INVESTIGATING THE EFFECT OF IMPLEMENTING A CONTEXT-BASED PROBLEM
SOLVING INSTRUCTION ON LEARNERS' PERFORMANCE

by

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Declaration

I declare that the project "*Investigating the effect of implementing a context-based problem solving instruction on learners' performance*" is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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   MR JJ DHLAMINI   DATE

Dedication

To

my wife Lillian

and our three sons

Musa, Andile and Banele

Acknowledgements

It would not have been possible to complete my PhD thesis without the support of the people around me, to only some of whom it is possible to give particular mention here.

Special thanks to my wife, Lillian. I cannot thank you enough for what you have done to me. You are really a partner in love and it is to you that this work is dedicated.

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Abstract

The aim of this study was to investigate the effect of context-based problem solving instruction (CBPSI) on the problem solving performance of Grade 10 learners, who performed poorly in mathematics. A cognitive load theory (CLT) was used to frame the study. In addition, CLT was used to: 1) facilitate the interpretation and explanation of participants' problem solving performance; and, 2) influence the design of CBPSI to hone participants' problem solving skills. The study was conducted in the Gauteng province of South Africa and involved a two-week intervention program in each of the nine participating high schools. Participants consisted of 783 learners and four Grade 10 mathematics teachers.

A non-equivalent control group design was employed, consisting of a pre- and post- measure. In addition, classroom observations and semi-structured interviews were conducted with teachers and learners. Teachers employed conventional problem solving instructions in four control schools while the researcher implemented CBPSI in five experimental schools. Instruction in experimental schools entailed several worked-out context-based problem solving examples given to participants in worksheets. The main aspects of CBPSI embraced elements of the effects of self-explanation and split-attention, as advocated by CLT. Due to the design of CBPSI participants in experimental schools became familiar with the basic context-based problem solving tasks that were presented to them through the worked-out example samples. In turn, the associated cognitive load of problem solving tasks was gradually reduced.

The principal instrument for data collection was a standardized Functional Mathematics Achievement Test. The pre-test determined participants' initial problem solving status before intervention. A post-test was given at the end of intervention to benchmark change in the functionality of CBPSI over a two-week period. Using one-way analysis of covariance (ANCOVA), Analysis of Variance (ANOVA), and other statistical techniques the study found that participants in experimental schools performed significantly better than participants in control schools on certain aspects of problem solving performance. In addition, semi-structured interviews and classroom observations revealed that participants rated CBPSI highly. On the whole, the study showed that CBPSI is an effective instructional tool to enhance the problem solving performance of Grade 10 mathematics learners.

Key terms

Problem solving skills

Real-life context

Context-based problem solving instruction

Conventional problem solving instruction

Disadvantaged socioeconomic background

Cognitive load theory

Human cognitive architecture

Worked-out examples

Self-explanation

Split-attention

Abbreviations

ACE	Advanced Certificate in Education
ANA	Annual National Assessment
ANCOVA	Analysis of covariance
ANOVA	Analysis of Variance
APA	American Psychological Association
C2005	Curriculum 2005
CAPS	Curriculum and Assessment Policy Statement
CBPSI	Context-based problem solving instruction
CLT	Cognitive Load Theory
CPSI	Conventional problem solving instruction
DBE	Department of Basic Education
DEC	Department of Education and Culture
DET	Department of Education and Training
DNE	Department of National Education
DoE	Department of Education
EIA	Evaluation of International Achievement
FDE	Further Diploma in Education
GDE	Gauteng Department of Education
H_0	Null hypothesis
H_1	Alternative hypothesis
HoA	House of Assembly
HoD	House of Delegates
HoR	House of Representatives
LO	Learning Outcome
LTSM	Learning and teaching support materials
MEC	Member of Executive Council
MPSAT	Mathematical Problem Solving Achievement Test
NCS	National Curriculum Statement
NP	National Party

OBE	Outcomes-Based Education
SACMEQ	Southern and Eastern Africa Consortium for Monitoring Educational Quality
SAIRR	South African Institute of Race Relations
SES	socioeconomic status
SSIP	Senior Secondary Improvement Programme
TIMSS	Trends in International Mathematics and Science Study
TIMSS-R	TIMSS-Repeat

