish how teachers integrate computational thinking and problem solving in the CAT classroom. Finally, a synthesis of the views expressed by teachers during interviews was furnished. The next chapter elaborates on the findings presented in Chapter 5 by way of discussion, conclusion and recommendations.

CHAPTER 6

FINDINGS, CONCLUSION AND RECOMMENDATIONS

6.1 INTRODUCTION

This chapter deals with the findings, conclusion and recommendations of this study and the findings from literature on computational thinking skills and problem solving are discussed. This is followed by the findings from the data analysis.

At this stage of the study, it is important to indicate how the research questions are addressed:

Research question 1: What are the essences of computational thinking and computational thinking skills with regard to CAT?

This research question was address by a thorough literature study conducted in Chapter 2, as well as the findings as portrayed in paragraph 6.2.1.

Research question 2: What are the essences of problem solving with regard to CAT?

This research question was address by a thorough literature study conducted in Chapter 3, as well as the findings as portrayed in paragraph 6.2.2.

Research question 3: How do teachers integrate computational thinking and problem solving in the CAT classroom?

This research question was address with the analysis of questionnaire and semi-structure interview data in Chapter 5 (cf. 5.2 and 5.3), as well as the findings and discussions of the emphirical investigation as discussed in paragraph 6.2.3 and 6.2.4

Research question 4: Which recommendations for teaching computational thinking and *problem solving can be put forward?*

This research question was address with the recommendations put forward in paragraphs 6.2.3 and 6.2.4.

Research question 5: What should be included in a computational thinking and problem-solving training programme for CAT teachers?

This research question was address with the proposed toolkit in Chapter 7.

6.2 DISCUSSIONS OF FINDINGS, IMPLICATIONS AND RECOMMENDATIONS

The findings of this study are discussed in sequence. Findings from the literature study on the essence of computational thinking and problem solving are discussed first. The conclusions of the questionnaire and interviews with teachers are finally discussed.

6.2.1 Findings from the literature review on the essence of computational thinking and computational thinking skills with regard to CAT

- For learners to be fluent in the 21st century world of work, they need to master life and career skills and acquire learning and innovation skills and information, media and technology skills. Critical thinking, problem solving, communication, collaboration and creativity, innovation and computational thinking are some of the skills learners need to master while they also require information literacy, media literacy and ICT literacy. Effective teaching and teachers fulfil the the specific aims of CAT in the CAT lab, can develop learners with 21st century skills (cf. 2.2).

- CAT as one of the two computer subjects in the South African school curriculum can be used as a vehichle to instil these skills in learners from Grades 10 – 12 (cf. 2.3).

- Computing is regarded as the study of information processes that use technology (cf. 2.4.1) while computation is the execution of a process. The combination of computing and computation can therefore lead to the development of computational thinking skills in learners (cf. 2.4.2).

- Computational thinking is a reasoning skill set that should be taught to all learners in schools. Although it is a relatively new concept, and normally associated with Computer Science and programming, literature shows that CAT as a medium in the South African school curriculum can be used to develop this skill in learners, as it is a way of thinking on how to solve problems (cf. 2.5.1).

- For a learner to be able to apply computational thinking, a set of diverse skills such as automation and abstraction, making of representations, analysing, evaluating is needed (cf. 2.5.2).

- Computational thinking is a process for thinking about data and ideas, and combining resources such as technology to solve problems. Thinking skills such as critical thinking, logical thinking, creativity, analytical thinking and original thinking are developed through computational thinking by means of experience, actively doing and interaction in the classroom (cf. 2.5.3).

- Literature reviewed indicates that computational thinking is not necessarily programming or computer science, but it is a skill that can be used in all subjects across the curriculum (cf. 2.5.4).

- Without functioning and adequate computers in classrooms, it is not possible to integrate computational thinking into the curriculum (cf 2.5.5).

- Computational thinking can be employed as a cognitive tool to enhance teaching and learning. As a cognitive tool, computational thinking can aid in the construction of knowledge. As a cognitive tool it can also strengthen cognitive functioning and assist in problem solving. Computational thinking’s role as a cognitive tool can be subdivided into information seeking, information presenting, knowledge organisation, knowledge integration and knowledge generation (cf. *Table 2.1*). However, these cognitive tools cannot function without the learner who provides the intelligence to employ the cognitive tools. Cognitive tools can include database, spreadsheets, concept maps, expert systems, multimedia/hypermedia software, computer programming languages and Microworlds. All these tools, however, do not form part of the CAT curriculum. Computational thinking is thus not to teach learners to think like computers, but to develop the mental tools so that computing can be used in solving complex problems (cf. 2.6.1).

- Mindtools are computer-based tools and learning environments that have been adapted or developed to function as intellectual partners with the learner to engage and facilitate critical thinking and higher-order learning, so mindtools and cognitive tools can be used interchangeably. Mindtools that can be employed by the CAT teacher to enhance computational thinking are for example: database, spreadsheets, concept maps, micro worlds or any other computer program that stimulates learning and thinking (cf. 2.6.2).

- Computational thinking emphasises higher-order thinking skills; it thus enables learners to provide explanations and make decisions. To improve learners' metacognitive skills, teachers must ensure that three kinds of knowledge such as declarative, procedural and conditional knowledge are mastered in the CAT classroom (cf. 2.6.3).

- When learners study computing, they gain insight to computational thinking, so it is important that learners understand the concepts of computing such as computation, communication, co-ordination, recollection, automation, evaluation and design. Learners learn computational thinking in a three-part framework. They must use a computational-rich environment and will eventually modify the environment. Finally, learners can create a model based on an original design. However, for learners to benefit from this three-part framework, teachers must ensure that learners understand algorithms, programs, data and information, computers and communication and the Internet (cf. 2.7.1).

- Learners can greatly benefit from computational thinking because it enhances their learning experience. Computational thinking matures learners into competent problem solvers while they simultaneously master technology beyond computer literacy or computer fluency (cf. 2.7.2).

- For teachers to be effective in teaching computational thinking, they first need to be skilled computational thinkers themselves. They need the relevant subject knowledge and the teaching skills in problem solving. Teachers must realise that they must guide learners through the problem-solving process, instead of doing the problem-solving process for learners. Teachers must have the necessary technical skills that are required for technology in the classroom and they must be skilled in designing effective and challenging assignments to assist learners in progressing to competent problem solvers (cf. 2.8.1).

- To teach learners to become skilled computational thinkers, teachers must learn how to think computationally and algorithmically. In other words, teachers must know when and how to use a computer to solve a problem; they must understand the principle of problem solving. When teachers give learners work which link to data, it must be complex sets of data, not merely a few lines of simple data (cf. 2.8.2).

- When learners encounter a complex problem, their existing knowledge of the content will bridge the connection between critical thinking and computational thinking (cf. *Figure 2.5*).

- Cognitive tool affordance will allow the CAT learners to be fluent in information seeking (database and search engines) and presentation (graphic organisers and concept maps), knowledge organisation (spreadsheet, presentation tools), knowledge integration (graphic organisation) and knowledge generation (collaborative learning) (cf. 2.8.3.1).

- To create a competent computational thinking learner, the CAT classroom must be converted to a computational thinking classroom, it is therefore the teacher's responsibility to create a thinking culture in the CAT classroom. CAT teachers must use teaching strategies that promote higher-order thinking and employ questions and different questioning techniques as they form the cornerstone of critical thinking. Teachers must encourage learners' collaboration and have class discussions on content. Active problem solving, trial and error and collaboration will all manifest in a computational thinking classroom. Content must be linked to real-world situations and opportunities created for learners to apply content to new situations and problems. Problem-based learning can be effectively used to engage problem-solving skills with new content. It is also essential that teachers use the computational thinking vocabulary in their daily activities in the classroom (cf. 2.8.4).

- Proper infrastructure is vital in teaching computational thinking; the CAT classroom must be equipped with working computers, including the tools to assist learners in a computational problem-solving environment. These tools include functioning hardware, up to date software, Internet and e-mail access. Without access to technology, the teaching of computational thinking cannot take place (cf. 2.8.5).

6.2.2 Findings from the literature review on the essence of problem solving with regard to CAT

- Problem-solving is a skill that must be central to any education programme. Research has shown that problem solving is a significant problem among learners. If learners use computers to solve problems, computational thinking is the required skill set (cf. 3.2 and 3.8).

- A problem can be described as a situation where the goal is known, but the "how" is not known (cf. 3.3.1). For any problem to be solved, there need to be a good reason to get to the solution. For a learner to be able to solve a problem, the problem must have value and it must be within the learners capability to find a solution (cf. 3.3.2).

- Problem-solving is a cognitive process that develops learners' ability to think in different ways about situations, issues and problems and they will use creative, analytical and planning skills to solve that problem. Teachers must ensure that learners understand the nature of and the limitations to the problem and they must agree that the solution to one problem can vary; that there are a number of ways of solving a problem. Problem-solving is a process that depends on a learner's skill and knowledge (cf. 3.3.3).

- Problem-solving competency can only be accomplished once learners are confronted with relevant problems and once they understand how to solve a problem. A problem that has value to learners will improve their knowledge; they will gain a deeper understanding of the subject domain; the problem must thus have educational value (cf. 3.3.4).

- For learners to be competent problem solvers, they need a range of skills. A profound knowledge of the subject and skills such as analysing, interpreting, reasoning, predicting, evaluating and reflecting are all necessary to develop a competent problem solver. Organisational skills along with confidence and persistence will also ensure competency in problem solving (cf. 3.3.3).

- Critical thinking is an essential part in solving any given problem. Teachers can facilitate critical thinking by asking the relevant type of questions. Questions that will lead to critical thinking are: open-ended, clarifying, focusing and probing questions. It is also important that teachers not only teach on assessment, but they must give learners the opportunity to explore content, analyse resources and apply their acquired knowledge (cf. 3.4).

- Problems can be grouped according to how the problem and goal are represented. Ill-defined problems are problems where the solution to the problem is not expected. Learners are often expected to make a judgement and to express personal belief or opinion about the problem. Well-defined problems are normally given to learners after certain content has been dealt with; rules and principles are applied in a straightforward way to arrive at a solution. It is important for learners to be able to solve well-defined problems before they attempt to solve ill-defined problems (cf. 3.5).

- Different cognitive strategies and techniques exist to master problem solving. The foremost reasoning processes include representing, planning, executing and self-regulating. In addition to the reasoning processes, different kinds of knowledge are required to ensure that learners are competent problem solvers (cf. 3.6). Knowledge required for effective problem solving is declarative knowledge (cf. 3.6.1), conceptual knowledge (cf. 3.6.2), procedural knowledge (cf. 3.6.1.3), metacognitive knowledge (cf. 3.6.1.4) and strategic knowledge (cf. 3.6.1.5).

- The problem-solving triad (cf. 3.7.1) explains how the problem-solving process evolves. Before problem representation can take place, learners must have an understanding of the problem. How they understand the problem will be reflected in how they use their metacognitive skills (cf. 3.7.1.1).

- Problem representation is central to problem solving as it is directly related to the learners' existing knowledge of the content of the problem. Problem representation can assist learners to better visualise the problem and thus the solution (cf. 3.7.1.2).

- Besides understanding and problem representation, learners' experience is also an important aspect in the problem-solving triad. Self-regulating learning will take place once learners can make a connection between the learning experience and the problem which implies that their thinking processes may be limited by the lack of experience or prior knowledge (cf. 3.7.1.3).

- For the transfer of learning to take place during the problem-solving process, learners must have an internal connection between the problem and the domain knowledge. Teachers must make sure that learners are fluent in applying knowledge, skills and strategy to one context before introducing new or different problems or tasks (cf. 3.7.1.4).

- To develop CAT learners into competent problem solvers is a long-term process. Problem-solving instruction can influence learners as they engage in computational thinking during the CAT problem-solving process (cf. 3.8). The cyclical model of the computational problem-solving process indicates that problem solving is not an erratic process (cf. *Figure 3.4*).

- Bloom's Revised Digital Taxonomy can be implemented in class to ensure that instruction and assessment are supported by changing levels of thinking skills. By integrating the different levels of Bloom's Digital Taxonomy, teachers equip learners to make a transfer of learning possible (cf. 3.8.1).

- CAT teachers can teach problem solving or they can use problem solving as a teaching strategy. Teachers must differentiate between the two teaching strategies. The focus for CAT teachers should be on teaching learners how to solve a problem by using existing knowledge. Progressive teaching methods such as problem-based learning (cf. 3.9.1), project-based learning (cf. 3.9.2) or inquiry-based learning (cf. 3.9.3) can be used as a strategy to teach how to solve a problem (cf. 3.9).

- Problem-solving activities/assignments in class can either be exercises or problems. If learners know the algorithm or they understand the conceptual structure of the activity/assignment, then the activity/assignment is considered to be an exercise. When the activity/assignment has no definite answer, or it is open-ended and the solutions can vary, then that activity/assignment is considered to be a problem that must be solved (cf. 3.10).

- In designing a problem to solve, teachers must ensure that activities are authentic, have real-world value and solvable by the learner. Activities must challenge learners' understanding and skills of CAT. Activities must not be well-defined and must offer learners the opportunity to think critically and creatively (cf. 3.11).

- Three factors that can influence the implementation of problem solving in the classroom are: the role of teachers and learners, technology and basic computer skills. Teachers often do not spend enough time on problem solving. Class discussions should be permitted (cf. 3.12.1) and access to different kinds of technology such as the Internet, Smartboards and personal technologies such as cell phones and iPods can influence teaching and learning (cf. 3.12.2). Basic computer skills and required software applications must be taught to mastery to warrant that learners can use these skills to enhance problem solving (cf. 3.12.3).

- In Grade 10 spreadsheets can be used as a cognitive tool to teach learners problem solving as well as teaching critical skills such as analysis and persistence (cf. 3.13.1).

- Teachers must, however, ensure that learners understand spreadsheet concepts, formulae and debugging formulae (cf. 3.13.2).

- Assessing problem solving differs from traditional assessment methods. Teachers must develop general problem-solving rubrics instead of using task specific rubrics that can be used as an assessment tool (cf. 3.14).

The summary of the findings and implications of the questionnaire survey follow below.

6.2.3 Questionnaire findings, implications and recommendations

The following section focuses on questionnaire findings, implications and recommendations by the researcher.

Finding 1

- Computers are not always upgraded and maintained as required in teaching CAT effectively (cf. *Table 5.3*). The implications are that CAT schools may not always have the latest application software programmes or the latest antivirus software. The lack of maintenance can also have a negative impact on the teaching and learning of CAT if all computers are not functioning in the CAT classroom.

Recommendations

- Schools must have a policy in place that provides for the updating, upgrading and maintenance of computers and computer software in the CAT classroom (Barr &

Stephenson, 2011:112). The CAPS document (DBE, 2011:11) states that there must be one computer per learner per period, and provision must be made to upgrade and replace equipment and software every four to five years.

Finding 2

- Technology in the classroom is a significant component to facilitate computational thinking and problem solving. It is encouraging to note that from responses to the questions on the use of visual technology that most teachers do use video clips, presentation tools and whiteboards in the CAT classroom (cf. *Table 5.4*). This can assist the learners in understanding difficult and abstract concepts. However, the majority of teachers do not use concept maps to assist learners (cf. *Table 5.4*). Concept maps can be of great help in mastering and learning challenging content such as theory.

- One of the reasons why teachers do not all use visual technology in the CAT classroom may be that teachers themselves do not always have access to the Internet at home (cf. *Table 5.1*) to download video clips and other Internet material that can be used in the CAT class. Besides the use of visual technology, using the Internet in class is an important factor for promoting computational thinking and problem solving. In the sample of teachers, the mean for the use of the Internet in the classroom was 3. This mean implies that teachers only use the Internet as a technology tool in the CAT classroom to promote computational thinking and problem solving for “*about half of the time*” (cf. *Table 5.5*). By using the Internet more frequently, computational thinking and problem-solving skills can be developed more effectively.

Recommendations

- Visual technology plays an important part in effectively teaching CAT. If teachers do not have access to the Internet at home, schools must ensure that teachers have Internet access during school hours so that they can download visual aid material (National Research Council of the National Academies, 2011:28). All schools that offer CAT must have access to the Internet (DBE, 2011a:11). It is therefore the schools' responsibility to ensure that Internet connectivity is available in CAT classrooms. It is the CAT teacher and the school's responsibility to budget for Internet connectivity. If a school cannot provide Internet connectivity owing to financial constraints, it might be a good idea for teachers to explore how to allow learners to Bring Your Own Device (BYOD) (Wolsey & Grisham (2012:4).

- Teachers can use concept maps with great success to assist learners in mastering the theoretical work of CAT (Stoica *et al.,* 2010:10). Teachers must guard against believing that a PowerPoint presentation is the equivalent of a concept map. PowerPoint presentations can be used to deliver content to learners, while a concept map is used to make a connection between different concepts. Teachers can either provide blank concept maps templates to learners after content has been dealt with, or learners can develop their own concept maps (at first with guidance by the teacher). Concept maps can also be created in the word processing application, giving learners further opportunity to master some of the Solution Development content, such as using the drawing canvas and working with shapes.

- The use of PowerPoint in the CAT class can either enhance learning or play a role in obstructing the learning process. Teachers must guard against overloading slides with text or portray slides that are not in a linear sequence – this may distract or confuse learners. The use of pictures in a PowerPoint presentation are of particular value when carefully chosen and relevant to the learning situation (Mason, 2012:90). Teachers can, however, at the end of a PowerPoint presentation, provide learners with a concept map to assist them organise new information and to make meaningful connections between the main ideas and other relevant information.

Finding 3

- To promote critical thinking skills, teachers must engage learners in higher-order thinking. In the sample of teachers, the means procedure for promoting higher-order thinking skills was 3.63. This indicates that teachers do not always use classroom practices that encourage critical thinking (cf. *Table 5.7*).

Recommendations

- It is the CAT teacher's responsibility to create a classroom atmosphere that promotes higher-order thinking skills (critical thinking) and consequently create a thinking environment in the class. This can be done by asking questions (Conklin, 2011:47-48), motivating learners, providing positive support, collaborative work groups (Crawford *et al*., 2005:7), providing classroom resources and opportunities for brainstorming (for example, in System Technology: what must I know before I want to buy a personal computer?), and discussing ideas and concepts (Sharma & Elbow, 2000:3). Teachers can establish word walls to identify glossaries or content specific language that can assist learners, especially where the language of instruction is different to the home language (cf. Chapter 7).

Finding 4

- The means procedure for allowing group work in the CAT classroom was 3.91. This is encouraging as it shows that the majority of teachers do allow group work in the CAT classroom (cf. 5.2.1.4). Group work is an important facet in computational thinking and problem solving.

Recommendations

- Teachers must encourage effective group work in the CAT class. Although the majority of teachers do allow group work, teachers must ensure the facilitation of the group work to enhance teaching and learning (Barr & Stephenson, 2011:52). This can be achieved by developing an activity or project (it can be a one lesson activity) for specific content. Learners must be prepared for the activity and the teachers should suggest strategies for managing the group effectively. Teachers must receive feedback from the group and provide learners with opportunities to reflect on the group work. Web 2.0 applications can be used for brainstorming and facilitating these group work sessions.

Finding 5

- Teachers mostly use textbooks and other sources in the CAT classroom (cf. *Graph 5.1*) to facilitate teaching and learning problem solving. Teachers also consider an exercise/activity from the textbook as problem solving, where most activities/exercises in textbooks are used to master skills (cf. *Table 5.11*). It is evident from the analysis that teachers do not know the difference between an exercise/activity and a problem. The means procedure for teachers understanding the difference between an exercise and a problem was 1.47 (cf. *Table 5.13*). This has far-reaching consequences for teaching and learning problem solving as it indicates that learners are most often engaged in mastering skills activities than problem-solving activities in the CAT class.

Recommendations

- As indicated in the literature review (cf. 3.10, *Table 3.8*) exercises/activities play a very important role to reinforce knowledge and understanding. An exercise can normally be assessed from a marking grid, because there is only one correct answer, whereas a problem has not only one correct answer. After Solution Development (such as spreadsheet) has been taught with the necessary content (as set out in the CAPS document), teachers should encourage learners to develop their own spreadsheets. Spreadsheets can be used as a cognitive tool to enhance the problem-solving skills of learners (Hoag, 2008:58; Lavidas *et al.,* 2011:2). This can be followed up with a presentation to the class where learners can develop their communication skills. Learners can also learn the theoretical content of CAT by solving a “short” problem, perhaps before the content is taught, then content is taught after which learners bring their solutions to class.

Finding 6

- Very few teachers use Bloom’s Revised Digital Taxonomy in setting assignments or formal assessments (cf. *Table 5.9*). Without using taxonomy, it is impossible for teachers to assess learners’ work at the proper cognitive levels.

Recommendations

- Just with any other tool, different technology applications support different thinking and learning tasks. Bloom’s Digital Taxonomy can assist teachers to correlate different technology tools with different levels of thinking. Bloom’s Digital Taxonomy can help teacher to determine what level of thinking is desired and to match a specific technology tool to the level of thinking (Clarke & Watt-Taff, 2014:46-47). It is the opinion of the researcher that teachers do not know how to implement Bloom’s Revised Digital Taxonomy, so it is recommended that teachers receive in-service training on this taxonomy to give them a better understanding (cf. Chapter 7).