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CHAPTER ONE

THEORETICAL BACKGROUND AND ORIENTATION OF THE PROBLEM STATEMENT

1.1 OVERVIEW OF THE STUDY

In schools, homes, workplaces and societies of every culture, learning is always driven by the desire to solve problems (Jonassen, 2000). The purpose of this study was to explore the use of a context-based problem solving instruction to develop the problem solving skills of high school learners of mathematics. *Context-based problem solving instruction* (CBPSI) refers to a teaching approach in which everyday problem solving knowledge and practices are uncovered when learners are exposed to tasks that give meaning to their everyday experiences (Dhlamini, 2011, p. 135). Activities situated within the real-life context of Financial Mathematics constituted a major component of this form of instruction in the study. Participants consisted of Grade 10 learners from a disadvantaged township[1] background who were performing poorly in mathematics problem solving (see section 6.2.7.1, section 7.5.3.7 & Figure 6.6). "Disadvantaged", in this study, is synonymous with "black[2]" - conflating race, class, language difference, cultural difference, educational difference and poverty (Tsanwani, 2009).

The experiment was conducted in the Gauteng[3] province of South Africa, and involved nine high schools located within disadvantaged communities. Therefore, schools that participated in the present study were also disadvantaged. Schools may be disadvantaged as a result of inadequate learning and teaching resources, poorly qualified teachers and large classes. A two-week intervention programme aimed at implementing CBPSI was administered. Given that problem solving is a cognitive activity (section 3.1), the current study employed cognitive load theory

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[1] A township is an area in South Africa normally occupied by persons of non-European descent, especially blacks (Probyn, 2009).

[2] In South Africa, it is standard practice to categorize someone by the color of their skin, as black, white and colored (Deaton, 1999). In this study, the term "black" is used to refer mainly to learners in disadvantaged township schools, and also to represent township communities.

[3] Gauteng is one of the nine provinces of South Africa.

(Dhlamini & Mogari, 2011; Sweller, 1988) to account for the observed problem solving behaviour and performance during context-based problem solving tasks.

1.2 AIM AND OBJECTIVES OF THE STUDY

The aim of this study was to investigate the effect of CBPSI on the problem solving performance of Grade 10 learners, who performed poorly in mathematics problem solving (Dhlamini, 2011). In order to achieve this aim, the following objectives were identified:

1. To find evidence of disparities in the mathematics problem solving performance between learners from a disadvantaged socioeconomic background and those from affluent socioeconomic backgrounds;
2. To use cognitive load theory (CLT) (Sweller, 1988) as a tool to understand and explain learners' problem solving performance in mathematics;
3. To use CLT to design a context-based problem solving instruction to enhance the problem solving performance of learners from disadvantaged schools;
4. To compare context-based problem solving instruction with conventional instruction[4] when common context-based problem solving tasks are tackled in class;
5. To investigate participants' views and opinions on implementation of context-based problem solving instruction; and,
6. To quantitatively evaluate the impact of context-based problem solving instruction on learners' problem solving performance.

Whereas objectives 1, 2, 3 and 6 target performance, it is equally important to establish participants' views towards the instructional approaches that were used in both groups during intervention.

1.3 CONTEXTUAL BACKGROUND TO THE PROBLEM

In the seventeenth century, South Africa was colonised by the English and the Dutch (Beinart, 2001). Later on, the Dutch chose to establish the new colonies of the Orange Free State and the Transvaal. The discovery of diamonds in these provinces (around 1900) resulted in an English

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[4] See section 1.9.4 for an explanation of conventional instruction as it applies to this study.

invasion and the Boer War (Beinart, 2001). Following independence from Great Britain, the two groups settled for an uneasy power sharing form of government. However, in 1948 the Afrikaner-dominated National Party (NP) won control of the South African parliament. With this victory, the NP government immediately imposed race-conscious laws, with black citizens becoming the primary victims (Beinart, 2001). For instance, the black population had no representation in parliament (Gaigher, 2006). Education, medical care, and other public services were all segregated, thus subjecting black people to services that were inferior to those enjoyed by their white counterparts (Beinart, 2001).

Despite the fact that blacks constituted the majority of the population, the oppressive government advocated a policy of preferential treatment for whites. This is illustrated by Table 1.1 reflecting the disproportionate treatment of blacks and whites in South Africa published in Macrae (1994) in 1978. In particular, the teacher-learner ratio should be noted, as it differed significantly between black and white schools.

Table 1.1: Disproportionate treatment of blacks and whites in South Africa in 1978[5]

Apartheid and people of South Africa		
	Blacks	**Whites**
Population	19 million	4.5 million
Land allocation	13 %	87 %
Share of national income	< 20 %	75 %
Ratio of average earnings	1	14
Minimum of taxable income	360 Rands	750 Rands
Doctors per population	1 per 44 000	1 per 400
Infant mortality rate	20 % (urban)	2.7 %
	40% (rural)	
Annual expenditure on education per learner	45 Dollas	696 Dollas
Teacher-learner ratio	1:60	1:22

Source: Macrae (1994)

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[5] In 1978, the value of the South African rand compared to the US dollar was US$0.87= SA R1.00 (South African Rand Rate Forecast, 2011).

Apart from other socioeconomic variables listed in Table 1.1, education became the strongest weapon used by the NP government to suppress the black community. The unacceptable teacher-learner ratio of 1:60 in township schools signaled serious challenges facing teachers in producing relatively good results in subjects they taught. In addition, different education departments for different races were introduced by the NP government. In order for these departments to manage and implement the assigned curriculum, the government used the philosophy and rules of the Education Affairs Act of 1984 (Macrae, 1994), though this came with many administrative challenges (see Figure 1.1).

Figure 1.1: The education structure of South Africa during the era of NP government
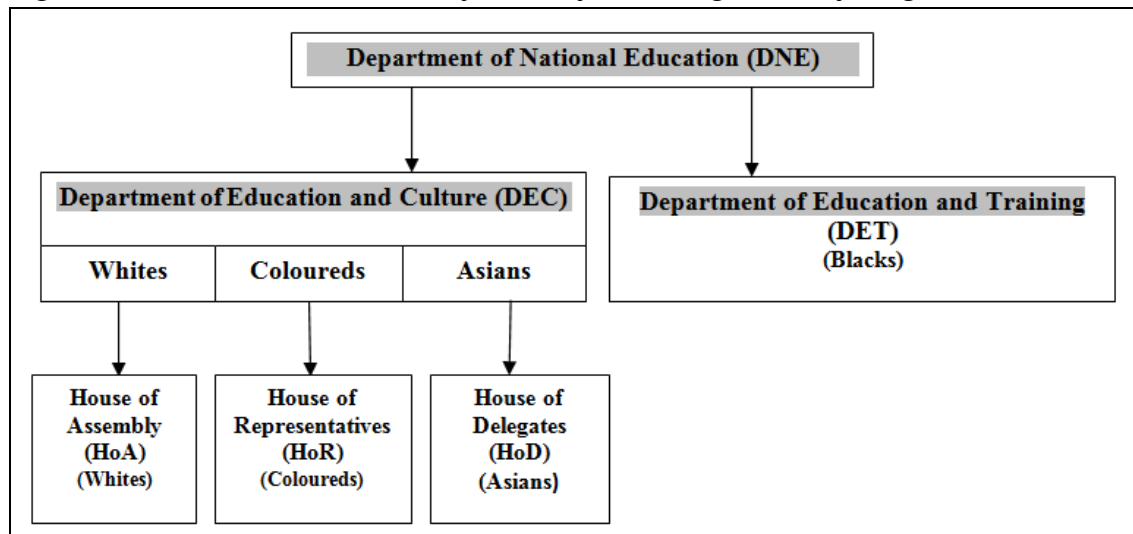
Source: Macrae (1994, p. 272)

This controversial model of separate education systems for different races clearly endorsed the government's intentions to impose inferior education on blacks. As shown in Figure 1.1, education for blacks was separated from other races: resources were not distributed equally among the different education departments, with township schools receiving the worst treatment. Consequently, the Department of Education and Training (DET), which catered for black schools, always performed poorly when compared to those departments that catered for the education of other races (Macrae, 1994). To date, learner performance in subjects such as

mathematics and science is still linked to the department of education to which a school belonged during the NP government (Baloyi, 2011; Reddy, 2007).