Finding 7

- According to the means procedure for sufficient teaching the mean calculated was 3.57 (cf. *Table 5.15*). This indicated that teachers perceived that they usually had enough teaching time. However, half of the teachers only teach with the emphasis on assessment (cf. *Table 5.14*). This implies that, although there might be sufficient teaching time to cover the content given in the CAPS, teachers do not have the time to make sure that learners have a deeper understanding of CAT. This can have a negative influence on teaching computational thinking and problem solving. Both these concepts take extra time beyond normal teaching time and if teachers can only finish the curriculum, they will definitely not have time to spend on these two concepts.

Recommendation

- When learners cannot answer a question or do a practical application, teachers should not provide the answer. By asking the correct questions to assist learners with their problem (while doing the content) the teacher can enhance critical thinking. Critical thinking will then lead to computational thinking – both these skills are required for problem solving (Conklin, 2011:47-48; Copeland, 2005:42-45). Examples of questions that will guide learners to the correct answer, while grounding critical thinking are: Why do you say that? What would be an alternative? What is another way of looking at it? Explain to me… What must you calculate? How will you...? If you do...?

The inferential statistics of the questionnaire survey further discloses the following interesting information on the different items of the questionnaire.

After cross-tabulations had been done with relevant questionnaire items, it was found that there was a significant positive correlation between all items included in the cross-tabulation (cf. *Table 5.21* to *Table 5.38*).

Teacher responses on computational thinking skills and problem-solving items were subjected to factor analysis (cf. 5.2.2.2) which presented the following information.

- Nine factors which were identified are (1) problem solving, (2) teaching and questioning, (3) collaboration, (4) taxonomy, (5) thinking, (6) algorithms, (7) resources, (8) exercises vs. problems and (9) representation (cf. *Table 5.41*).

- The factors: collaboration, exercises vs. problems, resources and representation can all be categorised under the overarching theme of problem solving (Duran, 2013:192). The factors: taxonomy, teaching and questioning, algorithms and thinking can be categorised under the overarching theme of computational thinking (Voskoglou & Buckley, 2012:32).). The main aim of this study was to explore the problem-solving skills and computational thinking skills of Grade 10 - 12 CAT teachers. When computers are used in the problem-solving situation, the need for computational thinking exists (Voskoglou & Buckley, 2012:29). When interpreting the factor loadings of the nine most significant factors it is evident that problem solving and computational thinking elements were both represented with high factor loadings. This indicates an evident relationship between these two factors. This implies that when teachers teach CAT, problem solving and computational thinking can not be taught without the other. Both skills are important if teachers want to implement the curriculum correctly.

6.2.4 Findings and implications from the interviews

After thematic coding had been done, two main themes, namely teachers and learners, were identified. Within these two main themes six sub-themes were identified. The findings and recommendations on these six sub-themes follow.

Finding 1: Learners – Life Skills

- Teachers expect from learners to have the necessary life skills such as independence, responsibility, persistence, self-exploration, confidence and communication skills (both listening, speak and digital) (cf. 5.3.1.1). Teachers wants learners to be respectful and be able to work in a group with diverse learners, i.e. learners must be able to function in a group and work together.

Recommendation

- Teachers expect from learners to have the necessary life skills such as independence, responsibility, persistence, self-exploration, confidence and communication skills (both listening, speak and digital) (cf. 5.3.1.1). Teachers want learners to be respectful and be able to work in a group with diverse learners, i.e. learners must be able to function in a group and work together. This is corroborated by literature (cf. 6.2.1). When learners have the necessary life skills, they will be more successful in problem solving – thus these skills form part of the essences of problem solving (cf. Research question 2).

Finding 2: Learners – Computer Skills

Teachers expect learners to have computer skills (as required by the content of the specific grade) such as computer literacy and keyboarding skills (cf. 5.3.1.2). Computer skills acquired in one package must be transferred to another package without teaching that skill again. Owing to lack of time, teachers feel that learners do not get the opportunity to master the necessary computer skills. Textbooks without problem solving and computational thinking activities are obstructing effective teaching and learning. Literature revealed that when computers are used for problem solving, it is necessary that learners be skilled and experienced in applications, as well as in problem solving (cf. 3.12.3).

Recommendation

The approach that the teacher follows to teach keyboarding skills to learners will enable learners to key in data accurately, with the correct techniques, quick, economical motions and control. The CAT classroom must be open to learners except during class time. Perhaps during breaks or even in the afternoons. This will offer learners the opportunity to practise certain skills. Allowing learners access to the CAT classroom will also create an opportunity for learners to obtain keyboarding skills, to do practical "homework" which can assist with mastering computer skills as required by the curriculum. Teachers can not merely teach from textbooks; extra activities with problems to be solved must be developed and used in the classroom.

Finding 3: Learners – Thinking skills

- Teachers expect learners to be able to use different thinking skills (cf. 5.3.1.3). For learners to be competent computational thinkers and problem solvers, they must be able to use both lower-order and higher-order thinking levels in the CAT classroom. CAT's categorisation as a 'non-designated' subject influences learners' subject choices. This categorisation attaches negative connotations to CAT as a subject. The result of not being a 'designated' subject prevent the academic achievers to opt for CAT as a subject choice.

Recommendation

- Teachers must create a classroom that will foster different kinds of thinking. Teachers must ask questions throughout the lesson to promote learners' thinking about what they are doing. Discussions should be held with the relevant parties on the matter of classifying CAT as a 'non-designated'[xi] subject. The Department of Basic Education needs to reconsider this designation in order for the subject to be considered as a viable option for academic achievers. Computer technology is considered as a necessary skill in almost all spheres of the working world and should subsequently be granted this importance as a school subject.

[xi] Subjects on the list of recognised 20-credit NSC subjects also known as the designated subject list.

Finding 4: Teachers – Scenarios/real-life activities

- Real-life situations in problems will add more value to the learning that take place (cf. 5.3.2.1). Scenarios that are used must link with the learners' frame of reference. All textbooks do not necessarily provide for this. This correlates with findings from the questionnaire where teachers felt that the PAT (scenario) adds educational value to the learners' education (cf. *Table 5.16*).

Recommendation

- When setting a scenario, teachers must consider the learners' age and grade and the context of the scenario must be within their frame of reference so that they have an interest in the context. Once learners are interested in the context of the scenario, they will become fully involved in learning and their interest will increase. Then they will realise the problems and become motivated to solve them because the problem relates to their daily practices. Authentic context must be provided for reflecting the way that knowledge will be used in real-life. Allow learners to start with small activities that are given in scenarios to prepare them for the PAT. In so doing, learners reflect on the activities and apply the information, knowledge, skill and attitude to complete the activity. In this process, information turns into knowledge that turns into skills.

Finding 5: Teachers – teaching time

- Teaching time is just sufficient to cover the content of the CAPS document, leaving very little time for covering problem solving in class (cf. 5.3.2.2). This has a negative impact on the learners' not mastering certain problem-solving skills. This is collaborated with findings from the questionnaire that implied that teachers do only have enough time to cover the curriculum, but not enough teaching time to form a deep understanding of the theory and practical work that forms part of CAT (cf. *Table 5.14*).

Recommendations

- Due to time constraints it is impossible to fit everything (from CAT content to problem solving) in the allocated teaching time for CAT. Problem-solving should not be taught in isolation, but it must be part of the CAT curriculum. Teachers must find ways to incorporate problem solving during teaching time. By considering the following aspects, teachers can incorportate problem solving with ease in every CAT lesson.
- Teachers must provide learners with opportunities to discuss relevant academic issues/content during classtime. Questions must be asked to encourage discussions.
- Closed-ended questions should be limited. This will enable the learners to engage with the content by employing higher-order thinking skills.
- Allow all learners an opportunity to respond to questions. Direct questions also to those learners who normally do not participate.
- Incorrect answers should not be corrected by the teacher. Rather guide the learner with information to reach the correct answer.
- Create a class atmosphere where learners will feel confident to attempt an answer, even if it may be incorrect. An incorrect answer should not be seen as a mistake, but as an opportunity to reach the correct answer through guidance.

Finding 6: Teachers – Professional qualification

- Many of the CAT teachers have a professional education qualification but not a specialisation in CAT (cf. 5.3.2.3). Many teachers were formerly Typing, Computyping or Computer Studies Standard Grade teachers. This was also confirmed by the analysis of descriptive statistics from the questionnaire data (cf. *Table 5.1*) that showed that 44% of teachers received in-service training. The lack of training impacts on the effective teaching of computational thinking and problem solving.

Recommendations

- Teachers must attend in-service training work sessions to assist their understanding of what computational thinking is and how it can influence problem solving in the CAT classroom. Teachers must be exposed to different ways of integrating computational thinking and problem solving while teaching content such as spreadsheets, database and word processing.

6.3 ADDITION TO THE BODY OF KNOWLEDGE

The researcher developed a toolkit for in-service teacher training to address some of the recommendations. The toolkit will contribute to the current body of knowledge in computational thinking and problem-solving skills in CAT classrooms. This toolkit is intended primarily for facilitators (such as CAT subject advisors or CAT mentor teachers) to enable them to conduct workshops for fellow CAT teachers. The toolkit offers an overview of some of the main issues related to computational thinking and problem solving in CAT. By using this toolkit, teachers will gain an understanding of what computational thinking skills and problem-solving skills are and how to develop these skills in Grades 10 – 12 CAT learners.

The toolkit is divided into two sections, namely Computational Thinking and Problem-solving. In addition to the toolkit, facilitators will receive a CD with pre-constructed PowerPoint presentations. These presentations can be used to facilitate the workshop or training session. The complete toolkit and CD is presented in Chapter 7.

6.4 PROBLEMS EXPERIENCED WITH THIS STUDY

The researcher experienced a number of problems with regard to the literature studies, such as deficient literature on computational thinking skills. Although there are many international studies and sources on computational thinking, these sources were all related to Computer Science as a field of study. Very few publications exist on CAT as a subject.

6.5 LIMITATIONS OF THE STUDY

These are the limitations of this study:

- As this was the first kind of research done in CAT with regard to computational thinking and problem-solving skills, this study covered a very broad spectrum.
- There were no available standardised questionnaires that could be adjusted for the empirical research. The questionnaire covered a wide range of questions.

6.6 FUTURE RESEARCH

The following suggestions are made for future research on aspects of concern on computational thinking and problem solving in the CAT classroom.

- Research is needed to determine which factors influence learners' capabilities to develop computational thinking and therefore to become better problem solvers by using computers.
- The development of a framework for the assessment of computational thinking in problem solving in CAT.

6.7 CONCLUSION

The findings from literature reviewed that computational thinking is a skill that all learners should master to be efficient learners in the 21st century. Although computational thinking is normally associated with computer science, it is not limited to computer science. Computational thinking should not be regarded as computer programming, but rather as a skill that can be taught across the curriculum. CAT as a school subject in the South African curriculum can be used to instill this skill in learners. Computational thinking is a reasoning skills set that assists in problem solving by employing computers and the functions of computers. Critical thinking, logical thinking, creativity and analytical thinking are all developed whilst computational thinking is mastered.

Computational thinking can be used as a cognitive tool that aid in the construction of knowledge. The cognitive tools (mindtools) to be used include databases, spreadsheets, concept maps and multi-media/hypermedia software. By developing higher-order thinking skills in learners, learners' meta-cognitive skills will improve, and therefore learners can use these tools to provide explanations and make decisions in solving problems. However, before teachers can teach computational thinking skills to learners, such teachers must be competent in the skill themselves. Relevant subject knowledge (theory and practical work in the case of CAT) and problem-solving skills must be mastered by learners. The CAT classroom must also be transformed into a computational thinking classroom. Teaching strategies, active problem-solving strategies, correct computer infrastructure and computational thinking vocabulary must be present at all times.

Problem-solving skills are essential for all learners to function as critical thinkers. When a computer is used to solve problems, computational thinking skills are needed. When learners are able to solve problems effectively, it will improve their knowledge and understanding of the subject content. Transfer of learning will take place once the learner has made a connection between the problem and the domain knowledge.

The results of this study allow us to better understand the problem solving and computational thinking skills in general. The results lead to the development of a computational thinking and problem-solving toolkit as depicted in the next chapter.

CHAPTER 7

COMPUTATIONAL THINKING AND PROBLEM-SOLVING TOOLKIT FOR CAT TEACHERS

7.1 INTRODUCTION

This chapter is devoted to the computational thinking and problem-solving toolkit that was developed by the researcher. The toolkit consists of a Booklet for Teachers, Guidelines for Facilitators and a CD for Teachers and Facilitators that contains the PowerPoint presentations that accompany the toolkit. The toolkit is presented on the next page.

The toolkit put forward in this chapter addresses the following research question:

- What should be included in a computational thinking and problem-solving training programme for CAT teachers?

7.2 THE TOOLKIT

The toolkit comprises of three parts. Part 1 is the booklet for teachers. This booklet evolved from the recommendations of the study. The booklet can be used as a handout during a workshop on computational thinking and problem solving. An accompanying CD was also developed for use by the facilitator of such a workshop. Part 2 provides guidelines to be followed by facilitators. These guidelines are provided as an accompanying document to the CD. The guidelines comprise slides as well as additional explanatory information to be used by the facilitator. Part 3 is the CD that will be used during the presentation.

COMPUTATIONAL THINKING AND PROBLEM-SOLVING TOOLKIT FOR CAT TEACHERS

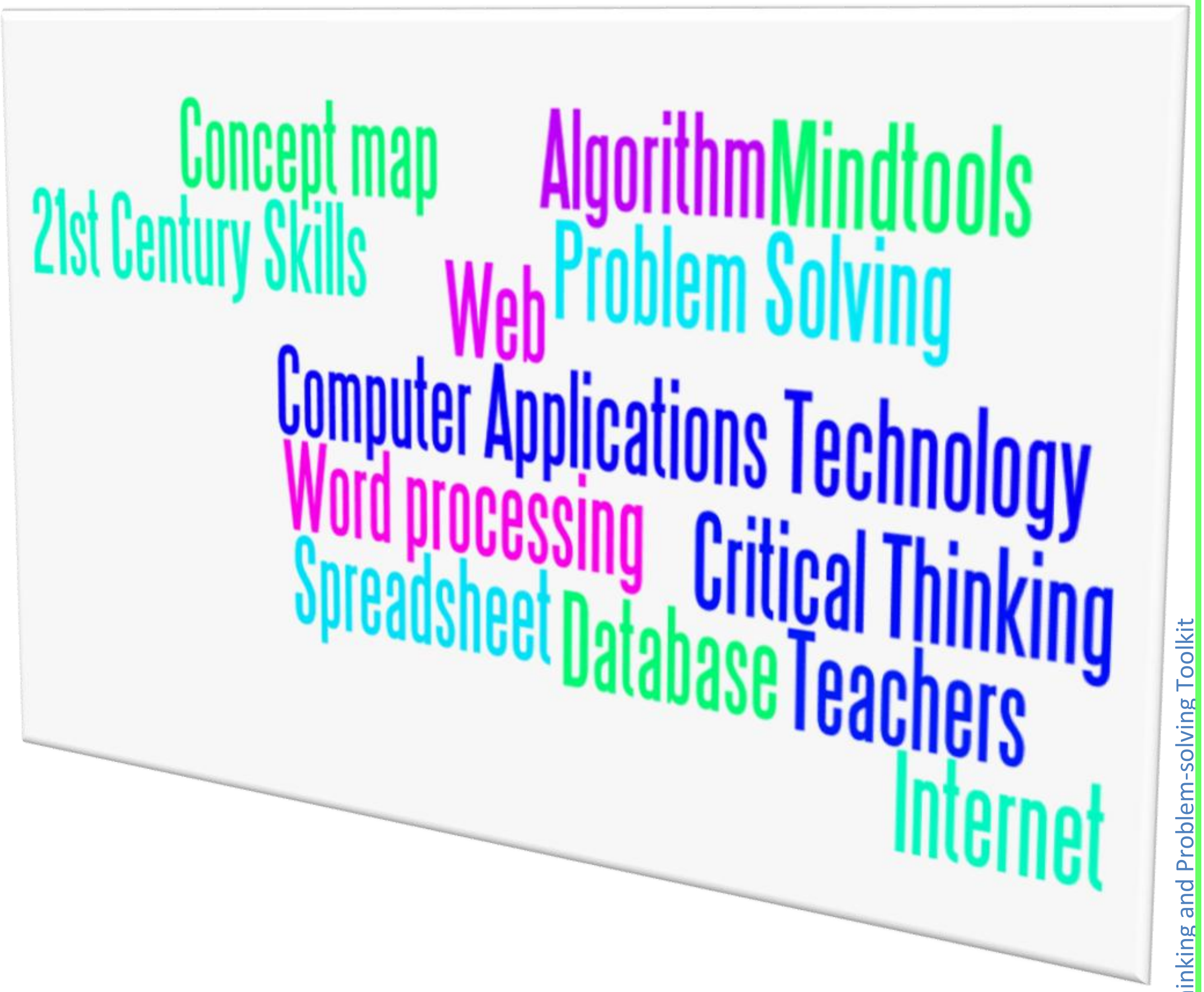


Table of Contents

List of Diagrams, Tables and Appendices

PURPOSE OF THE COMPUTATIONAL THINKING AND PROBLEM-SOLVING TOOLKIT

The CAPS document states that CAT teachers must teach learners how to use end-user applications proficiently to produce solutions to problems. They must also teach the mechanical/technical skills and functions of the end-user applications within the paradigm of computational thinking. Tasks or activities given to learners should encourage computational thinking. CAT is thus a vehicle that teachers can use to teach learners computational thinking skills and problem-solving skills. However, PhD research done by the researcher has shown that not all teachers are confident in integrating computational thinking and problem solving in the CAT classroom.

This toolkit is intended primarily for facilitators (such as CAT subject advisors or CAT mentor teachers) to enable them to conduct a workshop for fellow CAT teachers. The toolkit offers an overview of some of the main issues related to computational thinking and problem solving in CAT. By using this toolkit, teachers will gain an understanding of what computational thinking skills and problem-solving skills are and how to develop these skills in Grades 10 – 12 CAT learners.

How to use this toolkit

The toolkit consists of a booklet and a series of PowerPoint presentations (MS PowerPoint 2010). The booklet leads the discussion for each of the PowerPoint slides.

PowerPoint Presentation - Slide

Discussion of PowerPoint presentation

GLOSSARY OF ABBREVIATIONS, ACRONYMS AND TERMS

Abstraction	Similar to a summary. When a learner chooses the main idea from a web page, it is called abstracting.
Algorithm	Step-by-step instruction. Reinforces algorithmic thinking because learners must follow a specific order to do something. Examples: creating a table, a graph.
Automation	When computers do repetitive or monotonous tasks such as sorting, bookmarks and numbering pages.
CAPS	Curriculum and Assessment Policy Statement
CAT	Computer Applications Technology
CT	Computational Thinking
IT	Information Technology
PAT	Practical Assessment Task
PS	Problem-solving
Representation	Using a graph in a spreadsheet application to represent the information contained in the spreadsheet.
Trial and Error	Part of achieving the most efficient and effective combination of steps and resources. Example: experimenting with different graphs in a spreadsheet to represent information.

"If we teach today's students as we taught yesterday's, we rob them of tomorrow."

John Dewey

INTRODUCTION

Change of technology

PowerPoint Presentation - Slide
CHANGE OF TECHNOLOGY

Discussion of PowerPoint presentation

Our era is often said to be a time of rapid technological change. Things around us are changing radically and very fast. Since the beginning of the 21st century the world has become more interconnected; technology is continuously altering our relationship with information. Technology has changed the way schools educate learners through the use of computers in classrooms and even online education. Our learners are more digitally focused than ever before. We must therefore change the way we teach. Teaching does not occur only from a textbook. Learners learn through meaningful projects such as the PAT and authentic tasks. Mobile phones can access more information than is held in the library or in textbooks. Teachers regard themselves as learners as well as teachers; they are aware that they need to conduct action research and be aware of development in their fields – especially in CAT. Teaching and learning take advantage of digital technologies – the teacher no longer has the "monopoly" of academic learning or is the primary source of information. And if you as a teacher do not adapt, the world may simply leave you behind. Therefore – keep up with change! Become a teacher of the 21st century and develop learners for the 21st century!

21st century teacher

PowerPoint Presentation - Slide
21 ST CENTURY TEACHER

Discussion of PowerPoint presentation

What makes you a 21st century teacher? ***Diagram 1*** on the next page lists some of the characteristics of a 21st century teacher. How many of these attributes can you claim for yourself?

Diagram 1: Characteristics of a 21st century teacher

RE-THINK

Re-think how your learners interpret your lessons.

QUESTION

Allow learners to question what they are learning.

DIALOGUE

Allow dialogue in your class.

Facilitate learning

Facilitate learning as

FOCUS

Focus on the learner's point of view. Are you saying what they are hearing?

Real

Make learning real-life and relevant.

CONTRIBUTORS

Allow learners to contribute to their learning.

Collaborate

Collaborate with teachers from outside your circle.

USE

Let learners use their cell phones.

Question

Encourage and entertain all questions.

Create

Allow learners to be creative.