These observations are confirmed by the mathematics performance of Grade 8 South African learners in the Trends in International Mathematics and Science Study (TIMSS[6]) in 2003. Table 1.2 provides the average mathematics scale scores (SE) for schools from the ex-racial departments.

Table 1.2: Average mathematics scale scores of learners from different school types

Names of schools per former Department	Average mathematics scale score (SE)
ex-DET (Department of Education and Training) schools	227(2.9)
ex-HoR (House of Representatives) schools	314(8.6)
ex-HoD (House of Delegates) schools	366(24.9)
ex-HoA (House of Assembly) schools	468(20.3)
National average	264(5.5)
International average	467(0.5)

Source: *Adapted from Reddy (2007)*

The statistics provided in Table 1.2 reveal persistent learner performance variations between former white and historically black schools, despite huge investments and massive education policy changes since 1994[7] (Baloyi, 2011). The data in Table 1.2 reveals that learners from ex-House of Assembly (HoA) schools had an average mathematics score that was higher than the international average. On the other hand, learners from ex-DET schools scored lower than the national average: these learners scored more than 50% below the ex-HoA and the international average. Given this background, it is clear that these variations in performance in mathematics

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[6]TIMSS is a project run by the International Association for the Evaluation of International Achievement (EIA). EIA has been conducting cross-national research studies since 1959. The Human Sciences Research Council (HSRC) coordinates and manages the South African portion of the study (Reddy, 2007).

[7] In 1994, South African citizens elected a democratic government of National Unity. After these all-inclusive elections, attempts were made to improve the quality of mathematics instruction and learner performance, particularly in black township schools (Nkhoma, 2002; see also the later discussion in section 1.3).

across schools from different socioeconomic backgrounds are cause for serious concern if equity in education in South Africa is to be achieved.

Before the 2003 TIMSS results were released, South Africa had participated in TIMSS 1995 and 1999 (TIMSS-Repeat or TIMSS-R). Generally, the earlier studies had demonstrated poor performance by South African learners in mathematical and problem solving skills in comparison to other participating countries (Atagana *et al*., 2010; Howie, 2001, 2006; Reddy, 2006). For instance, in the 1995 TIMSS study, Grade 8 South African mathematics learners participated alongside 41 countries and earned a disappointing last position, with a mean score of 351 points out of a possible 800 points (Howie, 2001). This mean was significantly lower than the international benchmark of 513 (Howie, 2001; Mji & Makgato, 2006).

This dismal performance by South African Grade 8 learners in mathematics was repeated in the TIMSS-R 1999. In the TIMSS-R 1999 South African learners scored a mean of 275 in mathematics which compared unfavorably against the international mean of 487. This mean was lower than that of Morocco, Tunisia and other developing countries, such as Chile, Indonesia, Malaysia and the Philippines (Howie, 2001; Mji & Makgato, 2006). Results from TIMSS 2003 showed no improvement. Of the six African countries that participated, South Africa came last. Egypt, Botswana and Ghana made their debut in 2003, but outperformed South Africa, which had participated in previous studies (Reddy, 2006).

It is evident from these results that there are serious problems in mathematics instruction in South Africa. However, it seems these learning problems are more serious in disadvantaged schools, which are mostly located in township environments (Dhlamini, 2011; Dhlamini & Mogari, 2011). Poor performance in mathematics in these schools has been linked to poor training of teachers, most of whom are black. According to Gaigher (2006), "in 1988, only 13.5% of the black teachers in secondary schools had a degree, and almost 40% had no qualifications to teach in secondary schools" (p. 2).

Many black teachers depended on the security of a single textbook and notes that were to be summarised (Gerard, 2011). As a result, for many decades learners from township schools

suffered in the fields of mathematics, science and engineering (Gerard, 2011; Van der Berg, 2007). Macrae (1994, p. 271) has noted that "86% of the population, that is the black population, is seriously under-performing in mathematics". In 1990 the failure rate in mathematics among black learners at the matriculation[8] level was considerably higher than the national average (Macrae, 1994). For instance, of the 17 877 black learners who sat the 1990 mathematics matriculation examination, 15 920 (89%) failed (Maree, Aldous, Hattingh, Swanepoel & Van der Linde, 2006; Tsanwani, 2009; Van der Berg, 2007; Van der Berg & Louw, 2006).

With the election of a democratic government in 1994, attempts were made to improve the quality of mathematics instruction, particularly in black township schools (Nkhoma, 2002). However, little progress has been made thus far. In 2000, the Southern African Consortium for Monitoring Education Quality (SACMEQ) conducted an evaluation of Grade 6 mathematics and reading ability in 14 countries. Results showed that South Africa fell into the bottom half of the group (see Table 1.3) and that the difference in scores between socioeconomic classes was almost 100 points in both categories (Gerard, 2011).

Despite a national political mandate and educational efforts to address the problem, learners' performance in mathematics continues to be a subject of serious concern in South Africa. Recently, Maths Excellence (2009, p. 1) reported, "the World Economic Forum ranked South Africa 120th for mathematics and science education, well behind our troubled neighbour Zimbabwe (ranked 71st)". There is clearly an urgent need to address the problem of mathematics performance in South Africa.

More recently, in February 2011, more than six million Grade 3 and Grade 6 learners throughout South Africa wrote the Annual National Assessment (ANA) tests in literacy, numeracy, language and mathematics (Department of Basic Education [DBE], 2011a). The national average performance in mathematics in Grade 6 was 30% (DBE, 2011a). According to DBE (2011a, p. 20), "only 12% of Grade 6 learners scored 50% or more for mathematics in ANA in 2011".

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[8]A standard examination in South Africa is written only at the end of Grade 12; this is also known as the matriculation examination. The Grade 12 examination results are used as an indicator of South African learners' performance at school level.

Among Grade 3 learners: "only 17% scored more than 50% in their numeracy assessment; and the national average was 28%" (DBE, 2011a, p. 20). In the wake of these findings, the ANA report concluded that "the challenges for the schooling system in South Africa remain great" (DBE, 2011a, p. 36).

Table 1.3: Mean scores and scores of poor (Low Socioeconomic Status/ SES) and rich (High SES) learners in SACMEQ II Grade 6 mathematics test by country

MATHEMATICS (Countries arranged by mean scores)			
Country	Low SES	High SES	Mean
Mauritius	550.0	607.7	584.6
Kenya	546.9	587.1	563.3
Seychelles	532.4	567.8	554.3
Mozambique	527.5	532.6	530.0
Tanzania	509.0	545.5	522.4
Swaziland	511.3	522.2	516.5
Botswana	498.9	529.8	512.9
Uganda	496.3	519.2	506.3
South Africa	446.8	524.3	486.3
Zanzibar	474.0	483.9	478.1
Lesotho	448.6	444.9	447.2
Zambia	425.5	444.8	435.2
Malawi	428.2	442.2	432.9
Namibia	408.7	461.3	430.9
SACMEQ average			500.0

Source: Gerard (2011, p. 7)

Given this background, one can conclude that the state of mathematics education in South Africa is less than satisfactory. It seems that transition to the new curriculum, the National Curriculum Statement (NCS[9]), which is founded on the principles of Outcomes-Based Education (OBE), has done little to address the problem. For instance, of the 263 034 learners who sat for the 2010 mathematics matriculation national examination, only 47.4% passed, with a shockingly low 30.9% achieving the marks required for a university entrance (DBE, 2011a; Hunt, Ntuli, Rankin, Schöer & Sebastiao, 2011). In the last three years, the number of learners who take mathematics

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[9] NCS, as an OBE curriculum, was introduced in schools to improve the quality of learner performance in subjects like mathematics (Department of Education [DoE], 2006a). The OBE-driven curriculum has been in schools since 2005, when it was called Curriculum 2005 (C2005) (C2005 Review Committee, 2000; see also section 1.6).

as a subject at Grade 12 level has also declined. In 2008, the number of candidates who sat for the final Grade 12 examination was 298 921. In 2009 and 2010, these numbers dropped to 282 699 and 263 034 respectively (DBE, 2011a).