Be

Be just as tech savvy as your learners. Use blogs and wikis to create online

DESIGN

Let learners design and create websites.

Relate

Learn new ways to relate to your learners.

Code

Use tablets, use tablet applications. Explore

Flip

Flip the classroom with useful resources.

Discern

Teach learners how to

Incorporate

Incorporate seeing things from a different perspective.

Social Media

Be active on social media. Be social.

Web 2.0[1]

Learn, explore, integrate, utilise.

PowerPoint Presentation - Slide
21ST CENTURY SKILLS FOR LEARNERS

Discussion of PowerPoint presentation

Research has shown that one of the most important 21st century skills a learner must have, is to solve problems by effectively applying computation – and that is what computational thinking is! Computational thinking can magnify problem-solving skills that learners need to address authentic, real-world issues and problems.

Jeanette Wing in 2006 first coined the term ‘computational thinking’. She defined computational thinking as a unique set of problem-solving skills that underlies computing. Computing takes place when a learner utilises computer technology (hardware, software and a computer system[1]) to complete a task. She therefore claims that in the Internet age, computational thinking is just as important a skill as reading, writing and arithmetic thinking for every learner to have.

Computational thinking is not another “new thing” that teachers need to do in the already full CAT curriculum. It is, however, important that teachers realise that computational thinking is not to teach learners to think like a computer. It is also not to teach learners how to use a word processing or spreadsheet application. And most importantly, it is not the teaching of computer programming! Once learners have mastered computational thinking, it will help them understand and master technology of all sorts and solve problems in almost any discipline. For most primary

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[1] Interconnected computers that share a central storage system and different peripheral devices. These devices can operate independently, but they also have the ability to communicate with external devices and computers.

and secondary school learners, a computer is a game-playing tool. All CAT learners will be taught word processing, spreadsheet, database and presentation software. However, for learners to survive in the modern technological society, computational thinking will teach them how to combine the power of human intelligence and the computing agent (such as a computer) for solving complex problems.

COMPUTATIONAL THINKING

Why teach learners computational thinking?

PowerPoint Presentation - Slide
WHY TEACH LEARNERS COMPUTATIONAL THINKING?

Discussion of PowerPoint presentation

We all want learners to think on their own, to be independent, to trust their own judgement, to be able to identify which problems are easier to solve and to be able to explain concepts. Computational thinking will support all these attributes that we want learners to have. The promise of computational thinking is that it can improve problem solving and critical thinking by using the power of computing. By teaching our CAT learners computational thinking skills we prepare them to understand today’s digital tools that can help solve tomorrow’s problems. ***Diagram 2*** on the next page explains this.

Diagram 2: The computational thinker

It IS NOT thinking like a computer.
It IS NOT limiting creativity.
It IS NOT just learning applications.

It IS a way of thinking.
It IS making the impossible possible.
It IS creating solutions to problems.

COMPUTATIONAL THINKING LEARNER

has a collection of diverse skills that will help him/her to solve a problem effectively while using the computer as a partner.

ATTITUDES

Making mistakes
Mistakes are normal in solving problems.
I can enjoy things that go wrong

Perseverance
I don't give up. I am determined to find solutions.

Collaboration
I can use other people's ideas.
I can share my ideas.
We can talk together to solve a problem.
I can teach my peers and they can teach me.

Critical thinking

Problem-solving

Communicate

SKILLS

Decomposition
Can I break this problem into smaller parts?
Can I explain the different parts of this problem and solution?

Abstraction and Generalisation
Which information do I actually need?
What don't I need to know?
Have I made this more complicated than what I need to?

Algorithm design
What must I think about to make this happen?
What are the steps that I must follow to solve this problem?

Pattern recognition
Is this similar to a problem that I have already solved?

Logically organising and analysing data
How must I organise and analyse the data?

What is computational thinking?

PowerPoint Presentation - Slide
WHAT IS COMPUTATIONAL THINKING?

Discussion of PowerPoint presentation

There are many different definitions and opinions on what computational thinking really is. After careful consideration and taking into account the subject CAT, the best definition for computational thinking for the purposes of CAT is

A collection of diverse skills dealing with problem solving.

This will also include some obviously important skills that CAT and other subjects help develop, such as creativity, the ability to explain and team work. It also consists of some very specific problem-solving skills such as the ability to think logically, critically, algorithmically (thinking in steps/procedures) and recursively[2].

PowerPoint Presentation - Slide

CHARACTERISTICS OF COMPUTATIONAL THINKING

Discussion of PowerPoint presentation

It is possible to infuse the main characteristics of computational thinking with CAT.

Formulate problems in such a way that learners can use a computer to solve the problem.

- *The PAT is an excellent way where learners must read a scenario, formulate the problem and determine how the computer will help to solve the problem.*

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[2] The repeated application of a rule, definition or procedure to obtain results.

Logically organising and analysing data.

- *In information management learners must logically find and organise data.*
- *Learners must organise and sort files, folders, e-mail folders.*
- *Learners must use digital tools to analyse information.*
- *Internet search*

Representing data through abstractions such as models and simulations. This is the ability to filter out information that is unnecessary to solve a certain type of problem and generalise the information that is necessary

- *Learners must know which data to use for completing the PAT.*
- *In spreadsheets learners can represent data through graphs.*

Automating solutions through algorithmic thinking. This is the ability to develop a step-by-step strategy for solving a problem.

- *In spreadsheets learners learn different steps to determine a specific answer.*
- *The steps in creating a merged letter – the same steps are used even when the source documents are a spreadsheet file, a database file or an e-mail file.*
- *Let learners reflect on the processes that they used to complete an activity or the PAT.*

Identifying, analysing and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources.

- *Explore different ways of representing data to tell the most accurate story.*
- *Automation allows learners to explore other ways of telling the same story.*

Generalising and transferring this problem-solving process to a wide variety of problems.

- *This proves that you as a teacher do not need to be a computer scientist to include computational thinking in your lessons.*

When learners have mastered computational thinking skills, they will know when and how to use a computer to solve a problem. Learners will then know and be able to recognise that computing enables them to collect and manipulate large sets of data for decision making (*as in the PAT and in a database with queries and reports*).

Teaching computational thinking in the CAT classroom

PowerPoint Presentation - Slide
TEACHING COMPUTATIONAL THINKING IN THE CAT CLASSROOM

Discussion of PowerPoint presentation

Now that you know what computational thinking is, the next question is automatically, “How to teach computational thinking skills in the CAT classroom?” It might come as a surprise, but you are already implementing many of the elements of computational thinking in the CAT classroom. For example, when you teach learners how to create and use styles in a word processing document, you are teaching them abstraction of formatting options. Creating and using a formula in a spreadsheet is also abstraction. Therefore you immediately can start implementing computational thinking in the CAT classroom. Start by using the computational vocabulary and include critical thinking in your tasks. Use mindtools (later more on this concept) as far as possible and make sure that your tasks include problem solving.

Computational thinking vocabulary

PowerPoint Presentation - Slide
COMPUTATIONAL THINKING VOCABULARY

Discussion of PowerPoint presentation

The table on the next page includes the computational thinking vocabulary (CSTA, 2011:14). This has been adjusted for use in the CAT classroom. Words such as data collection, data analysis, data representation, problem decomposition, abstraction, algorithms and procedures, automation, simulation and parallelisation should be included in your daily teaching. The first column provides the term, followed by a definition and then examples of how you as a CAT teacher can incorporate these words in your classes. ***Table 1*** shows the vocabulary.

Table 1: Computational thinking vocabulary

CT Vocabulary	**CT definition**	**Grade 10**	**Grades 11,12**
Data Collection	The process of gathering appropriate information.	Design a questionnaire to collect appropriate information to answer questions. For example, asking how many learners were absent from school in the past month and whether they were suffering from flu.	Learners develop a questionnaire to collect both open-ended and closed-ended questions to be used in the PAT.
Data Analysis	Making sense of data, finding patterns and drawing conclusions.	Create a graph and answer relevant questions.	Use appropriate statistical methods (formulae as set out in the CAPS) to answer "if-questions".
Data Representation	Depicting and organising data in appropriate graphs, words or images.	Plot data by using different graph formats and select the most effective visual presentation.	Use more complex graphs to represent data. Use webpage/PowerPoint to represent data.
Problem Decomposition	Breaking down tasks into smaller, manageable parts.	In planning the publication of the school brochure, identify roles, responsibilities, timeline and resources	Consider a large-scale problem such as the PAT. Break it up into smaller parts. Discuss the

		are needed to complete the project.	variables that are within the learners' control and what variables are determined by outside factors.
Abstraction	Reducing complexity to define main idea.	After teaching theory content, identify key concepts. Summarise theory.	Choose a social network media and analyse the essential characteristics of the social media network. Development of questionnaires in the PAT to obtain information.
Algorithms and Procedures	Series of ordered steps taken to solve a problem or achieve some end.	Converting a word table to a spreadsheet.	Converting an html table to a spreadsheet.
Automation	Having computers do repetitive or tedious tasks.	Sorting in a spreadsheet.	Numbering pages.
Simulation	Representation of a model or a process.	Create a spreadsheet to simulate a monthly budget.	
Parallelisation	Collaboration between specialist	Divide class into groups. Hand out a task. Groups compare their end	

	groups.	results of tasks to see if they can improve on their tasks.

Adapted from CSTA (2011:14)

PowerPoint Presentation - Slide
CRITICAL THINKING

Discussion of PowerPoint presentation

Critical thinking is also sometimes referred to as higher-level thinking or higher-order thinking. When you do research on critical thinking, you will find adjectives such as comparing, classifying, patterning, hypothesising, critiquing, to name a few. In Bloom's taxonomy the three levels that require higher-order thinking are analysis, synthesis and evaluation. In Bloom's Revised Taxonomy (Appendix A) it is analysis, evaluate and create.

When critical thinking is thus linked with the power of a computer, computational thinking provides a new way of understanding and describing our world and elements of our daily lives. For instance, breaking down the homework tasks that learners have to do today (decomposition), avoiding a sports injury by recognising possible dangers (pattern recognition), using a timetable to organise a school day into periods (abstraction) or the recipe of a cake (algorithm design).

To put it simply, when learners think critically, they think with a purpose, they ask questions, raise questions, have a viewpoint and can make assumptions.
Critical thinking will provide learners with skills that they need to be successful in life. Critical thinking will help learners make sense of the information explosion. Web search engines return tens of thousands of resources. Learners must have the skills to determine what information is relevant. They must be trained to evaluate the reliability of web sources, and they must be able to think independently to construct a solid argument to support their conclusions.

A critical thinking classroom allows for learners to become actively involved in doing things and thinking about the things they are doing. To encourage active learning in the classroom, the classroom space must accommodate interaction between learners. Do not limit your talking activities in the CAT classroom. Allow learners to have meaningful discussions on the topic. This will lead to a deeper understanding of the domain content. Promote learning in small groups – learning in a group setting often helps learners to achieve more. To encourage thinking, it is critical that the correct questions must be asked throughout a lesson. The next section will explain more on questioning.

Questioning

PowerPoint Presentation - Slide
QUESTIONING

Discussion of PowerPoint presentation

To simply just feed learners with endless content (declarative sentences to remember) in theory is similar to repeatedly stepping on the brakes in a vehicle that is already at rest. Instead, your learners need questions to turn on their intellectual engines and they need to generate questions from questions. Thinking is driven from questions.

Example

For example, the statement that hardware can be described as a device that is physically connected to my computer or it is a computer component that can be physically touched is the answer to the question, "How will you explain hardware in your own words?"

Hence every declarative statement in the textbook is an answer to a question. Questions asked by a teacher explain tasks and issues and they express problems. Sometimes answers such as "yes", "not" or single word answers can be a full stop in a thought. During class time, ask open-ended questions that do not assume the "one right answer". This will encourage learners to think and respond creatively without fearing to give the "wrong" answer. Allow learners to think before they answer. It is therefore important that one answer must lead to another question to stimulate thinking. Encourage questions in your classroom that show that your learners are really thinking. When there is silence in your class and you are a “traditional” teacher and no learner asks a question, it equals no understanding. Often learners have no questions – they only sit in silence, therefore their minds are silent as well!

Use visual aids in your classroom that will constantly remind learners of the critical thinking process. Make posters that read:

Why do I think that?
Is it fact or opinion?
What is the best option?
What would happen if…?

As you move through the theory content, direct their attention to the signs when appropriate. In this way learners will constantly be reminded that many of the same thinking strategies and skills apply to different topics and problems. Consider the following next time when you ask questions in class (we know this, but tend to forget it!):

Ask the question first, then ask a learner to answer.

- In this way you ensure that all learners are listening to your question.
- Posing the question before identifying someone to respond lets learners know they will be held accountable and should be prepared to answer every question.

Allow “thinking time” by waiting at least 7-10 seconds before expecting learners to respond.

- Since most teachers wait only 1-3 seconds before expecting a response, the increased wait time can seem like an eternity and feel very uncomfortable at first.
- Learners should not “shout out” the answers or answer in a “choir”.
- During the “thinking time”, repeat and rephrase the question; it is also a good idea to let learners use the time to write down their answers.

Ensure that all learners get the opportunity to answer rather than relying on volunteers.

- Keep track of who answers, so you can warrant that all learners have equal opportunities to answer a question.
- If a learner is not ready to answer or he/she does not know the answer, allow the learner to “pass” and then give him/her another opportunity later.

Learners must be held accountable by expecting, requiring and facilitatitng their participation and contribuition to the class discussions.

- Do NOT answer your own question! If the learners know you will give them the answers after a few seconds of silence, why will they think?
- Do NOT accept “I don’t know” for an answer!
- Give more thinking time, by moving on moving on and then coming back to the learner for a response later.
- Guide and lead learning in formulating an quality answer
- If none of the above is working, and the learning is still not able to answer the question, offer two or more options and let the learner choose an answer.

The classroom athmosphere must be encouraging – this will create an safe environment for risk taking by learners in the process of learning from their mistakes.

  - ALWAYS “dignify” incorrect responses by saying something positive about learners’ efforts. Never embarrass a learner – this will hinder class participation.
  - When learners make mistakes, build their confidence and trust by asking follow-up questions to help them self-correct and achieve success.
  - Admit your own mistakes and “think aloud” examples of a reflection process that demonstrates increased awareness, new insights, concept clarification etc.

PowerPoint Presentation - Slide
BLOOM'S TAXONOMY vs. BLOOM'S DIGITAL TAXONOMY

Discussion of PowerPoint presentation

By asking appropriate questions in the classroom and in tests, examinations or tasks, you will develop CAT learners' critical thinking skills. How many of these questions do you use in your classroom on a daily basis? How many of these questions appear in tasks/tests or examinations to test higher-order thinking (critical skills)? ***Table 2*** on the next page can assist you in asking the proper type of questions – the example questions are based on Bloom's Digital Taxonomy. (If you are unsure about Bloom's Taxonomy (BT) and Bloom's Digital Taxonomy (BDT) refer to Appendix A for clarification.)

Table 2: Questioning with Bloom's Digital Taxonomy

1 **KNOWLEDGE (BT)** **REMEMBERING (BDT)**	Define Fill in the blank List Identify	Label Match Name	Describe Retrieve Name Highlight	Bookmark Search Bullet pointing
Identification and recall of information	Retrieve *the file DEFINITONS.docx.* Define the *word LAN.* Give a definition *for social networking.* List four reasons Bookmark *the word SOCCER in the document.* Do a basic Internet *search on…*		Highlight *the sentence starting with "In the beginning …"* Name four reasons why Match *the words of column A with the correct description in column B.* Label *the diagram of a home network.* *Create a* bulleted list *in a word processing document.*	
2 **COMPREHENSION (BT)** **UNDERSTANDING (BDT)**	Describe Explain Summarise Differences	Compare Comment Subscribe	Categorise	
Organising and selection of facts and ideas	*What are the* differences *between phishing and pharming?* Explain *how you can prevent identity theft.* Compare *RAM to ROM.* What differences *exist between RAM and ROM?*		*Make a short* summary *of the web document using your word processor.* Categorise *the different types of Internet connections available to a home user.* Subscribe *to a social network such as Facebook/ RSS aggregator*	

3 **APPLICATION (BT)** **APPLYING (BDT)**	Demonstrate Give an example Show Solve	Construct Find out Make Use	Determine Illustrate Operate	Carry out Interview
Use of facts, algorithms, rules and principles.	Demonstrate *how to make a screen capture of a web page.* Determine *the average of column B1..B10.* Use *the if-function to determine which learner will receive a discount.* Demonstrate *how you will insert a picture into a word document.* *Use Skype to* interview/communicate.		Solve *the following problem by using the correct spreadsheet functions.* Use *an appropriate graph to represent the information.* Find *the word “buffer” and replace it with the word “spool” in red italics.* Load *the printer driver for a specific printer.* Upload *a picture onto FaceBook.*	
4 **ANALYSIS (BT and BDT)**	Analyse Categorise Classify Compare	Debate Determine the factors Diagram Differentiate	Specify Distinguish Examine Find	Integrate Link Tagging Validate
Separating a whole into components parts.	Classify *computers according to their size, price and capabilities.* What are the parts or features *of a network?* Outline/diagram/map *a computer network.*		What evidence can you present *to show that a web page is a reliable source of information?* *How does a desktop computer* compare/contrast *with an embedded computer?*	

5 **EVALUATING** **Developing opinions, judgements or decisions**	Review Check Judge Comment	Choose Compare Justify Select	Rank Prioritise Justify Collaborate	Networking
	Use instant messaging to work together. Use social network tools to come to a conclusion (networking)			
6 **CREATING (BDT)** **SYNTHESIS (BT)**	Create Construct Design	Formulate Generate Plan	Predict Produce Rearrange Reorganise	Suggest Write
	Create *a presentation to present the findings of your research.* Design *a poster in a word processing document.* Generate *a report in a database application.*		Create *a webpage with HTML.* Plan *a calendar.*	

Visit http://edorigami.wikispaces.com for a great resource by Andrew Churches on Bloom's Digital Taxonomy.

Mindtools

PowerPoint Presentation - Slide
MINDTOOLS

Discussion of PowerPoint presentation

Why not combine technology and traditional methods of teaching? Mindtools are selected computer programs that simulate learning and thinking in learners. Computer application software such as spreadsheets, database and presentation application software was developed as aids to make computer users more productive. A mindtool can be used as an intellectual partner with the learner to engage and facilitate critical thinking and higher-order learning. It is therefore important that as teacher you must learn how to use mindtools as a means of learning in the classroom.

Let us look at some of the mindtools that you can use in the CAT classroom to enhance critical thinking and problem solving.

Concept Mapping[3]

PowerPoint Presentation - Slide
CONCEPT MAPPING

Discussion of PowerPoint presentation

When you want to organise and represent tacit knowledge, words, images, thoughts, ideas or facts a concept map is a useful tool. Concept maps can be used very successfully with CAT theory to illustrate links between different ideas, concepts and to highlight how all these ideas or concepts are connected. In this way a learner can

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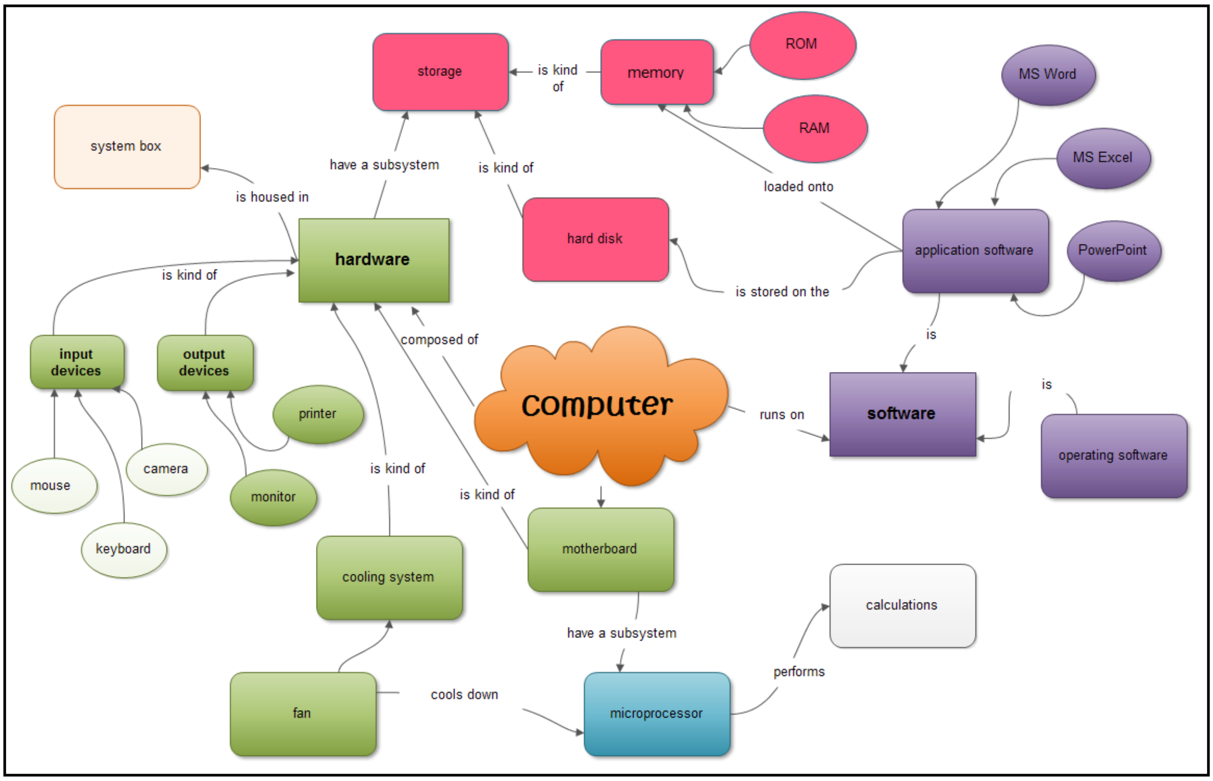
[3] A mind map is very similar to a concept map. A mind map consists mainly of one concept and is represented as a tree diagram. A concept map consists of several concepts and is represented in the form of a network (Jenson, 2012:81).

develop an expert-knowledge framework of the content. Concepts maps can assist learners to make sense of content and help them to learn meaningfully when used. Learners cultivate critical thinking skills when concept mapping is used to analyse the different elements of new or complicated subject content. ***Diagram 3*** below shows a concept map of System Technology.