This section has illuminated two critical issues regarding mathematics instruction in South Africa. Firstly, South African learners generally demonstrate poor mathematics problem solving skills when compared to learners from other countries. Secondly, within a South African education context, there is a persistent performance gap between learners from different socioeconomic groups. The performance in mathematics of learners from township schools remains the least impressive (see also section 2.14). In this study, poor performance in mathematics is addressed within the context of learners' problem solving skills (Dhlamini & Mogari, 2011; see also section 1.4). The purpose of this study was to enhance the mathematics performance of participants from a disadvantaged background. This purpose was achieved by enhancing participants' problem solving skills and abilities (Dhlamini, 2011). The following section demonstrates the link between mathematics performance and learners' problem solving skills and abilities.

1.4 LINKING LEARNERS' PERFORMANCE IN MATHEMATICS TO PROBLEM SOLVING ABILITY

The link between mathematics performance and problem solving ability has been emphasised by many researchers (see, for example, Baloyi, 2011; Dhlamini, 2011; Dhlamini & Mogari, 2011; Dhlamini & Mogari, 2012a; Dhlamini & Mogari 2012b; Gaigher, 2006; Mji & Makgato, 2006; Pimta, Tayruakham & Nuangchalerm, 2009; Reys, Lindquist, Lambdin, Smith & Suydam, 2001; Sepeng, 2010; Sepeng, 2011; Sweller, Clark & Kirschner, 2010; Venkatakrishnan & Graven, 2006; Voskoglou, 2008). Voskoglou (2008) concluded that problem solving is a principle component of mathematics. Sweller *et al*. (2010) acknowledge that "problem solving is central to mathematics" (p. 1303). In addition, Kilpatrick, Swafford and Findell (2001, p. 420) explained that studies in almost every domain of mathematics have demonstrated that problem solving provides an important context in which learners can learn about numbers and other mathematical topics. Kontra (2001) proposed that "any mathematical problem solving performance is built on a foundation of basic mathematical knowledge" (p. 4).

From these views it is clear that problem solving is the foundation of all mathematics activity (Cobb, Yackel & Wood, 2011). One can thus assume that performance in mathematics is a reflection of one's problem solving abilities. The latter corroborates Pimta *et al*.'s (2009, p. 381) assumption that "learners who perform badly in mathematics do not do well in the area of problem solving". Given this background, the researcher argued that one way to enhance the mathematical performance of learners in disadvantaged schools was to design instruction aimed at improving the problem solving skills of the learners.

When addressing issues around problem solving performance it is important to recognise the role of cognition. Cognitive science provides a useful framework to explain the influence of the components of human cognitive architecture on problem solving performance (see Chapter 3 & Chapter 4). As a fundamental component of human cognitive architecture a long-term memory provides a means to develop durable and effective problem solving schemas. A schema consists of "a mental problem solution representation that is stored in long-term memory and which can allow an individual to efficiently solve a particular type of problems" (Rockwell, Griffin & Jones, 2011, p. 88). Therefore, according to Sweller *et al*. (2010, p. 1304), "We can teach aspiring mathematicians to be effective problem solvers only by providing them with a large store of domain-specific schemas".

Models of problem solving are generally derived from and influenced by schema theories of cognitive psychology (Jonassen, 2003; Scardamalia & Bereiter, 2006; Schnotz & Kürschner, 2007). Given this background, other researchers have emphasised the importance of schemas in problem solving, and have concluded that it is at least as important as the particular solution obtained (Jonassen, 2011; Rockwell *et al*., 2011, Plass, Moreno & Brünken, 2010; Van Loon-Hillen, Van Gog & Brand-Gruwel, 2012). The current study borrowed from the model of problem solving postulated by Sweller (1988, 2010) because his model provides explicit frameworks for the development of schemata to enhance learners' problem solving skills and hence the achievement of school outcomes in mathematics (see, Dhlamini & Mogari, 2011; Plass *et al*., 2010; Sweller, Ayres & Kalyuga, 2011). A problem solving instruction that is proposed in this study is largely influenced by the assumptions of the cognitive load theory (see section 8.4.1 & Figure 8.1).