Diagram 3: Example of a concept map



There are different ways that a concept map can be created – learners can either use a word processing application or use a Web 2.0 application.

Visit http://web2014.discoveryeducation.com/ for more websites that you can use.

Microsoft Word is a word processing program that has the ability to draw shapes. These shapes can be linked to create a concept map (instructions at the back of the toolkit)

http://freemind.sourceforge.net/wiki/index.php (Download Free, install on computer.)

PowerPoint Presentation - Slide
MULTIMEDIA/HYPERMEDIA

Discussion of PowerPoint presentation

This mindtool gives you as the teacher an entire lesson to cover with pictures, words, video and sound by using a multimedia program such as MS PowerPoint or any other Web 2.0 applications[4] (See Appendix C).

In contrast to a concept map, you can use PowerPoint presentations to deliver content to learners. Web 2.0 applications are different from web sites where you are only a passive viewer of content. Web 2.0 applications allow teachers to interact and collaborate via social media as creators for user-generated content in a virtual community. Think about a lesson/content that you need to add some new life to the lesson. When integrating a Web 2.0 tool, it might just be the thing to excite your learners. Suddenly, teaching abstract concepts such as RAM, ROM, memory, networks becomes lots of fun if learners can visualise what the content is about. This is most beneficial to learning.

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[4] Popular term for Internet technology and applications such as social networking sites, video sharing, blogs, wikis, RSS and social bookmarking.

The Search Internet Mindtool

PowerPoint Presentation - Slide
SEARCH INTERNET MINDTOOL

Discussion of PowerPoint presentation

As a CAT teacher you should be very efficient in your searching techniques. The Internet has changed the world we live, learn and teach in, so the Internet can and must be used for successful learning. However, searches can return an overwhelming number of results. For learners to be successful in an Internet search, they need search skills to create efficient search terms. Have you ever tried the Web 2.0 application Boolify (http://www.boolify.org) to assist you in teaching your CAT learners the basics of a good search using popular search engines?

CAT content as mindtools

PowerPoint Presentation - Slide
SPREADSHEETS AS MINDTOOLS

Discussion of PowerPoint presentation

From grade 11, database and spreadsheet application form a major part of the CAT curriculum. Database and spreadsheet applications are regarded as mindtools because learners are engaged in problem solving and mental processes that require learners to analyse content to gain understanding of that content.

Working with spreadsheets allows learners to visualise data in several ways (by using graphs), allowing them to think about the data in different ways. Logical (the use of functions) and algorithmic thinking (steps on how to do certain calculations/how to create a graph) which are essential ingredients for computational thinking can be introduced by using spreadsheets.

PowerPoint Presentation - Slide
DATABASE AS MINDTOOLS

Discussion of PowerPoint presentation

Databases allow learners to store, retrieve and sort data in an organised way. Databases specifically help learners to provide structure to their mental models while facilitating understanding of the content. Working with databases requires learners to analyse the data or information that they store or retrieve (creation of queries and reports). The Dinosaur database is an example of how a database lesson can be used to develop computational thinking.

In this example, the learner was asked to populate an Excel Database on ten different dinosaurs. In addition to the information, learners were also required to obtain a picture of each dinosaur, and respond to specific questions about their research after completing several queries.

In conducting the research, populating the fields and responding to the questions, learners were required to think in depth about the content, to compare and contrast, and engage in meaningful processing of information.

Although word processing is not seen as a mindtool, as an application it can also be used to enforce computational thinking skills. When learners just use word processing for the keying in, formatting or printing of documents, the processing power of the computer is not fully exploited. When learners apply computational thinking, they will instead of editing a repeated mistake (such as a spelling error), apply the Find and Replace Command. Applying Styles to certain formatting elements of a document and to use this formatting to create a table of contents, is computational thinking. Similarly, when learners use the mailmerge command to associate data from a spreadsheet for words in word processing document.

PROBLEM-SOLVING

As discussed earlier, computational thinking is a skill that learners will use especially when they are involved in problem solving. Research has shown that teachers consider doing normal textbook activities as problem solving; there might thus be a misconception that problem solving is taught in the CAT classroom.

Why teach learners problem solving?

The CAPS document stipulates that learners taking CAT must be able to solve problems. It is important that we teach learners the ability to solve a problem in one context and then to transfer that ability to new and different contexts and situations. Learners must be able to use their knowledge of Solution Development to solve problems in real-life scenarios.

What is a problem?

PowerPoint Presentation - Slide
PROBLEM-SOLVING

Discussion of PowerPoint presentation

A problem must have real-world value and use; it must challenge learners to display their grasp and use of skills (word processing, spreadsheet, database etc.) that are important in CAT. A problem has an achievable solution, although novice problem solvers (Grades 10 and 11) might need help and support in the problem-solving process. Novice problem solvers will start off with defined problems that have a clear structure, a clearly stated start and goal, and a set of steps for moving through the problem. Normally there is only one correct answer. Ill-defined problems are not clearly defined, they are real-world problems. Learners will work through trial and error; they might feel uncomfortable as they encounter the problem-solving process.

PowerPoint Presentation - Slide
TEACHING PROBLEM-SOLVING IN THE CAT CLASSROOM

Discussion of PowerPoint presentation

As a teacher you can play an important role in learners becoming confident problem solvers. The following pointers can assist you to become more confident and at ease in teaching problem solving.

- In problem solving, the process is more important than the answer. Learners must therefore know that it is all right not to have a quick answer or an instant solution.
- When learners do not know the answer/strategy of the solution, model the problem-solving process rather than giving them the answer. Make sure that they understand your thinking.
- Use questions to enhance the problem-solving process.
- By allowing a learner to read or say the problem out loud, it slows down the thinking process, making the problem more accurate and allowing you access to the learning understanding.
- Do not waste time working through problems that learners already understand – identify specific problems, difficulties or confusions.
- Do not be apprehensive about using group work! Very often learners can help one another; talking about a problem helps learners to think more critically about the steps needed to solve the problem. Group work also teaches learners that there is more than one strategy to the solution – and that some strategies are more effective than others.
- When a learner disagrees with you or another learner, do not interpret that as dislike or disrespect. The fact that learners are using different strategies to solve a problem is a positive consequence of the class's diversity.

- When learners work with problems (for example, a difficult spreadsheet problem), their learning might be hampered by their lack of confidence. Provide them with positive reinforcement when they have mastered a new concept or skill.

Is exercise solving the same as problem solving?

PowerPoint Presentation - Slide

EXERCISE SOLVING vs. PROBLEM-SOLVING

Discussion of PowerPoint presentation

As a teacher you know that the CAT learners must learn how to solve "problems". But are your learners solving true problems or are the merely solving exercises? When learners solve problems it requires critical thinking and decision-making skills, whereas exercise solving requires the application of previously learned skills and procedures. Research conducted on problem solving in the CAT classroom has shown that teachers consider a textbook activity as solving a problem. However, it is important that you know there is a big difference between an activity to reinforce skills and an activity that requires problem solving. ***Table 3*** highlights the difference between exercise solving and problem solving.

Table 3: Exercise solving vs. Problem-solving

Exercise solving	**Problem-solving**
A process used to obtain the one and only right answer for the data given.	A process used to obtain a best answer to an unknown, subject to some constraints.
The situation is well defined. The problem statement is very clear and all the necessary known and unknown information is available.	The situation is ill-defined. There may be some ambiguity in the given information. Learners must define the problem themselves. Assumptions may need to

Exercise solving	**Problem-solving**
	be made about what is known and what needs to be found.
The learner has come across similar exercises in textbooks, in class or in homework.	The learner has not encountered this situation before; it is all new.
Learners are helped in a way that the exercise gives tips, rules to be used or even gives prescriptions.	There is nothing in the problem statement that will guide learners to what skill, knowledge or technique they must use to solve the problem.
The learner can only follow one approach and this will lead to the correct answer.	Learners can follow more than one approach to find the correct answer.
The usual method is to recall familiar solutions from previously solved exercises.	The algorithm for solving the problem is unclear.
Communication skills are not essential.	To get to the result of the problem learners must have oral and/or communication skills.

Mourtas *et al*. (2004:10)

PowerPoint Presentation - Slide
PROBLEM-SOLVING PROCESS

Discussion of PowerPoint presentation

Problem-solving is the process of applying a method to an unknown problem to obtain a satisfactory solution. Solving a spreadsheet problem, for example, can be difficult and sometimes tedious. Show your learners how to follow a structured method, such as the one described below in ***Table 4***. Articulate your method while using it so learners can see the connections.

Table 4: The problem-solving process

STEPS		**ACTIVITIES THAT TAKE PLACE DURING THIS STEP**
1.	Understand the problem	Learners must define or identify the problem in their own words. They must ask questions such as “What must be done?”, “Why?” and “How?”
2.	Think about the problem	Learners must determine by themselves what information is needed. They must decide what information will be relevant, useful and essential for solving the problem. Learners can collect information from the print, web or other sources.
3.	Plan possible solutions	Learners must think through possible strategies. The solution will be determined by the type of problem. They must decide on strategies such as using a spreadsheet, a database, a word processor, a diagram, a table or chart or work backwards. Then they must choose the best strategy. Remind learners what they are required to find or calculate.

STEPS		ACTIVITIES THAT TAKE PLACE DURING THIS STEP
4.	Do/Carry out the plan/Select the best solution/Implement	Learners must select the best idea that will help to solve the problem. Ask learners to collect examples of similar problems and strategies used to solve them. Remind learners to be patient and persistent. Most problems are not solved on the first attempt. Encourage them to try a different strategy and keep trying.
5.	Check the final solution. Evaluate the final solution. Look back.	As a teacher you should monitor the problem-solving process throughout – especially with novice problem solvers. Learners must evaluate the solution to determine whether their answer makes sense. Does it answer the questions asked in Step 1? Could the problem be solved in another way? What did I learn from solving this problem?

Problem-based learning is a good example of how as a teacher you can use problem solving as a teaching strategy.

Problem-based learning as an approach to teach problem solving

PowerPoint Presentation - Slide
PROBLEM-BASED LEARNING

Discussion of PowerPoint presentation

You might ask what problem-based learning is. In brief, it is a learner-centred teaching strategy in which learners learn about a subject such as CAT through the experience of problem solving. By using this strategy, learners learn about different thinking strategies and domain knowledge (such as word processing, spreadsheet functions, database).

PowerPoint Presentation - Slide
PROBLEM-BASED LEARNING - THE PAT

Discussion of PowerPoint presentation

Many of you might think that you never employ this teaching strategy in your classroom, but the PAT is an excellent example of how this learner-centred teaching strategy is employed in the CAT classroom. Learners learn about a subject (such as Solution Development) through being involved in problem solving. Using the PAT teaches learners both thinking strategies and domain knowledge.

Scenarios (such as the PAT) can also be used to reinforce computational thinking. Virtually all the computational skills and characters are involved in the PAT at some point. Let us use the Grade 11 PAT topic of 2014 to show you how individual computational thinking skills can contribute to the solution of this complex, real-world problem (see Appendix D). You will also realise how a whole set of skills can work together to make the problem-solving process more efficient and effective.

Understanding the relationship and interactions between the skills in the problem-solving process is an essential part of building effective problem-solving skills. But teachers must be aware that these computational thinking skills are not always explicitly known to the learners. Teachers therefore play an important role in helping learners to leverage the power of computational thinking skill by calling attention explicitly to how these skills work together in solving problems.

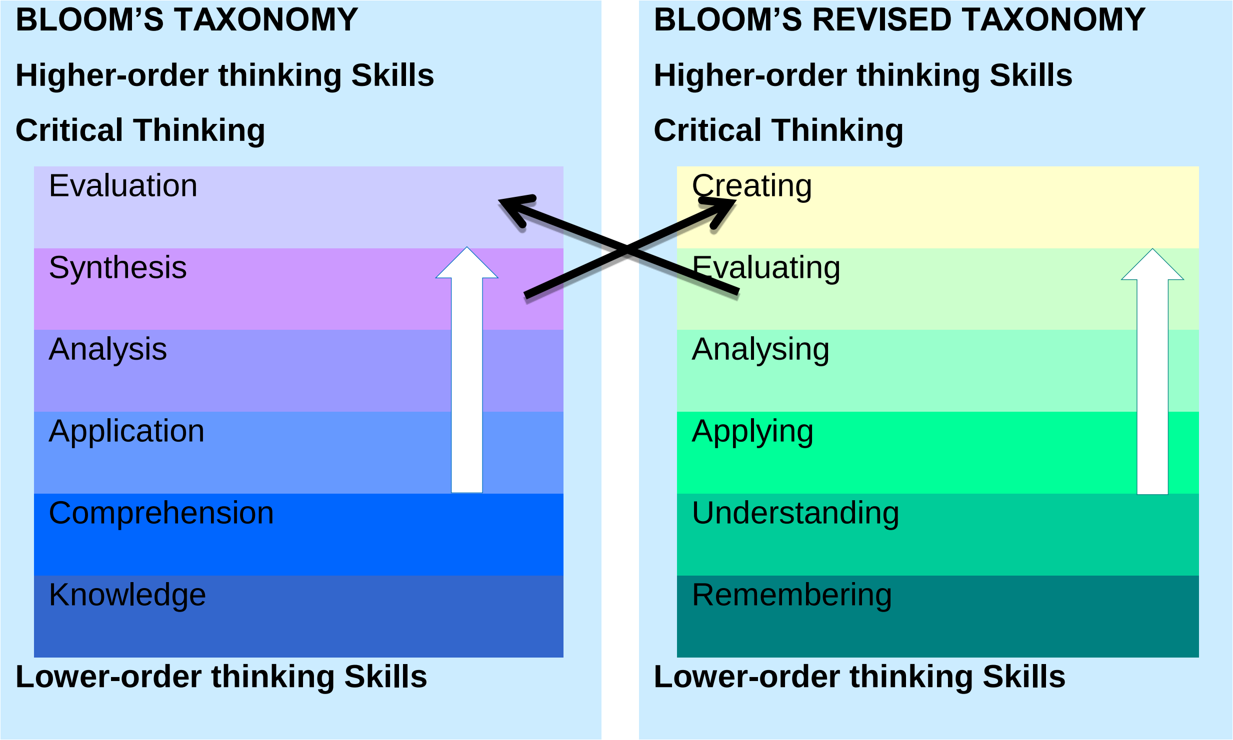
Closing note

I hope that you have developed an understanding of computational thinking and problem solving and that you can recognise the computational thinking skills that you are already including in your CAT lessons. By teaching your learners computational thinking you will empower them with skills that they need to become effective and confident problem solvers of the future. For learners to become successful problem solvers, you as the teacher must accept that learners' problem-solving abilities often develop slowly; it is a long-term process. It is thus important that problem solving must continuously form an integral part of CAT, and develop a problem-solving culture in the classroom

APPENDICES

Appendix A: Bloom's Taxonomy vs. Bloom's Digital Taxonomy

As a teacher you are familiar with Bloom's Taxonomy that was created in the 1950s. Owing to the technological changes this taxonomy was revisited and revised by Lorin Anderson in 2001. In Bloom's Revised Taxonomy, the original nouns were replaced by verbs. Bloom's Revised Taxonomy is very useful in the CAT classroom – especially for Solution Development.



Appendix B: Using Microsoft Word 2010 to create a concept map

1. On a new page, insert a drawing canvas by clicking the ***Insert tab***.
   Selecting ***Shapes*** in the Illustrations group.
   Click ***New Drawing Canvas.***
2. Select the Insert tab.
   Click ***Shapes*** and choose ***Oval*** under the Basic Shapes section.
   Click and hold your mouse and drag your mouse to the size you want the circle. Hold the ***Shift*** key as you drag to keep your shape as a circle. This first shape is usually the main idea that you start from. The size can be adjusted by clicking the circle and dragging it from the edges.
3. Key in your concepts or ideas into the inside of each circle by right-clicking on the circle.
4. Repeat the process again and place the next circle with your next concept near the first circle. You can alter the size of the circle depending on how much importance you place on the concept.
5. Link your concepts either with an arrow like a flow chart or a simple line. To use an arrow, click the ***Shapes*** button, choose the type of line you want under the Lines section.
6. To connect shapes, click on the first shape and then click on the second shape.
7. To draw a straight line, click ***Line Button*** image and drag to draw the line.
8. If you need to change the length of any of the arrows or lines, click on the line and point to the circles that appear at the end, then drag them to the desired length.
9. Repeat the process with other concepts to make your concept map.
10. When you have finished, save your document.

Appendix C: List of Web 2.0 applications (there are many more) that can be used in the CAT classroom.

Web 2.0 applications	Explanation	Web address	21st century skills that are developed
Edmondo	Social learning environment and one of the best ways to teach with technology.	http://www.edmodo.com	Communication skills
Bubble.us	Assist in developing critical thinking that enables learners to create mind mapping and brainstorming diagrams online.	http://bubbl.us	Brainstorming Creativity
SlideShare	Teachers or learners can upload PowerPoint presentations, Word document and Adobe files to share publicly or privately.	http://slideshare.net	Communication skills
Mindomo	Mind mapping tool that lets learners create mind maps to organise, explore, analyse and evaluate ideas.	http://www.mindomo.com	Critical thinking Problem-solving Team collaboration Communication skills.
GoogleDocs	Easy-to-use online application software such as word processor, spreadsheet and presentation editor that enables teachers and learners to create, store and share instantly and securely, and collaborate online in real	https://docs.google.com/	Critical thinking Problem-solving Team collaboration Creativity Communication skills

	time.		
Wordle	Creates word clouds by pasting or entering text in the provided box in the application. The word clouds show which words appear more frequently in the original text.	http://wordle.net	Creativity Critical thinking
The Visual Ranking Tool	The Visual Ranking Tool lets learners brainstorm a list of items or use a provided list to assign a ranking based on determined criteria.	http://educate.intel.com/en/ThinkingTools/VisualRanking	Critical thinking Analysis Evaluation
Pinterest	Top-of-the-line bulletin board used to create and manage theme-based image collections.	http://www.pinterest.com/	Collaboration Critical thinking
Boolify	Is an educational Boolean search tool aimed at primary and secondary learners. As a teacher you can use this application to teach learners the basics of a good search using popular search engines.	http://www.boolify.org	Information literacy Critical thinking

Visit the following website for more information on Web 2.0 applications: http://www.web2teachingtools.com

Appendix D: Grade 11 PAT - 2014 (DBE, 2014:2)

New Trends and Technology

Computer-based technology never stops evolving; over the years it has been rapidly changing and expanding. While it might seem that current technology has reached its limits, it is still spreading its proverbial wings. Practically every device available today is somehow linked to computer technology.

The moment a new technology is born, it has an effect on us. Our lives change as a result of technologies - for better or worse. Not only does technology help us stay more connected with our family and friends, but it also enables us to stay more connected with our work.

The editor of your school's newspaper wants to publish a series of articles on the impact that new technologies and trends may have on people's lives.

The Grade 11 CAT learners are requested to investigate the matter.

To be able to determine the impact on peoples' lives, you need to find information related to new computer-based trends and technologies.

You are required to investigate:

at least ***one*** new computer-related technology from Column A below (which is later referred to as Technology 1) and

at least ***one*** other computer technology/trend from Column B below (which is later referred to as Technology 2).