Finally, in order to develop problem solving skills and abilities in learners, that is, to improve learners' performance in mathematics, Pimta *et al*. (2009) believe that teachers' instruction should comply with Bloom's theory. Bloom's theory is believed to provide three domains of learning, namely, cognitive, affective and psychomotor, that influence learner achievement (see section 2.10). In particular, the cognitive domain provides a link to "students' own background knowledge and skills" (Pimta *et al*., 2009, p. 382). In this context, background knowledge and skills refer to the knowledge and expertise that are familiar to the learner, and these can be derived from familiar real-life experiences. Given this background, this study argues that one way to develop learners' problem solving skills is to design a problem solving instruction that is sensitive to learners' real-life experiences (Dhlamini, 2011; Dhlamini & Mogari, 2012b). Instruction that connects mathematics with out-of-school world is usually called context-based instruction (Jurdak, 2006; Kasanda *et al*., 2005).

A context-based instruction is favoured for its role in fostering more positive attitude to mathematics, and to generate motivation in learners. As such context-based instruction has become widely recommended to provide a sound basis of mathematics understanding for further study (Palm, 2005). According to Durak (2006), four reasons are often advanced for using context-based instruction in mathematics classrooms: 1) the enhancement of the learning of mathematics; 2) the development of competent citizens; 3) the development of general problem solving competencies; and, 4) the utility of mathematical applications in solving problems in extra-mathematical areas or everyday life. The current study falls within the third argument (the competency argument). In this study the phrase *context-based problem solving instruction* is used to define instruction that utilises everyday experiences of learners to promote their problem solving skills and performance (see section 1.1 & section 1.9.7). Thus, a context-based problem solving approach is important as a way of doing, learning and teaching mathematics. It will stimulate learners' interest in mathematics and help them to understand how mathematics concepts relate to their everyday lives.

1.5 THEORETICAL ORIENTATION OF THE STUDY

One of the fundamental human cognitive processes is problem solving (Wang & Chiew, 2010). Wang and Chiew (2010, p. 81) describe problem solving as "a cognitive process of the brain that

searches a solution for a given problem or finds a path to a given goal". It is on this basis that the cognitive load theory (CLT) (Sweller, 1988; 2010) was used to frame this study. The theory was considered for its claim that it is concerned with "the manner in which cognitive resources are focussed and used during learning and problem solving" (Sweller & Chandler, 1991, p. 294). CLT has been defined as an instructional design theory with the aim of assisting instructional designers to reduce the load caused by poorly designed learning material (Dhlamini & Mogari, 2011; Dhlamini & Mogari, 2012b; Gerjets & Scheiter, 2003; Gerjets, Scheiter & Catrambone, 2004; Schnotz & Kürschner, 2007; Sweller, 2010; Van Loon-Hillen *et al*., 2012).

The cognitive load mentioned in this definition refers to the load imposed on the working memory, which is the processing part of the cognitive system, when learners have to deal with complex tasks such as problem solving (see, Dhlamini & Mogari, 2011; Van Loon-Hell *et al*., 2012). In terms of this explanation, learners may be bombarded by information and, if the complexity of their instructional material is not properly managed, cognitive overload will result. This cognitive overload impairs learning, including problem solving schema acquisition. In this study an attempt was made to keep participant cognitive load at a manageable level in order to make working memory resources that are essential for learning and problem solving schema construction more readily available (see section 3.4.2).

Because the working memory is severely limited in its processing ability, the necessity for adapting instruction to this cognitive constraint is the main focus of CLT. Information learned is stored in long-term memory in the form of schemata or schemas, such as problem solving schemata. A schema categorises elements of information according to the manner in which they will be used (Fuchs, Fuchs, Prentice, Hamlett, Finelli & Courey, 2004; Sweller, 2010). In terms of problem solving, a schema is defined as a construct that allows problem solvers to group problems into categories in which the problems in each category require similar solutions (Steele & Johanning, 2004). A schema retains a mental problem solution representation that allows an individual to efficiently solve a class of similar problems (Rockwell *et al*., 2011, p. 88). According to CLT, "The construction and automation of schemata are considered to be the two main prerequisites of problem solving expertise" (Gerjets & Scheiter, 2003, p. 33).