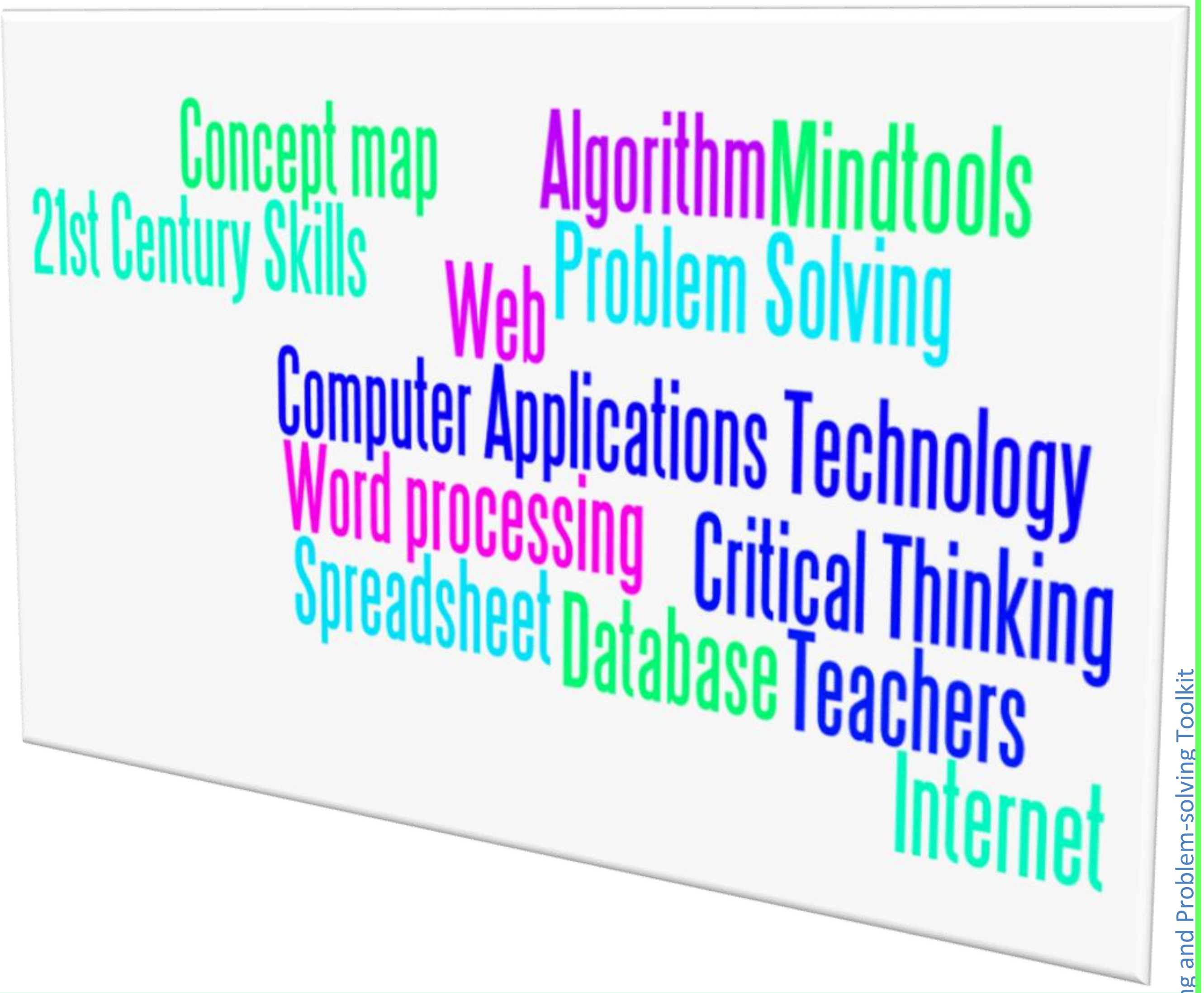
Column A	**Column B**
Cloud computing	Games and Gamification
3-D Printing	Internet of Things
Wearable devices	e-Collaboration
Flexible displays	New Focus on Online learning

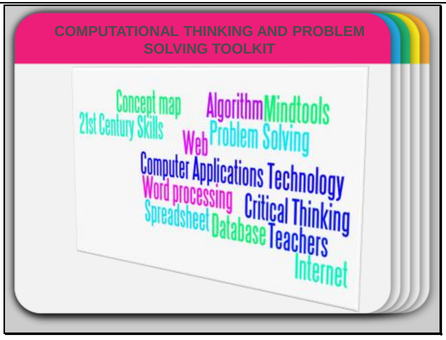
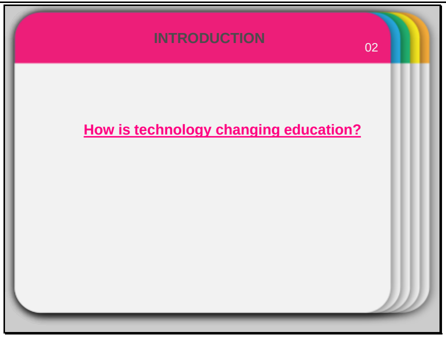
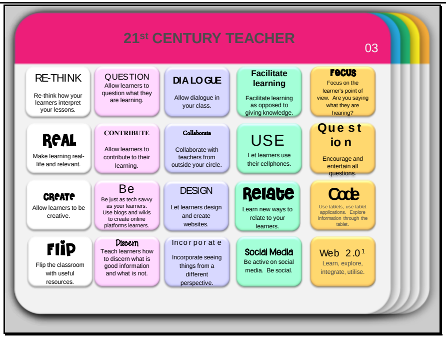
Virtual assistants	New Focus on Mobile Devices, Apps and Mobile learning
Natural User Interfaces	Virtual and remote labs
4K Displays	New Focus on Risks and Concerns regarding Online Privacy/Identity

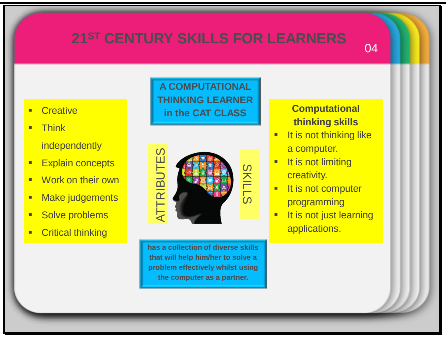
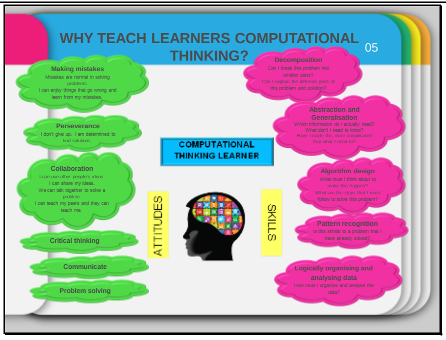
You need to compile a formal report of your investigation that could be considered for publication in your school's newspaper.

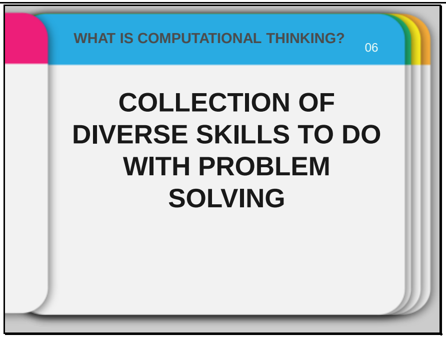
Other than the articles in the school's newspaper, the information will also be shared online in the format of a website. You will therefore also need to create a website based on your investigation.

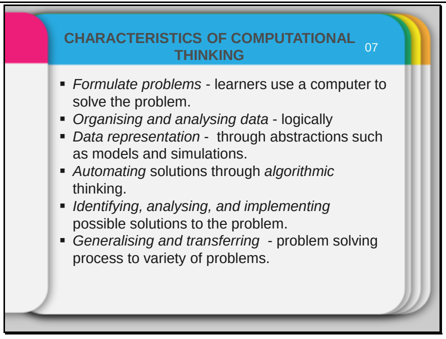
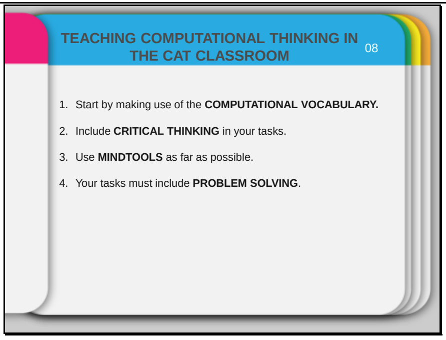
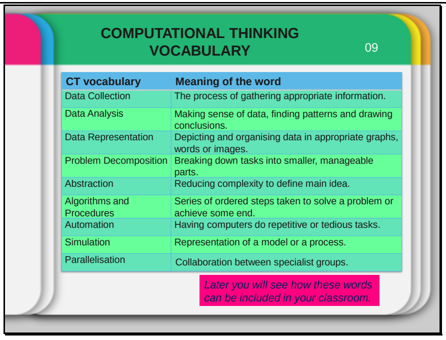
COMPUTATIONAL THINKING AND PROBLEM-SOLVING TOOLKIT FOR FACILITATORS



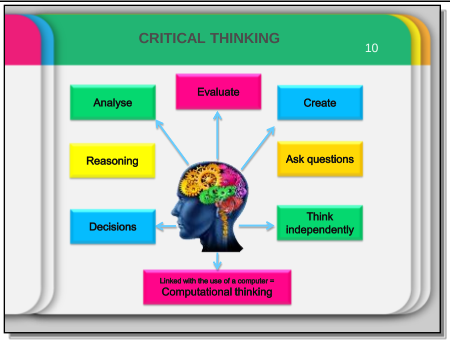
Slide 1	 COMPUTATIONAL THINKING AND PROBLEM SOLVING TOOLKIT Concept map 21st Century Skills Algorithm Mindtools Web Problem Solving Computer Applications Technology Word processing Critical Thinking Spreadsheet Database Teachers Internet	Welcome all attending CAT teachers to the workshop. Provide a brief introduction on why the workshop is needed – refer to the CAPS document.
Slide 2	 INTRODUCTION 02 How is technology changing education?	Show the video on Computational Thinking to the teachers – this video will provide teachers with a better understanding of computational thinking and problem solving.
Slide 3	 21st CENTURY TEACHER 03 RE-THINK Re-think how your learners interpret your lessons. QUESTION Allow learners to question what they are learning. DIALOGUE Allow dialogue in your class. Facilitate learning Facilitate learning as opposed to giving knowledge. Focus Focus on the learner's point of view. Are you saying what they are hearing? REAL Make learning real-life and relevant. CONTRIBUTE Allow learners to contribute to their learning. Collaborate Collaborate with teachers from outside your circle. USE Let learners use their cellphones. Question Encourage and entertain all questions. CREATE Allow learners to be creative. Be Be just as tech savvy as your learners. Use blogs and wikis to create online platforms learners. DESIGN Let learners design and create websites. Relate Learn new ways to relate to your learners. Code Use tablets, use tablet applications. Explore information through the tablet. Flip Flip the classroom with useful resources. Discern Teach learners how to discern what is good information and what is not. Incorporate Incorporate seeing things from a different perspective. Social Media Be active on social media. Be social. Web 2.0[1] Learn, explore, integrate, utilise.	These are some of the attributes that any successful 21st century teacher must. Allow time to discuss each of these attributes.

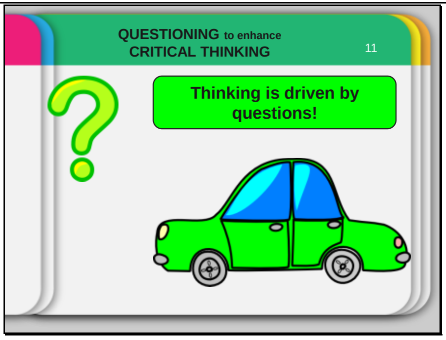
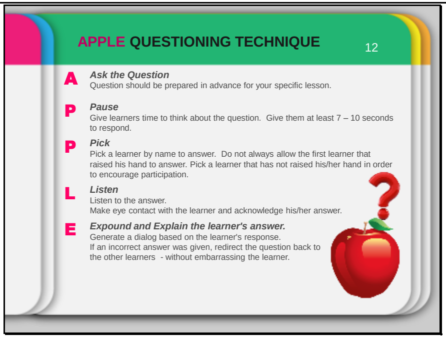
Slide 4	 21ST CENTURY SKILLS FOR LEARNERS A COMPUTATIONAL THINKING LEARNER in the CAT CLASS - Creative - Think independently - Explain concepts - Work on their own - Make judgements - Solve problems - Critical thinking ATTRIBUTES SKILLS **Computational thinking skills** - It is not thinking like a computer. - It is not limiting creativity. - It is not computer programming - It is not just learning applications. has a collection of diverse skills that will help him/her to solve a problem effectively whilst using the computer as a partner.	What are 21st century skills for learners? In the past a learner was a young person who went to school, spent a specified amount of time in the school, learnt certain subjects, wrote examinations and matriculated. Today we must see learners in a new context: ▪ First, we must maintain learners' interest by assisting them to realise how what they are learning prepares them for life in the real world. ▪ Second – we must instill curiosity, which is fundamental to lifelong learning. ▪ Third – we must be flexible in how we teach. ▪ Fourth – we must excite learners to become even more resourceful so that they will continue to learn outside the formal school day.
Slide 5	 WHY TEACH LEARNERS COMPUTATIONAL THINKING? **Making mistakes** Mistakes are normal in solving problems. I can enjoy things that go wrong and learn from my mistakes. **Perseverance** I don't give up. I am determined to find solutions. **Collaboration** I can use other people's ideas. I can share my ideas. We can talk together to solve a problem. I can teach my peers and they can teach me. **Critical thinking** **Communicate** **Problem solving** ATTITUDES COMPUTATIONAL THINKING LEARNER SKILLS **Decomposition** Can I break this problem into smaller parts? Can I explain the different parts of this problem and solution? **Abstraction and Generalisation** Which information do I actually need? What don't I need to know? Have I made this more complicated that what I need to? **Algorithm design** What must I think about to make this happen? What are the steps that I must follow to solve this problem? **Pattern recognition** Is this similar to a problem that I have already solved? **Logically organising and analysing data** How must I organise and analyse the data?	Explain by telling the following story (adapted from www.quantumprogress.com): Imagine a pencil. What makes this such a powerful tool? It's the limitless number of things you can do with it. What if the moment you are given a pencil, you are told you can only use it in certain ways? Maybe to count things, like this: The power of a pencil lies in realizing what you can do with it—for instance, write down the stories inside your head, imagine and draw the space around you in a drawing, record the music that flows through your ears. How is this like a computer? It is not enough to provide learners with a computer or an iPad and set them loose, and it's is not much better to train them to be "literate" with classes in PowerPoint or how to be good consumers of information

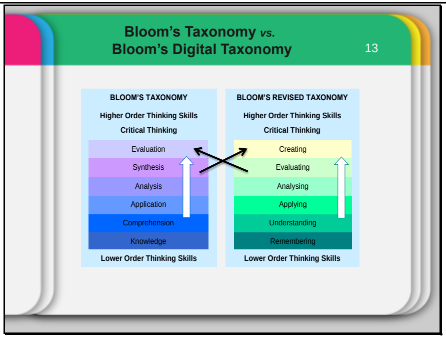
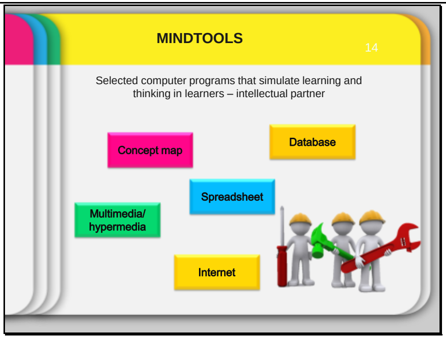
<table>
<tr><td></td><td></td><td>from the Internet. If the computer really is a pencil, then learners must learn how to think computationally and algorithmically so that they fully understand what a computer can (and cannot) do, and then be able to instruct it to do so.</td></tr>
<tr><td>Slide 6</td><td>
WHAT IS COMPUTATIONAL THINKING? 06
COLLECTION OF DIVERSE SKILLS TO DO WITH PROBLEM SOLVING</td><td>Critical thinking that is linked with the power of a computer = computational thinking.

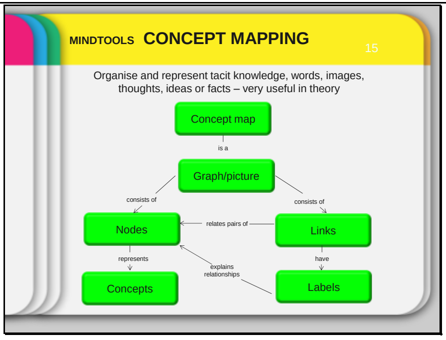
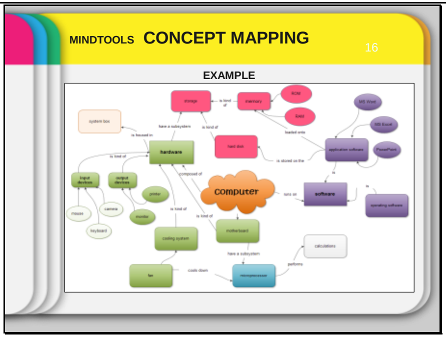
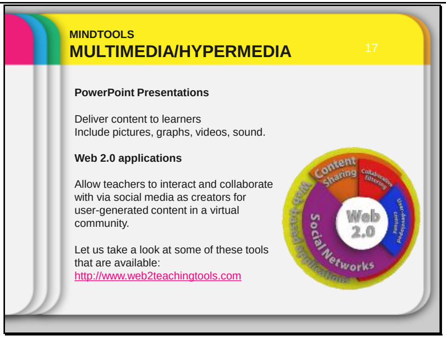
Very useful website is: https://www.google.com/edu/computational-thinking/</td></tr>
<tr><td>Slide 7</td><td>
CHARACTERISTICS OF COMPUTATIONAL THINKING 07
▪ <i>Formulate problems</i> - learners use a computer to solve the problem.
▪ <i>Organising and analysing data</i> - logically
▪ <i>Data representation</i> - through abstractions such as models and simulations.
▪ <i>Automating</i> solutions through <i>algorithmic</i> thinking.
▪ <i>Identifying, analysing, and implementing</i> possible solutions to the problem.
▪ <i>Generalising and transferring</i> - problem solving process to variety of problems.</td><td></td></tr>
<tr><td>Slide 8</td><td>
TEACHING COMPUTATIONAL THINKING IN THE CAT CLASSROOM 08
1. Start by making use of the COMPUTATIONAL VOCABULARY.
2. Include CRITICAL THINKING in your tasks.
3. Use MINDTOOLS as far as possible.
4. Your tasks must include PROBLEM SOLVING.</td><td></td></tr>
<tr><td>Slide 9</td><td>
COMPUTATIONAL THINKING VOCABULARY 09
<table>
<tr><th>CT vocabulary</th><th>Meaning of the word</th></tr>
<tr><td>Data Collection</td><td>The process of gathering appropriate information.</td></tr>
<tr><td>Data Analysis</td><td>Making sense of data, finding patterns and drawing conclusions.</td></tr>
<tr><td>Data Representation</td><td>Depicting and organising data in appropriate graphs, words or images.</td></tr>
<tr><td>Problem Decomposition</td><td>Breaking down tasks into smaller, manageable parts.</td></tr>
<tr><td>Abstraction</td><td>Reducing complexity to define main idea.</td></tr>
<tr><td>Algorithms and Procedures</td><td>Series of ordered steps taken to solve a problem or achieve some end.</td></tr>
<tr><td>Automation</td><td>Having computers do repetitive or tedious tasks.</td></tr>
<tr><td>Simulation</td><td>Representation of a model or a process.</td></tr>
<tr><td>Parallelisation</td><td>Collaboration between specialist groups.</td></tr>
</table>
<i>Later you will see how these words can be included in your classroom.</i></td><td>▪ Teachers should understand the different words in the vocabulary. Explain each word by means of an example:

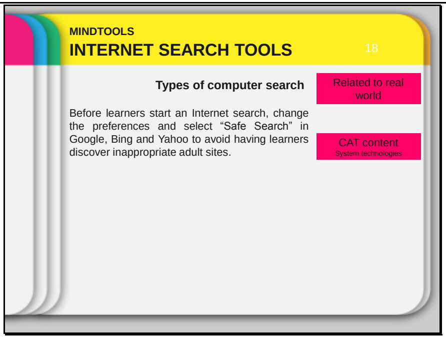
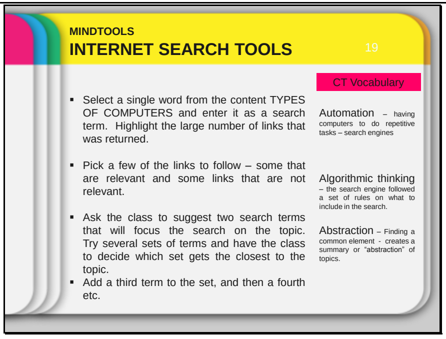
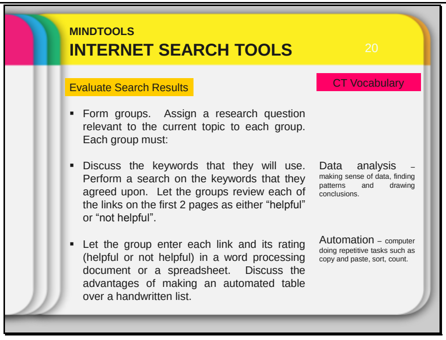
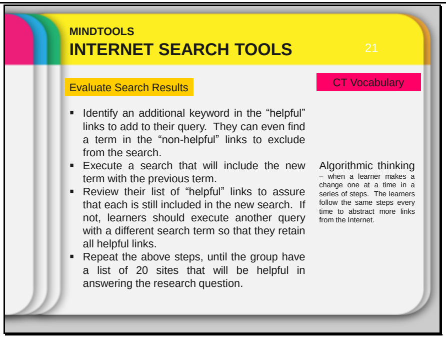
– Data Collection: Different sources such as the Internet, Library, Books, Questionnaires.
– Data Analysis: Making summaries of data collected. Deciding what is important and what must be left out.</td></tr>
</table>

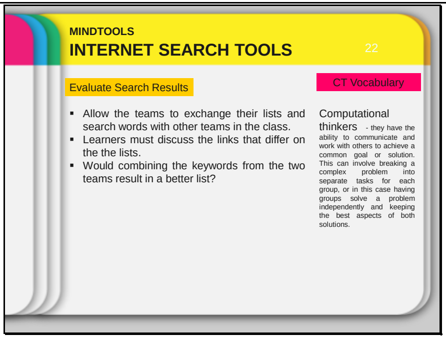
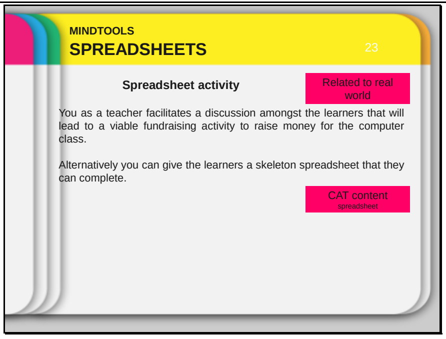
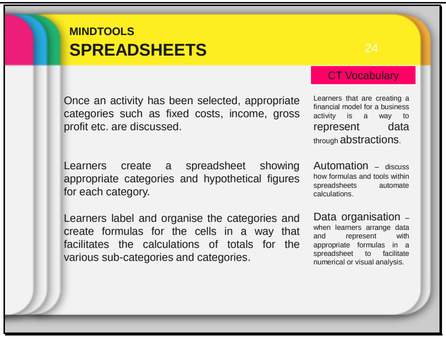
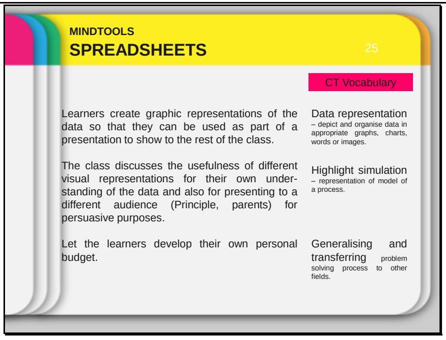
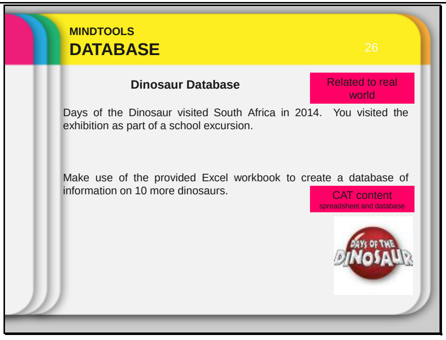
		– Data Representation: Plotting data on graphs. – Problem Decomposition: PAT – that is broken into different phases. – Abstraction: From the scenario of the PAT – you derive at the main question. – Algorithms and Procedures – steps you will follow to reach a goal. In the PAT – learners do phase 1, then phase 2 and then phase 3. – Simulation: Budget in spreadsheet – Parallelisation: Working with other learners/teachers. Group work. ▪ It is important that examples from the CAT content must be given to teachers. ▪ Ask teachers to give more examples and let them have a discussion on how they understand and interpret the words.
Slide 10	 CRITICAL THINKING 10 Analyse Evaluate Create Reasoning Ask questions Decisions Think independently Linked with the use of a computer = Computational thinking	Critical thinking is the ability to think clearly and rationally. It includes the ability to engage in reflective and independent thinking. A learner with critical thinking skills is able to do the following : ▪ understand the logical connections between ideas; ▪ analyse, construct and evaluate arguments; ▪ detect inconsistencies and common mistakes in reasoning; ▪ solve problems systematically; ▪ identify the relevance and importance of ideas; and ▪ reflect on the justification of one's own beliefs and values.

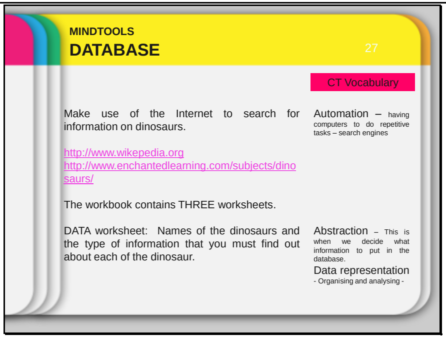
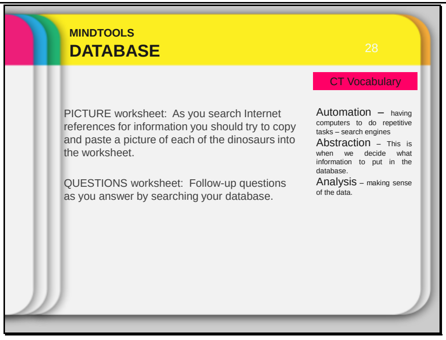
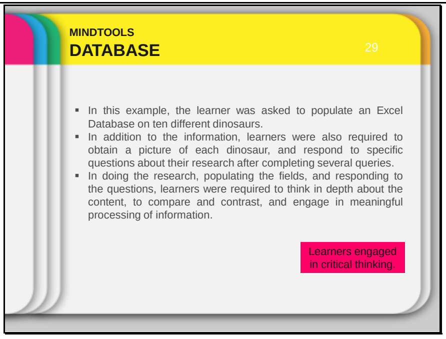
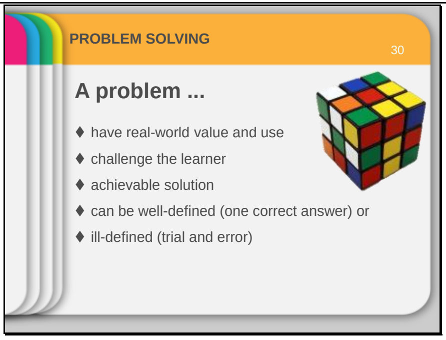
		If you are still unsure about critical thinking, the following YouTube video can help: https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=video&cd=4&cad=rja&uact=8&ved=0CDYQtwIwAw&url=http%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3D6OLPL5p0fMg&ei=PHAdVM7EFMLd7QbPx4DYCw&usg=AFQjCNEBV22yomADSWS2Ay7HKTU3Gdk8Xg
Slide 11	 QUESTIONING to enhance CRITICAL THINKING 11 Thinking is driven by questions!	The pointers in the Toolkit on questioning are very important (see page 17). Allow teachers to discuss these pointers.
Slide 12	 APPLE QUESTIONING TECHNIQUE 12 **A** *Ask the Question* Question should be prepared in advance for your specific lesson. **P** *Pause* Give learners time to think about the question. Give them at least 7 – 10 seconds to respond. **P** *Pick* Pick a learner by name to answer. Do not always allow the first learner that raised his hand to answer. Pick a learner that has not raised his/her hand in order to encourage participation. **L** *Listen* Listen to the answer. Make eye contact with the learner and acknowledge his/her answer. **E** *Expound and Explain the learner's answer.* Generate a dialog based on the learner's response. If an incorrect answer was given, redirect the question back to the other learners - without embarrassing the learner.	▪ Remember, there are many different types of questions. ▪ The response and outcome the teacher wants dictates the type of question the teacher should use in the classroom. ▪ Pose questions within the ability of the learner to whom the question is addressed. ▪ Pose questions to the inattentive learners. ▪ Learners must provide complete answers. Refrain from YES or NO answers. ▪ Have learners speak loudly so that all may hear. ▪ Keep questions on the issue at and. ▪ Write questions in your lesson plan. ▪ Use spontaneous questions. Planning is essential to effective questioning, but by listening carefully to learners' responses, even spontaneous questions can be very effective.

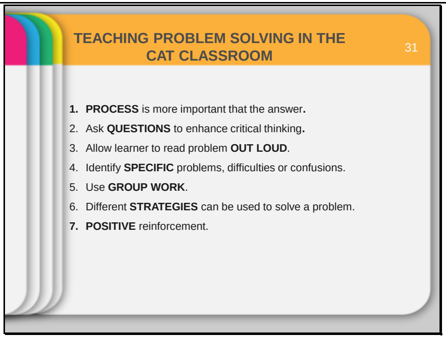
Slide 13	 Bloom's Taxonomy *vs.* Bloom's Digital Taxonomy 13 BLOOM'S TAXONOMY Higher Order Thinking Skills Critical Thinking Evaluation Synthesis Analysis Application Comprehension Knowledge Lower Order Thinking Skills BLOOM'S REVISED TAXONOMY Higher Order Thinking Skills Critical Thinking Creating Evaluating Analysing Applying Understanding Remembering Lower Order Thinking Skills	Many teachers are not using any taxonomy! First discuss why a taxonomy is important: As a teacher, you should attempt to move learners up the taxonomy as they progress in their knowledge. Tests that are written solely to assess knowledge are unfortunately very common. However, to create thinkers as opposed to learners who simply recall information, we must incorporate the higher levels into our daily teachings and tests. A few reasons why teachers are not implementing a taxonomy can be: ▪ They might have low expectations concerning the learners ability. ▪ Using taxonomy can be difficult and time consuming for the teacher. However, it is important that we as teachers help our learners to become critical thinkers. Building on knowledge and helping kids begin to apply, analyse, synthesise, and evaluate is the key to helping them grow and prosper in school and beyond.
Slide 14	 MINDTOOLS 14 Selected computer programs that simulate learning and thinking in learners – intellectual partner Concept map Database Spreadsheet Multimedia/ hypermedia Internet	Mindtools are cognitive tools such as selected computer programs that stimulate learning and thinking in learners. Mindtools in education are a set of five tools that learners and teachers can use in combination with "traditional" teaching and learning methods. The combination of technology and traditional methods of teaching work great together. Thus, both teachers and learners alike will be better served by programs that devote a greater percentage of instructional time to problem solving and active learning.

Slide 15	 MINDTOOLS **CONCEPT MAPPING** 15 Organise and represent tacit knowledge, words, images, thoughts, ideas or facts – very useful in theory Concept map is a Graph/picture consists of consists of Nodes relates pairs of Links represents explains relationships have Concepts Labels	A concept map is a hierarchical form of structure diagram that illustrates conceptual knowledge and their relationships within a specific topic from general to specific concepts. It consists of concept labels (aka nodes) which are connected together by lines, these lines are labeled with directions Concept map was developed by Joseph Novak and it is based on the theory that prior knowledge is very important in order to gain deep learning on new concepts. So by understanding what you already knew, and relating new concepts to what you knew, meaningful deep learning can easily occur.
Slide 16	 MINDTOOLS **CONCEPT MAPPING** 16 **EXAMPLE**	Determine how many teachers are using concept mapping. Let them share their experiences with novice concept mapping teachers.
Slide 17	 MINDTOOLS **MULTIMEDIA/HYPERMEDIA** 17 **PowerPoint Presentations** Deliver content to learners Include pictures, graphs, videos, sound. **Web 2.0 applications** Allow teachers to interact and collaborate with via social media as creators for user-generated content in a virtual community. Let us take a look at some of these tools that are available: http://www.web2teachingtools.com	▪ PowerPoint can be an effective tool to present material in the classroom and encourage learner learning. ▪ Use PowerPoint to cue and guide the lesson rather than project long and complete sentences. ▪ Consider using different colour slide backgrounds to change the pace of the presentation. ▪ Use clip art and graphics sparingly. Research shows that it is the best to use graphics only when the graphics support the content. ▪ PowerPoint supports multimedia such as video, audio and animations – this feature can be

		very handy in the CAT classroom to explain abstract ideas. ▪ Remember that PowerPoint can reduce the opportunity for classroom interaction – be careful that you do not just disseminate content.
Slide 18	 MINDTOOLS **INTERNET SEARCH TOOLS** 18 **Types of computer search** Before learners start an Internet search, change the preferences and select "Safe Search" in Google, Bing and Yahoo to avoid having learners discover inappropriate adult sites. Related to real world CAT content System technologies	Remember to make sure that the venue has Internet access to all computers. The Internet Search Tool slides make use of an example to show how computational thinking can be incorporated into a normal CAT class.
Slide 19	 MINDTOOLS **INTERNET SEARCH TOOLS** 19 CT Vocabulary ▪ Select a single word from the content TYPES OF COMPUTERS and enter it as a search term. Highlight the large number of links that was returned. ▪ Pick a few of the links to follow – some that are relevant and some links that are not relevant. ▪ Ask the class to suggest two search terms that will focus the search on the topic. Try several sets of terms and have the class to decide which set gets the closest to the topic. ▪ Add a third term to the set, and then a fourth etc. Automation – having computers to do repetitive tasks – search engines Algorithmic thinking – the search engine followed a set of rules on what to include in the search. Abstraction – Finding a common element - creates a summary or "abstraction" of topics.	CT vocabulary is indicated on the right-hand side of the slide. Make teachers aware of how they can use the CT vocabulary on a daily basis.
Slide 20	 MINDTOOLS **INTERNET SEARCH TOOLS** 20 Evaluate Search Results CT Vocabulary ▪ Form groups. Assign a research question relevant to the current topic to each group. Each group must: ▪ Discuss the keywords that they will use. Perform a search on the keywords that they agreed upon. Let the groups review each of the links on the first 2 pages as either "helpful" or "not helpful". ▪ Let the group enter each link and its rating (helpful or not helpful) in a word processing document or a spreadsheet. Discuss the advantages of making an automated table over a handwritten list. Data analysis – making sense of data, finding patterns and drawing conclusions. Automation – computer doing repetitive tasks such as copy and paste, sort, count.	To judge the quality of information – what should learners consider?
Slide 21	 MINDTOOLS **INTERNET SEARCH TOOLS** 21 Evaluate Search Results CT Vocabulary ▪ Identify an additional keyword in the "helpful" links to add to their query. They can even find a term in the "non-helpful" links to exclude from the search. ▪ Execute a search that will include the new term with the previous term. ▪ Review their list of "helpful" links to assure that each is still included in the new search. If not, learners should execute another query with a different search term so that they retain all helpful links. ▪ Repeat the above steps, until the group have a list of 20 sites that will be helpful in answering the research question. Algorithmic thinking – when a learner makes a change one at a time in a series of steps. The learners follow the same steps every time to abstract more links from the Internet.	

Slide 22	 MINDTOOLS **INTERNET SEARCH TOOLS** 22 Evaluate Search Results ▪ Allow the teams to exchange their lists and search words with other teams in the class. ▪ Learners must discuss the links that differ on the the lists. ▪ Would combining the keywords from the two teams result in a better list? CT Vocabulary Computational thinkers - they have the ability to communicate and work with others to achieve a common goal or solution. This can involve breaking a complex problem into separate tasks for each group, or in this case having groups solve a problem independently and keeping the best aspects of both solutions.	
Slide 23	 MINDTOOLS **SPREADSHEETS** 23 **Spreadsheet activity** Related to real world You as a teacher facilitates a discussion amongst the learners that will lead to a viable fundraising activity to raise money for the computer class. Alternatively you can give the learners a skeleton spreadsheet that they can complete. CAT content spreadsheet	The following slides show the teachers how spreadsheets can be used as a mindtool in the CAT classroom. Make teachers attentive on the CT vocabulary as indicated in the pink blocks.
Slide 24	 MINDTOOLS **SPREADSHEETS** 24 CT Vocabulary Once an activity has been selected, appropriate categories such as fixed costs, income, gross profit etc. are discussed. Learners that are creating a financial model for a business activity is a way to represent data through abstractions. Learners create a spreadsheet showing appropriate categories and hypothetical figures for each category. Automation – discuss how formulas and tools within spreadsheets automate calculations. Learners label and organise the categories and create formulas for the cells in a way that facilitates the calculations of totals for the various sub-categories and categories. Data organisation – when learners arrange data and represent with appropriate formulas in a spreadsheet to facilitate numerical or visual analysis.	
Slide 25	 MINDTOOLS **SPREADSHEETS** 25 CT Vocabulary Learners create graphic representations of the data so that they can be used as part of a presentation to show to the rest of the class. Data representation – depict and organise data in appropriate graphs, charts, words or images. The class discusses the usefulness of different visual representations for their own understanding of the data and also for presenting to a different audience (Principle, parents) for persuasive purposes. Highlight simulation – representation of model of a process. Let the learners develop their own personal budget. Generalising and transferring problem solving process to other fields.	
Slide 26	 MINDTOOLS **DATABASE** 26 **Dinosaur Database** Related to real world Days of the Dinosaur visited South Africa in 2014. You visited the exhibition as part of a school excursion. Make use of the provided Excel workbook to create a database of information on 10 more dinosaurs. CAT content spreadsheet and database DAYS OF THE DINOSAUR	The following slides will show how a database can be used to instill computational thinking in the CAT classroom. The pink blocks show the CT vocabulary to the teachers.

Slide 27	 MINDTOOLS **DATABASE** 27 CT Vocabulary Make use of the Internet to search for information on dinosaurs. http://www.wikepedia.org http://www.enchantedlearning.com/subjects/dinosaurs/ The workbook contains THREE worksheets. DATA worksheet: Names of the dinosaurs and the type of information that you must find out about each of the dinosaur. Automation – having computers to do repetitive tasks – search engines Abstraction – This is when we decide what information to put in the database. Data representation - Organising and analysing -	Load the file MINDTOOLS DINO for teachers.
Slide 28	 MINDTOOLS **DATABASE** 28 CT Vocabulary PICTURE worksheet: As you search Internet references for information you should try to copy and paste a picture of each of the dinosaurs into the worksheet. QUESTIONS worksheet: Follow-up questions as you answer by searching your database. Automation – having computers to do repetitive tasks – search engines Abstraction – This is when we decide what information to put in the database. Analysis – making sense of the data.	
Slide 29	 MINDTOOLS **DATABASE** 29 ▪ In this example, the learner was asked to populate an Excel Database on ten different dinosaurs. ▪ In addition to the information, learners were also required to obtain a picture of each dinosaur, and respond to specific questions about their research after completing several queries. ▪ In doing the research, populating the fields, and responding to the questions, learners were required to think in depth about the content, to compare and contrast, and engage in meaningful processing of information. Learners engaged in critical thinking.	
Slide 30	 PROBLEM SOLVING 30 **A problem ...** ♦ have real-world value and use ♦ challenge the learner ♦ achievable solution ♦ can be well-defined (one correct answer) or ♦ ill-defined (trial and error)	

<table>
<tr>
<td>Slide 31</td>
<td>


TEACHING PROBLEM SOLVING IN THE CAT CLASSROOM

31

1. **PROCESS** is more important that the answer.
2. Ask **QUESTIONS** to enhance critical thinking.
3. Allow learner to read problem **OUT LOUD**.
4. Identify **SPECIFIC** problems, difficulties or confusions.
5. Use **GROUP WORK**.
6. Different **STRATEGIES** can be used to solve a problem.
7. **POSITIVE** reinforcement.
</td>
<td></td>
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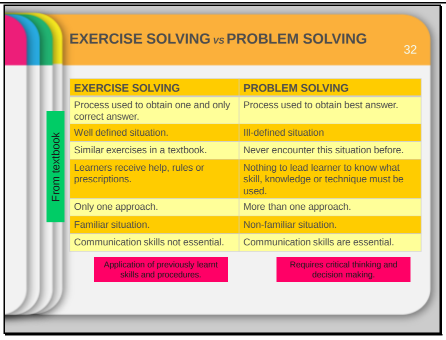
<tr>
<td>Slide 32</td>
<td>


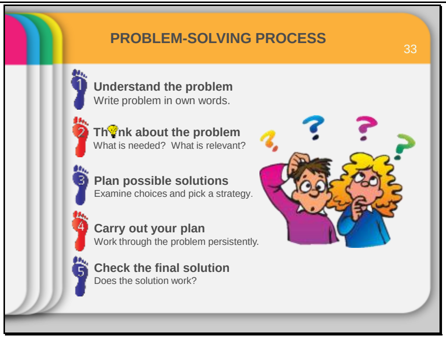
EXERCISE SOLVING vs PROBLEM SOLVING

32

From textbook

<table>
<tr><th>EXERCISE SOLVING</th><th>PROBLEM SOLVING</th></tr>
<tr><td>Process used to obtain one and only correct answer.</td><td>Process used to obtain best answer.</td></tr>
<tr><td>Well defined situation.</td><td>Ill-defined situation</td></tr>
<tr><td>Similar exercises in a textbook.</td><td>Never encounter this situation before.</td></tr>
<tr><td>Learners receive help, rules or prescriptions.</td><td>Nothing to lead learner to know what skill, knowledge or technique must be used.</td></tr>
<tr><td>Only one approach.</td><td>More than one approach.</td></tr>
<tr><td>Familiar situation.</td><td>Non-familiar situation.</td></tr>
<tr><td>Communication skills not essential.</td><td>Communication skills are essential.</td></tr>
</table>

Application of previously learnt skills and procedures.

Requires critical thinking and decision making.
</td>
<td>It is very important that the teachers must understand the difference between exercise solving and problem solving.</td>
</tr>
<tr>
<td>Slide 33</td>
<td>


PROBLEM-SOLVING PROCESS

33

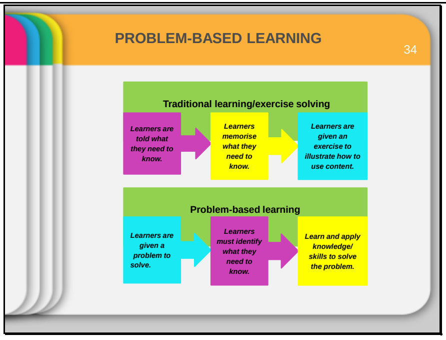
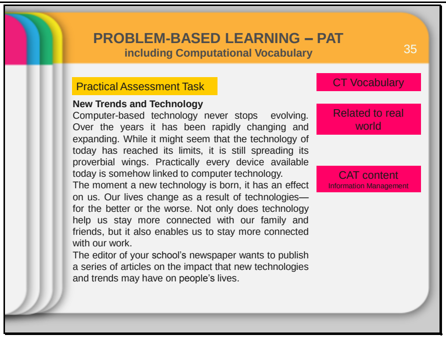
1 **Understand the problem**
Write problem in own words.

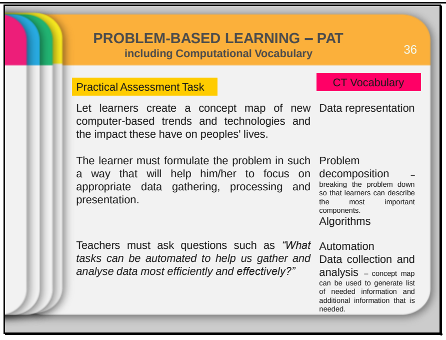
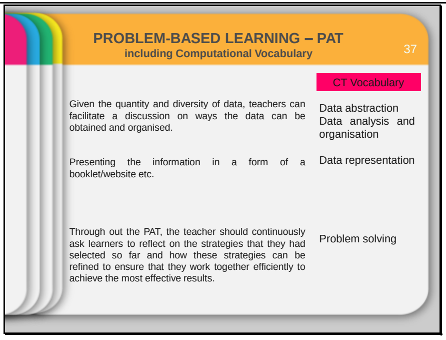
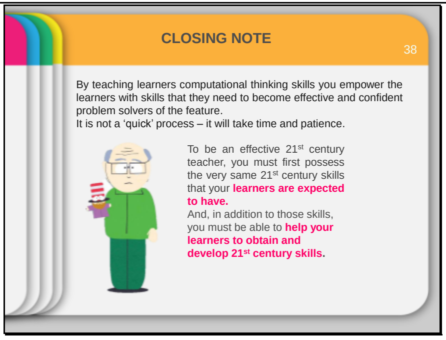
2 **Think about the problem**
What is needed? What is relevant?

3 **Plan possible solutions**
Examine choices and pick a strategy.

4 **Carry out your plan**
Work through the problem persistently.

5 **Check the final solution**
Does the solution work?
</td>
<td>The process is only a guide for problem solving. It is useful to have a structure to follow to make sure that nothing is overlooked. Nothing here is likely to be brand new to anyone, but it is the pure acknowledgement and reminding of the process that can help the problems to be solved.
This is however not the only problem-solving process that can be used – there are numerous problem-solving processes that learners can employ.</td>
</tr>
</table>

Slide 34	 PROBLEM-BASED LEARNING Traditional learning/exercise solving *Learners are told what they need to know.* *Learners memorise what they need to know.* *Learners are given an exercise to illustrate how to use content.* Problem-based learning *Learners are given a problem to solve.* *Learners must identify what they need to know.* *Learn and apply knowledge/ skills to solve the problem.*	Problem-based learning (PBL) is an approach that challenges learners to learn through engagement in a real problem. It is a format that simultaneously develops problem-solving strategies, knowledge bases and skills by placing learners in the active role of problem-solvers. PBL teaches learners 21st century competencies such as problem solving, critical thinking, collaboration, communication, and creativity/innovation. PBL is "started" by an open-ended question (not a yes/no question) that learners understand and find intriguing. Learners see the need to gain knowledge, understand concepts, and apply skills in order to answer the question. Learners are allowed to make some choices about the products to be created, how they work, and how they use their time, guided by the teacher and depending on age level and PBL experience. PBL includes processes for learners to provide and receive feedback on the quality of their work, leading them to make revisions or conduct further inquiry. Learners present their work to other people, beyond their classmates and teacher. Does this not remind you of the PAT? Can the PAT be adjusted?
Slide 35	 PROBLEM-BASED LEARNING – PAT including Computational Vocabulary Practical Assessment Task **New Trends and Technology** Computer-based technology never stops evolving. Over the years it has been rapidly changing and expanding. While it might seem that the technology of today has reached its limits, it is still spreading its proverbial wings. Practically every device available today is somehow linked to computer technology. The moment a new technology is born, it has an effect on us. Our lives change as a result of technologies—for the better or the worse. Not only does technology help us stay more connected with our family and friends, but it also enables us to stay more connected with our work. The editor of your school's newspaper wants to publish a series of articles on the impact that new technologies and trends may have on people's lives. CT Vocabulary Related to real world CAT content Information Management	Refer to page on Problem-based learning.

Slide 36	 **PROBLEM-BASED LEARNING – PAT** **including Computational Vocabulary** 36 Practical Assessment Task CT Vocabulary Let learners create a concept map of new computer-based trends and technologies and the impact these have on peoples' lives. Data representation The learner must formulate the problem in such a way that will help him/her to focus on appropriate data gathering, processing and presentation. Problem decomposition – breaking the problem down so that learners can describe the most important components. Algorithms Teachers must ask questions such as *"What tasks can be automated to help us gather and analyse data most efficiently and effectively?"* Automation Data collection and analysis – concept map can be used to generate list of needed information and additional information that is needed.	Data representation can be used to find patterns, identify inter-relationships amongst part of the system, create models and simulations (that learners can use to conduct "what if" scenarios to explore both causes and solutions).
Slide 37	 **PROBLEM-BASED LEARNING – PAT** **including Computational Vocabulary** 37 CT Vocabulary Given the quantity and diversity of data, teachers can facilitate a discussion on ways the data can be obtained and organised. Data abstraction Data analysis and organisation Presenting the information in a form of a booklet/website etc. Data representation Through out the PAT, the teacher should continuously ask learners to reflect on the strategies that they had selected so far and how these strategies can be refined to ensure that they work together efficiently to achieve the most effective results. Problem solving	Data abstraction: Different levels of questioning in phase 1. Data analysis and organisation: Analysing and organising the information from web searches, questionnaires, books etc. into a format that is understandable for the reader. Data representation can be used to find patterns, identify inter-relationships amongst part of the system, create models and simulations (that learners can use to conduct "what if" scenarios to explore both causes and solutions).
Slide 38	 **CLOSING NOTE** 38 By teaching learners computational thinking skills you empower the learners with skills that they need to become effective and confident problem solvers of the feature. It is not a 'quick' process – it will take time and patience. To be an effective 21st century teacher, you must first possess the very same 21st century skills that your **learners are expected to have.** And, in addition to those skills, you must be able to **help your learners to obtain and develop 21st century skills.**	

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APPENDIX A – APPLICATION TO CONDUCT RESEARCH

education
Department of Education
FREE STATE PROVINCE

- Ref no: 16/4/1/ - 2012........

- APPLICATION FORM TO REGISTER RESEARCH PROJECTS IN THE FREE STATE DEPARTMENT OF EDUCATION

- Please complete all the sections of this form that are applicable to you. If any section is not applicable please indicate this by writing N/A.
- If there are too few lines in any of the sections please attach the additional information as an addendum.
- Attach all the required documentation so that your application can be processed.

- Send the application to:

- Director: Strategic Planning, Policy & Research
- Room 319

Old CNA Building Maitland Street BLOEMFONTEIN 9300	**OR**	Free State Department of Education Private Bag X20565 BLOEMFONTEIN 9300.

Tel: 051 - 404 9283/404 9221
Fax: 086 6678 678

1 **Title** (e.g. Mr, Ms, Dr, and Prof):

M	R	S	

2 **Initials and surname**:

C	L		S	C	H	L	E	B	U	S	C	H			

3 **Telephone**: Home:

Work:

0	5	7	-	9	1	0	3	5	7	2	

Cell:

0	8	2	-	2	0	2	2	5	5	1	

Fax:

0	8	6	-	6	9	6	1	6	7	2	

E-Mail

			-	lschlebu@cut.ac.za		

4 **Home Address**:

2	0		G	O	E	D	E	H	O	O	P		C	R	E
J	I	M		F	O	U	C	H	E		P	A	R	K	
W	E	L	K	O	M										
												9	4	6	0

APPENDIX A – APPLICATION TO CONDUCT RESEARCH

5 Postal Address:

B	*O*	*X*		*8*	*5*	*9*									
W	*E*	*L*	*K*	*O*	*M*										
												9	*4*	*6*	*0*

6.1 Name of tertiary institution/research institute

Central University of Technology, Welkom Campus, Welkom.

6.2 Occupation: *Lecturer in Computer Applications Technology*

6.3 Place of employment: *Central University of Technology, Welkom Campus*

7 Name of course: *PhD*

8 Name of supervisor/promoter: *Dr. A Rambuda*
Please attach **a letter from your supervisor** confirming that you have registered for the course you are following.

9 Title of research project: *An exploration of Grades 10 – 12 Computer Applications Technology teachers' problem-solving skills and computational thinking skills in the Free State.*

10 Concise explanation of the research topic:

This research project will explore how Grade 10 - 12 CAT teachers make use of Problem-solving skills and Computational thinking skills to teach CAT learners in the Free State province.

11 Application value that the research may have for the Free State Education Department:

At the end of the researcher will develop a toolkit that can be used by learning facilitators/mentors/in-service trainers to ensure that all CAT teachers can integrate computational thinking and problem solving in the CAT classroom.

12. The full particulars of the group with whom the research is to be undertaken:

Grade 10 – 12 CAT Teachers in the Free State province.

APPENDIX A – APPLICATION TO CONDUCT RESEARCH

12.1 List of schools/Directorates in the Department/Officials:

Randomly selected schools that offer CAT in the Free State province.

12.2Grades:

Grade 10 - 12 CAT teachers

12.3 Age and gender groups:

Not applicable.

12.4 Language groups:

English and Afrikaans speaking Teachers

12.5 Numbers to be involved in the research project:

± 100 teachers

13 Full particulars of how information will be obtained eg questionnaires, interviews, standardized tests. **Please include copies of questionnaires, questions that will be asked during interviews, tests that will be completed or any other relevant documents regarding the acquisition of information**.

Included as an attachment.

14 The **starting and completion dates** of the research project: (Please bear in mind that research is usually not allowed to be conducted in the schools during the fourth term.)

1 st term of 2014 – 15 February 2014 – 15 March 2014

15 Will the research be conducted **during or after school hours**?

Questionnaire that will be filled in after school hours.

16 If it is necessary to use school hours for the research project, **how much time** will be needed?

Not at all.

17 **How much time will be spent on the research project** by individual teachers and/or learners?

± 20 minutes to complete the questionnaire

APPENDIX A – APPLICATION TO CONDUCT RESEARCH

18 Have you included:

18.1 A letter from **your supervisor** confirming your registration for the course you are following? Yes

18.2 A draft of the letter that will be sent **to the principals** requesting permission to conduct research In their schools? Yes

18.3 A draft of the letter that will be sent **to parents** requesting permission for their children to participate in the research project?.(If applicable) NA

18.4 Copies of **questionnaires** that you wish to distribute? Yes

18.5 A list of **questions** that will be asked during the interviews? NA

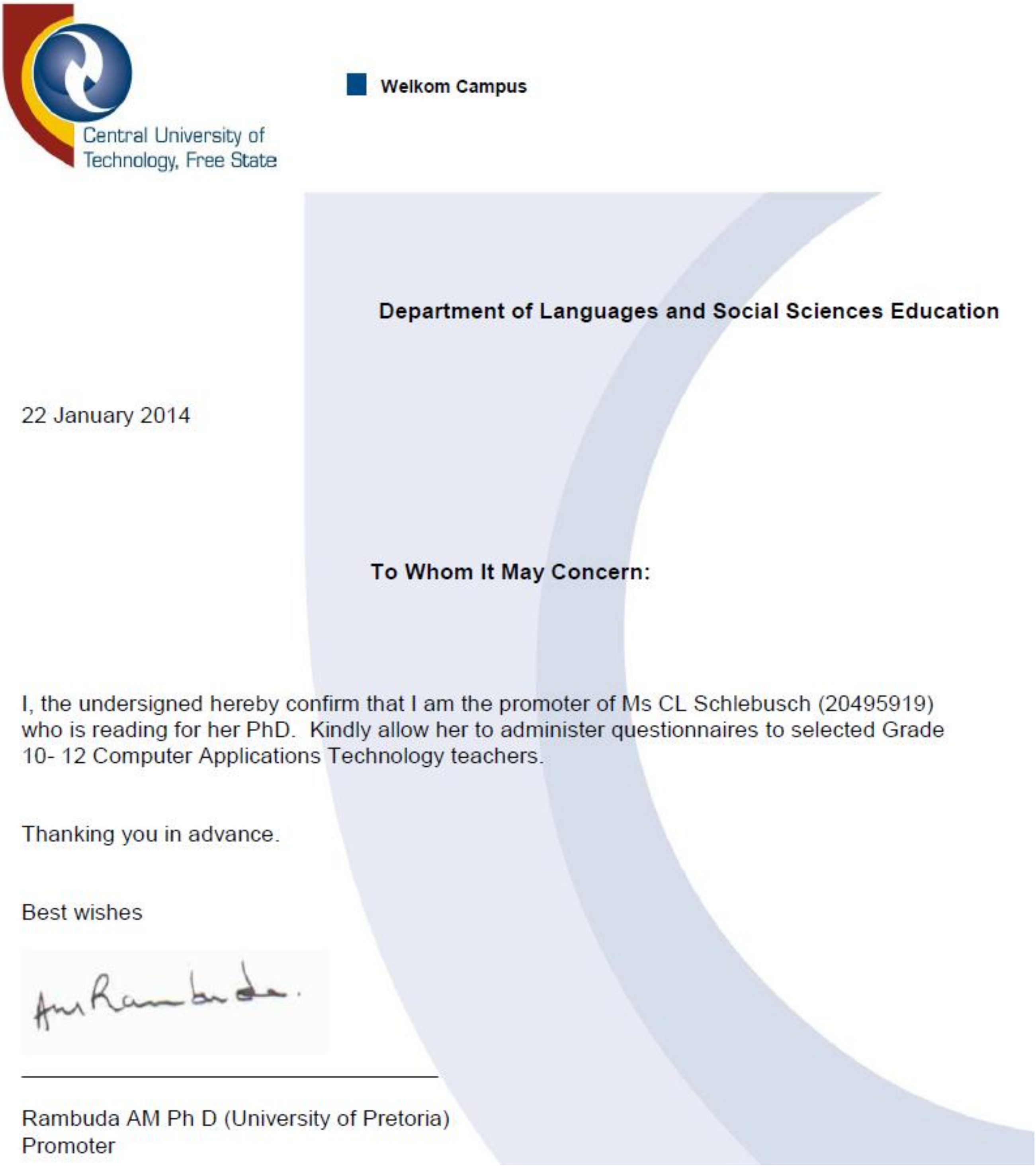
I confirm that all the information given on this form is correct.

Schlebusch

…………………………………… 22 January 2014

SIGNATURE **DATE**

APPENDIX B – LETTER FROM PROMOTOR



Central University of Technology, Free State

Welkom Campus

Department of Languages and Social Sciences Education

22 January 2014

To Whom It May Concern:

I, the undersigned hereby confirm that I am the promoter of Ms CL Schlebusch (20495919) who is reading for her PhD. Kindly allow her to administer questionnaires to selected Grade 10- 12 Computer Applications Technology teachers.

Thanking you in advance.

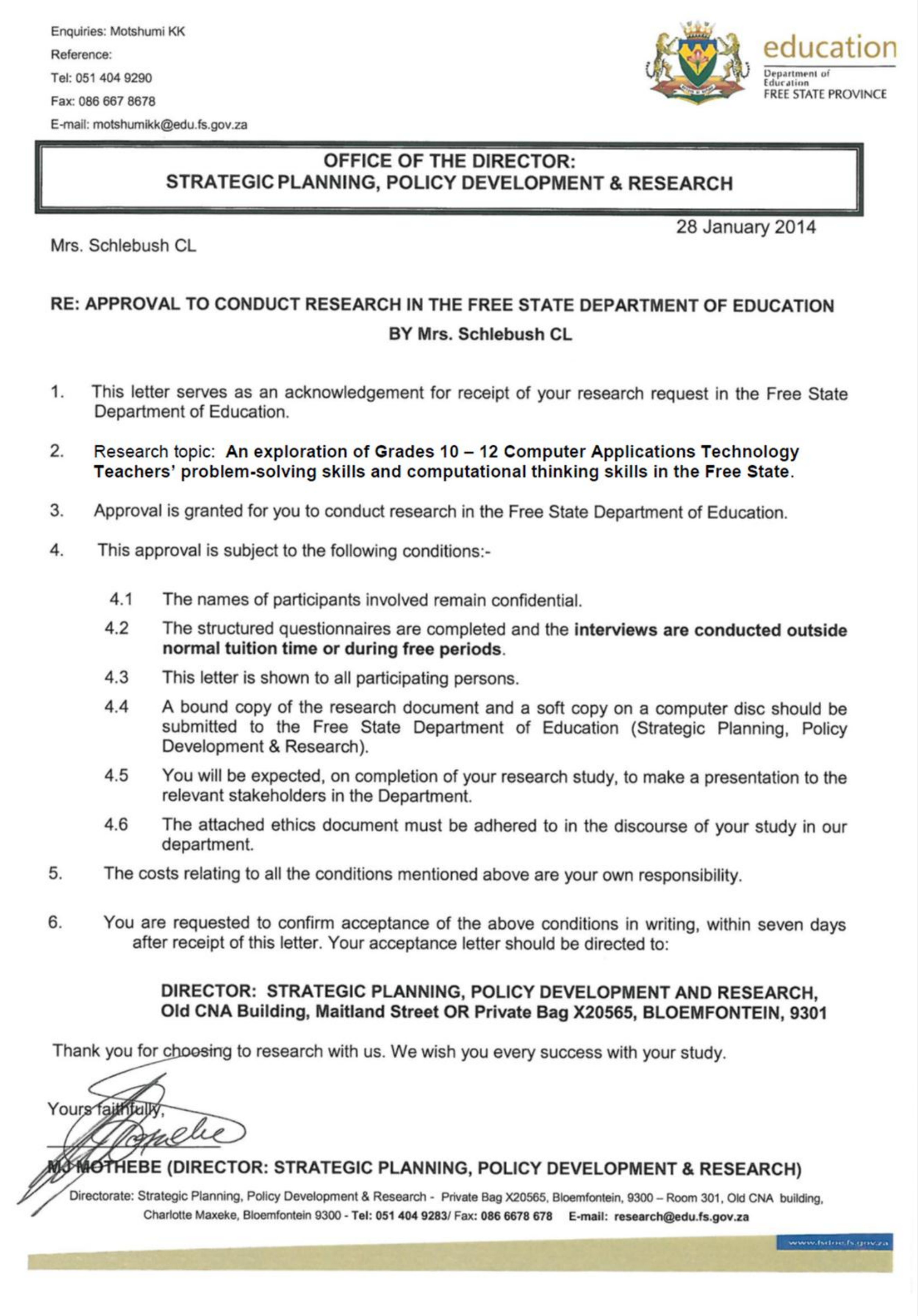
Best wishes

AM Rambuda.

Rambuda AM Ph D (University of Pretoria)
Promoter

Acting Department Manager
Department of Languages and Social Sciences Education
, Welkom • PO Box 1881 • WELKOM • SOUTH AFRICA • 9460 •
Tel: +27 57 910 3607 • **Fax:** 0866192507 • **E-mail:** arambuda@cut.ac.za • **Website:** www.cut.ac.za

APPENDIX C – PERMISSION TO CONDUCT RESEARCH



Enquiries: Motshumi KK
Reference:
Tel: 051 404 9290
Fax: 086 667 8678
E-mail: motshumikk@edu.fs.gov.za

education
Department of Education
FREE STATE PROVINCE

OFFICE OF THE DIRECTOR:
STRATEGIC PLANNING, POLICY DEVELOPMENT & RESEARCH

28 January 2014

Mrs. Schlebush CL

RE: APPROVAL TO CONDUCT RESEARCH IN THE FREE STATE DEPARTMENT OF EDUCATION BY Mrs. Schlebush CL

1. This letter serves as an acknowledgement for receipt of your research request in the Free State Department of Education.
2. Research topic: **An exploration of Grades 10 – 12 Computer Applications Technology Teachers' problem-solving skills and computational thinking skills in the Free State**.
3. Approval is granted for you to conduct research in the Free State Department of Education.
4. This approval is subject to the following conditions:-
    - 4.1 The names of participants involved remain confidential.
    - 4.2 The structured questionnaires are completed and the **interviews are conducted outside normal tuition time or during free periods**.
    - 4.3 This letter is shown to all participating persons.
    - 4.4 A bound copy of the research document and a soft copy on a computer disc should be submitted to the Free State Department of Education (Strategic Planning, Policy Development & Research).
    - 4.5 You will be expected, on completion of your research study, to make a presentation to the relevant stakeholders in the Department.
    - 4.6 The attached ethics document must be adhered to in the discourse of your study in our department.
5. The costs relating to all the conditions mentioned above are your own responsibility.
6. You are requested to confirm acceptance of the above conditions in writing, within seven days after receipt of this letter. Your acceptance letter should be directed to:

DIRECTOR: STRATEGIC PLANNING, POLICY DEVELOPMENT AND RESEARCH,
Old CNA Building, Maitland Street OR Private Bag X20565, BLOEMFONTEIN, 9301

Thank you for choosing to research with us. We wish you every success with your study.

Yours faithfully,

MJ MOTHEBE (DIRECTOR: STRATEGIC PLANNING, POLICY DEVELOPMENT & RESEARCH)

Directorate: Strategic Planning, Policy Development & Research - Private Bag X20565, Bloemfontein, 9300 – Room 301, Old CNA building, Charlotte Maxeke, Bloemfontein 9300 - **Tel: 051 404 9283**/ Fax: **086 6678 678** **E-mail: research@edu.fs.gov.za**

www.fsdoe.fs.gov.za

APPENDIX D – QUESTIONNAIRE

CAT TEACHER QUESTIONNAIRE

CAT TEACHER QUESTIONNAIRE

Please respond by making a cross (manually) or clicking (electronically) over the appropriate shaded block.

PART 1: Personal data

For office use only

1. My education district

Fezile Dabi	1 ☐	Lejweleputswa	2 ☐	Motheo	3 ☐	Thabo Mofutsanyana	4 ☐	Xhariep	5 ☐

☐

2. My gender

Male	1 ☐	Female	2 ☐

☐

3. My CAT qualification

Tertiary	1 ☐	In-service training	2 ☐

☐

4. I have access to a computer at home.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

5. I have access to Internet at home.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

PART 2: Experience in the teaching of CAT

6. My years of teaching experience in CAT.

0 – 2 years	1 ☐	3 – 4 years	2 ☐	5 – 8 years	3 ☐

☐

7. The highest grade that I teach CAT.

Grade 10	1 ☐	Grade 11	2 ☐	Grade 12	3 ☐

☐

8. I find CAT easy to teach.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

PART 3: School details

9. The location of my school. (Choose one only)

Urban	1 ☐	Rural	2 ☐

☐

10. My school supports the upgrade of the computers that are used for teaching CAT. ☐

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

11. My school supports the maintenance of the computers that are used for teaching CAT. ☐

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

PART 4: Problem solving and computational thinking

12. I only use a textbook to teach CAT. ☐

Yes	1 ☐	No	2 ☐

13. Is there a difference in the language of teaching and the home language of the CAT learners? ☐

Yes	1 ☐	No	2 ☐

Answer the following questions to best describe your typical teaching and learning actions in the CAT classroom.

14. When I talk, I "question", I do not "tell". ☐

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

15. I make use of video clips to explain difficult content to my learners (*example*: memory, ROM, RAM etc.) ☐

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

16. My lessons present problems that develop learners' thinking skills. (Learners ask questions, make plans, organise information, and create ideas). ☐

Always	5 ☐	Usually	4 ☑	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

17. I redirect learners' questions in such a way that learners are encouraged to arrive at their own answers. ☐

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

18. I prefer it when it is quiet in my class during practical lessons.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

19. I allow learners to discuss work in class so that they can have a better understanding of the work.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

20. I allow learners to have class discussions in their home language.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

21. If a learner cannot find an answer to a question, I will give the learner the answer.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

22. When I give a problem to my learners to solve, the learners can relate to the problem.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

23. I allow for team work in the CAT classroom.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

24. I make use of concept maps (mind maps) to help learners to master content.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

25. I think that basic computer skills are important in CAT.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

26. I set my own CAT assignments.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

27. I set my own CAT formal assessments.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

28. When I set assignments, I set the assignment according to a specific taxonomy.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

29. I use the following taxonomy when I set assignments.

Bloom's Taxonomy	1 ☐	Bloom's Revised Digital Taxonomy	2 ☐	Other	3 ☐	I do not use a taxonomy	4 ☐

30. When I set formal assessments, I set the assessments according to a specific taxonomy.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

31. I use the following taxonomy when I set formal assessments.

Bloom's Taxonomy	1 ☐	Bloom's Revised Digital Taxonomy	2 ☐	Other	3 ☐	I do not use a taxonomy	4 ☐

32. I use the Internet in my class to actively engage learners in the learning process.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

33. When teaching the learners how to do an Internet search, I only use Google as a search engine.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

34. I use different search engines when I teach.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

35. When learners do activities (exercises) in class, I consider that as problem solving.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

36. I use algorithms (steps/procedures) when I teach.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

37. I think that the following are examples of different algorithms (procedures):
(*Tick all that are appropriate.)*

		YES		NO	
37.1	The recipe to bake a cake.	☐	1	☐	2
37.2	To save a document.	☐	1	☐	2
37.3	To create a mail merged letter.	☐	1	☐	2
37.4	To find the maximum in a range.	☐	1	☐	2

38. I give the learners pre-constructed spreadsheets and expect them to follow the instructions and do calculations as required by instructions.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

39. When I teach a spreadsheet application, such as MS Excel 2010 or 2013, I give the learners the opportunity to create their own spreadsheets from scratch.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

40. I give the learners a “story problem” and they have to construct (design) a spreadsheet from the given information.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

41. When I teach a database application such as MS Access 2010 or 2013 my learners work with pre-created databases.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

42. When I teach a database application, such as MS Access 2010 or 2013, I give the learners the opportunity to create their own database from scratch.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

43. I make use of presentation tools during my lessons to assist the learners in creating a mental picture of the content.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

44. I have electronic resources such as a whiteboard in my class.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

45. My learners have Internet access in the CAT classroom.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

46. My learners have access to electronic mail in the CAT classroom.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

47. I think that the majority of learners in my CAT classroom are competent problem solvers.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

48. I think that the majority of learners in my CAT classroom have computational thinking skills.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

49. I think that the PAT adds educational value to the CAT learners.

Yes	1 ☐	No	2 ☐

☐

50. I allow enough time in class for my learners to do the PAT thoroughly.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

51. I think that the learners develop their problems solving skills by doing the PAT.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

52. I think that the learners actually learn by doing the PAT.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

53. I think my learners understand the reason behind doing the PAT.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☑	Seldom	2 ☐	Never	1 ☐

☐

54. I think my learners enjoy doing the PAT.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

55. I make use of open-ended questions/problems that can be solved in different ways.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

56. I phrase my questions in such a way as to encourage critical thinking skills in my CAT learners.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

57. I only teach with the emphasis on assessment.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

58. If a learner cannot find an answer to a question, I ask more questions.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

☐

A CAT activity can either be an exercise (to master content) or a problem that my learners can solve (to foster critical thinking). I think that the following statements (items 59 – 64) could be linked to either a problem or/and exercise. (Tick the appropriate box.)

		EXERCISE		PROBLEM	
59.	Communication skills are necessary.	☐	1	☐	2
60.	Learner can only follow one approach.	☐	1	☐	2
61.	The learner has not encountered this situation before.	☐	1	☐	2
62.	The situation is well defined.	☐	1	☐	2
63.	Assumptions need to be made.	☐	1	☐	2
64.	The algorithm is clear.	☐	1	☐	2

65. I can cover the curriculum with the teaching time that I have.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

66. I have enough teaching time to provide learners with a deeper learning of theory (*example*: Clear understanding of what RAM and ROM is.).

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

67. I have enough teaching time to provide learners with a deeper understanding of practical work (*example*: IF-function, nested functions, forms, integration etc.).

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

68. I do allow learners to help one another with practical problems that they may experience in Word or Excel.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

69. If a learner does not know what to do (for example which function to use in Excel) I will tell the learner which function to use.

Always	5 ☐	Usually	4 ☐	About half the time	3 ☐	Seldom	2 ☐	Never	1 ☐

70. I have attended a workshop on problem solving.

Yes	1 ☐	No	2 ☐

71. I have attended a workshop on computational thinking.

Yes	1 ☐	No	2 ☐

APPENDIX E – LETTER TO CAT TEACHERS

Central University of Technology, Free State

FACULTY OF HUMANITIES

10 YEARS AS A UNIVERSITY OF TECHNOLOGY

RESEARCH TO EXPLORE THE PROBLEM-SOLVING SKILLS AND COMPUTATIONAL THINKING SKILLS

Dear CAT teacher

I am a PHD student at the Central University of Technology, Free State (Welkom Campus). I am involved in a project which is attempting to explore the problem solving and computational skills of Grade 10 - 12 CAT teachers in the Free State province. As such the project will provide useful information which could be of a supportive nature to CAT teachers in general.

Attached in a questionnaire which attempts to gain information on the problem-solving skills and computational thinking skills.

I have received permission to undertake the study from the Free State Department of Education Department. I will be grateful if you could be of assistance with the research by giving the enclosed questionnaires to the Grade 10 – 12 CAT teachers at your cluster meeting.

Kindly answer by making a cross over the appropriate shaded block.

For example: My gender

Male	1	Female	[✓ 2]

Completion of the questionnaires should not take longer than 20 minutes. The name of the school and teachers involved will remain anonymous. The completion of the questionnaire is not compulsory. I will collect the questionnaires on Thursday, 20 March 2014.

Obviously the success of the research will largely be dependent on the number of questionnaires that are returned. Your assistance in this regard will be greatly appreciated.

Yours sincerely

Ms CL Schlebusch

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Tel: +27 057 910 3574 • **Fax:** +27 86 696 1672 • **E-mail:** lschlebu@cut.ac.za • **Cell: 082 2022 551**

APPENDIX F – LIST OF INTERVIEW QUESTIONS

Short interview questions with CAT teachers

- What problem-solving activities do you give to your learners to do in CAT?

- What computational thinking skills are developed by the problem-solving activities that you give to your learners?

- Why do some teachers only teach application without the paradigm of computational thinking and not within the framework of problem solving?

- How best would you integrate computational thinking with teaching CAT concepts?

- In your opinion, what are the effective ways of teaching computational thinking to learners?

APPENDIX G – LIST OF SCHOOLS OFFERING CAT IN THE FREE STATE PROVINCE

Number	District	School Name
1	Fezile Dabi	AFRIKAANSE HSKOOL KROONSTAD
2	Fezile Dabi	AFRIKAANSE HSKOOL SASOLBURG
3	Fezile Dabi	BARNARD MOLOKOANE SS
4	Fezile Dabi	BODIBENG SS
5	Fezile Dabi	BOITLAMO SS
6	Fezile Dabi	BRENTPARK CS
7	Fezile Dabi	DR REGINALD CINGO CSS
8	Fezile Dabi	EENDRACHT VOLKSKOOL
9	Fezile Dabi	FALESIZWE SS
10	Fezile Dabi	HEILBRON CS
11	Fezile Dabi	HTS SASOLBURG
12	Fezile Dabi	IKETSETSENG CSS
13	Fezile Dabi	KANANELO SS
14	Fezile Dabi	KROONSTAD CSS
15	Fezile Dabi	MATLWANGTLWANG SS
16	Fezile Dabi	MFUNDO THUTO SS
17	Fezile Dabi	MOTSWELA SS
18	Fezile Dabi	NAMPO ASS
19	Fezile Dabi	NGWATHE SS
20	Fezile Dabi	NKGOPOLENG SS
21	Fezile Dabi	PARYS SKOOL SS
22	Fezile Dabi	PELE-YA-PELE SS
23	Fezile Dabi	PHEHELLANG SS
24	Fezile Dabi	PHIRITONA SS
25	Fezile Dabi	RETSHEDISITSWE SS
26	Fezile Dabi	SALOMON SENEKAL CS
27	Fezile Dabi	SAMUEL SEBEGO PAKI SS
28	Fezile Dabi	SAREL CILLIERS CS
29	Fezile Dabi	SASOLBURG SS
30	Fezile Dabi	SEDIBA-THUTO SS
31	Fezile Dabi	STEYNSRUS CS
32	Fezile Dabi	TSEBO-ULWAZI SS
33	Fezile Dabi	TWEELING CS
34	Fezile Dabi	VAAL CHRISTIAN CI/S
35	Fezile Dabi	VAALPARK SS
36	Fezile Dabi	VILLIERS CS
37	Fezile Dabi	WEIVELD ASS
38	Fezile Dabi	WILGERIVIER CS
39	Fezile Dabi	YAKHISISWE SS
40	Lejweleputswa	BAHALE SS
41	Lejweleputswa	BOSHOF CS
42	Lejweleputswa	BOTHAVILLE SS
43	Lejweleputswa	BULTFONTEIN CS

APPENDIX G – LIST OF SCHOOLS OFFERING CAT IN THE FREE STATE PROVINCE

44	Lejweleputswa	CONCORDIA SS
45	Lejweleputswa	DUNAMIS CHRISTIAN SCHOOL
46	Lejweleputswa	EDMUND RICE SCHOOL
47	Lejweleputswa	ED-U-COLLEGE WELKOM CI/S
48	Lejweleputswa	ELDORET SS
49	Lejweleputswa	GOUDVELD SS
50	Lejweleputswa	HARMONIE SS
51	Lejweleputswa	HENNENMAN SS
52	Lejweleputswa	HENTIE CILLIERS HS
53	Lejweleputswa	HOOPSTAD CS
54	Lejweleputswa	HTS WELKOM
55	Lejweleputswa	KAGISANO CS
56	Lejweleputswa	KHELENG SS
57	Lejweleputswa	KUTLOANONG SS
58	Lejweleputswa	LEBOGANG SS
59	Lejweleputswa	LEKGARIETSE
60	Lejweleputswa	LENAKENG TS
61	Lejweleputswa	LESEDING TS
62	Lejweleputswa	MAMELLO SS
63	Lejweleputswa	MAREMATLOU SS
64	Lejweleputswa	MOPHATE SS
65	Lejweleputswa	PHEHELLO SS
66	Lejweleputswa	REATLEHILE SS
67	Lejweleputswa	RIEBEECKSTAD SS
68	Lejweleputswa	SANDVELD CS
69	Lejweleputswa	SENZILE CS
70	Lejweleputswa	STAATSPRES. SWART CS
71	Lejweleputswa	TAIWE SS
72	Lejweleputswa	THEUNISSEN CS
73	Lejweleputswa	THOTAGAUTA SS
74	Lejweleputswa	TIKWANE CSS
75	Lejweleputswa	UNITAS CSS
76	Lejweleputswa	WELKOM HIGH SS
77	Lejweleputswa	WELKOM SS
78	Lejweleputswa	WELKOM-GIMNASIUM SS
79	Lejweleputswa	WESSEL MAREE SS
80	Lejweleputswa	WINBURG CS
81	Motheo	ACADEMY OF EXCELLENCE CI/S
82	Motheo	ACCELERATED CHRISTIAN COLLEGE SI/S
83	Motheo	ALBERT MOROKA SS
84	Motheo	ATLEHANG SS
85	Motheo	BARTIMEA SCHOOL FOR THE DEAF AND BLIND
86	Motheo	BLOEMFONTEIN SOUTH HIGH SS
87	Motheo	BLOEMFONTEIN SS

APPENDIX G – LIST OF SCHOOLS OFFERING CAT IN THE FREE STATE PROVINCE

88	Motheo	C EN N H MEISIESKOOL ORANJE
89	Motheo	CALCULUS BLOEMFONTEIN SI/S
90	Motheo	CASTLEBRIDGE CI/S
91	Motheo	CHRISTIAAN DE WET CS
92	Motheo	COMMTECH CSS
93	Motheo	CURRO BLOEMFONTEIN INDEPENDENT SCHOO
94	Motheo	DANKBAAR CVO SCHOOL
95	Motheo	DR VILJOEN CS
96	Motheo	DR. BLOK SS
97	Motheo	EUNICE SS
98	Motheo	EXCELSIOR CVO SCHOOL
99	Motheo	FICHARDTPARK SS
100	Motheo	GREY-KOLLEGE SS
101	Motheo	HEATHERDALE CSS
102	Motheo	HTS LOUIS BOTHA
103	Motheo	IKAELELO SS
104	Motheo	JIM FOUCHE SS
105	Motheo	KAELANG SS
106	Motheo	KGAUHO SS
107	Motheo	KYRIOS INDEPENDANT SCHOOL
108	Motheo	LADYBRAND ACADEMY
109	Motheo	LADYBRAND SS
110	Motheo	LEKHULONG SS
111	Motheo	LENYORA LA THUTO CSS
112	Motheo	LERATONG SS
113	Motheo	LEREKO SS
114	Motheo	LOUW WEPENER CS
115	Motheo	MARTIE DU PLESSIS HS
116	Motheo	MOEMEDI SS
117	Motheo	NAVALSIG CSS
118	Motheo	PETUNIA SS
119	Motheo	POPANO SS
120	Motheo	PRESIDENT STEYN CS
121	Motheo	REAMOHETSE SS
122	Motheo	ROSENHOF HIGH SCHOOL
123	Motheo	SAND DU PLESSIS SS
124	Motheo	SEEMAHALE SS
125	Motheo	SEHUNELO SS
126	Motheo	SENTRAAL SS
127	Motheo	SHANNON INTERMEDIATE SCHOOL
128	Motheo	ST ANDREW`S CS
129	Motheo	ST BERNARDS SS
130	Motheo	ST MICHAEL`S CS
131	Motheo	TSOSELETSO SS

APPENDIX G – LIST OF SCHOOLS OFFERING CAT IN THE FREE STATE PROVINCE

132	Motheo	VULAMASANGO SS
133	Thabo Mofutsanyana	BEACON SS
134	Thabo Mofutsanyana	BETHLEHEM CSS
135	Thabo Mofutsanyana	BETHLEHEM CVO SCHOOL
136	Thabo Mofutsanyana	DIKWENA SS
137	Thabo Mofutsanyana	DINARE SS
138	Thabo Mofutsanyana	DIRKIE UYS CS
139	Thabo Mofutsanyana	ED-U-COLLEGE QQ SI/S
140	Thabo Mofutsanyana	FICKSBURG CSS
141	Thabo Mofutsanyana	HARRISMITH HOeRSKOOL SS
142	Thabo Mofutsanyana	IKAHENG ZAKHENI SS
143	Thabo Mofutsanyana	IPHONDLE SS
144	Thabo Mofutsanyana	ITHABISENG SS
145	Thabo Mofutsanyana	KGOLATHUTO SS
146	Thabo Mofutsanyana	KGOTSO-UXOLO SS
147	Thabo Mofutsanyana	KOALI SS
148	Thabo Mofutsanyana	KWETLISONG SS
149	Thabo Mofutsanyana	LEKGULO SS
150	Thabo Mofutsanyana	LERATO UTHANDO CSS
151	Thabo Mofutsanyana	LINDLEY CS
152	Thabo Mofutsanyana	MAANANKOE SS
153	Thabo Mofutsanyana	MAKABELANE CSS
154	Thabo Mofutsanyana	MAKGABANE SS
155	Thabo Mofutsanyana	MANTHATISI SS
156	Thabo Mofutsanyana	MARALLANENG SS
157	Thabo Mofutsanyana	MARQUARD CS
158	Thabo Mofutsanyana	MOSIUOA LEKOTA SS
159	Thabo Mofutsanyana	NEW HORIZON COLLEGE SI/S
160	Thabo Mofutsanyana	NKARABENG SS
161	Thabo Mofutsanyana	NKHOBISO SS
162	Thabo Mofutsanyana	NTHABISENG SS
163	Thabo Mofutsanyana	NTSU SS
164	Thabo Mofutsanyana	PAUL ERASMUS SS
165	Thabo Mofutsanyana	PHUKALLA SS
166	Thabo Mofutsanyana	REITZ CS
167	Thabo Mofutsanyana	RETIEF CS
168	Thabo Mofutsanyana	SASAMALA SS
169	Thabo Mofutsanyana	SEKGUTLONG SS
170	Thabo Mofutsanyana	SEOTLONG ASS
171	Thabo Mofutsanyana	TAUNG SS
172	Thabo Mofutsanyana	THAHAMESO SS
173	Thabo Mofutsanyana	THIBOLOHA SCHOOL FOR DEAF AND BLIND
174	Thabo Mofutsanyana	TLHORONG SS
175	Thabo Mofutsanyana	TSHIBOLLO SS

APPENDIX G – LIST OF SCHOOLS OFFERING CAT IN THE FREE STATE PROVINCE

176	Thabo Mofutsanyana	VOORTREKKER SS
177	Thabo Mofutsanyana	VREDE CS
178	Thabo Mofutsanyana	WITTEBERG SS
179	Xhariep	AJC JOOSTE CS
180	Xhariep	EDENBURG (REITZ-STEYNSTR) CS
181	Xhariep	HENDRIK POTGIETER AS
182	Xhariep	JACOBSDAL LANDBOUSKOOL
183	Xhariep	KOFFIEFONTEIN CS
184	Xhariep	LERE LA THUTO SS
185	Xhariep	PELLISSIER CS
186	Xhariep	SPRINGFONTEIN SS
187	Xhariep	THABO-VUYO SS
188	Xhariep	ZASTRON CS