Several instructional claims raised by CLT constituted a theoretical basis for the arguments raised in this study. Hence, in Chapter 3, special attention is paid to the subject of human cognitive architecture, as this is believed to influence learners' problem solving behaviour and learning in general. Cognitive architecture refers to the notion that the human mind has structures, such as working memory, long-term memory and schemata (Bethel & Borokhovski, 2010; see also Chapter 3). In Chapter 4, cognitive load theory is presented as a theoretical framework for the study and it is demonstrated how this learning theory is used in the study to explain participants' observed problem solving behaviour during context-based problem solving tasks. It is also used to account for the observed enhancement of participants' problem solving performance (see also Dhlamini & Mogari, 2011).

1.6 THE PROBLEM STATEMENT

The 1994 elections brought hope and excitement to the people of South Africa, particularly the disadvantaged sectors of society. From an educational perspective, the new government faced the challenge of transforming the system of education. This process involved drafting a new curriculum. Curriculum 2005[10] (C2005), informed by the principles of OBE, was introduced in 1998. Following challenges and intense consultation with stakeholders, in 2000 a major refinement of C2005 was initiated, resulting in a revised NCS, which was implemented in 2004 (Chisholm, 2005; Department of Education [DoE], 2002; Pudi, 2006). Amongst other things, the new curriculum was intended to address the perennial problem of poor performance in mathematics.

At the time of this study, the new curriculum had been in place for more than 10 years, but the performance of learners in mathematics had continued to be of national concern. After the release of the 2010 Grade 12 final examination results, the Minister of Basic Education, Angie Motshekga, stated, that the Department of Basic Education was certainly not happy with the number of passes in mathematics" (DBE, 2011a). Furthermore, the South African Institute of Race Relations (SAIRR) (2011) acknowledged that poor performance in both end-of-year Grade 12 examinations and in mathematics appeared inevitable. Generally, schools in the townships

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[10]Curriculum 2005 (C2005) was so called because it represented a process of curriculum reform that was to be introduced on an incremental level from 1998 to 2005 (Pudi, 2006).

continued to register poor performance in mathematics (Gerard, 2011). Good performance in mathematics is synonymous with the former model-C[11] schools and the independent schools (Gauteng Department of Education [GDE], 2010).

Given this background, the researcher observed that there was a need to seek ways and means to redress the problem of poor performance in mathematics. One possible way was to investigate the state of problem solving skills among learners of mathematics, given that this is largely a function of their success. The focus was on improving learners' problem solving skills by incorporating the use of real-life context in mathematical problem solving processes to foster a deeper and more meaningful understanding of content (DoE, 2005).

1.7 RESEARCH QUESTIONS

The following were the over-arching research questions that guided this study:

1. How can context-based problem solving instruction be incorporated in the teaching and learning of financial mathematics?
2. What challenges, if any, does the incorporation of context-based problem solving instruction pose in the teaching and learning of financial mathematics?
3. Will the incorporation of context-based problem solving instruction have any influence on learners' performance in financial mathematics?

1.8 SIGNIFICANCE OF THE STUDY

The primary aim of this study was to investigate the effect of context-based problem solving instruction (CBPSI) on the problem solving performance of Grade 10 learners, who performed poorly in mathematics problem solving. The value of this research lay in its potential to tackle low performance in mathematics among learners from disadvantaged communities in the interests of social equality.

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[11] During the National Party government, white learners' schools under the control of the House of Assembly (HoA) were known as model-C schools (Macrae, 1994; see also Figure 1.1 in section 1.2).

The study was born out of a realisation that research into the learning effects of the use of problem solving instruction in an everyday context had not received much attention in South Africa up to this point. The use of CBPSI has been explored in other parts of the world (see, for example, Bennett & Lubben, 2006; Bennett, Lubben & Hogarth, 2007; Klosterman & Sadler, 2010; Neves, Silva & Teodoro, 2011, Taasoobshirazi & Carr, 2008; Vithal, 2008; Worrell & Proffeto-McGrath, 2007). However, at the time of this study, it was observed that results from these studies were either limited or inconclusive in providing effective remedy to the problem of poor performance in Grade 10 mathematics classrooms (Kasanda *et al.*, 2005). According to Van Loon-Hell *et al.* (2012, p. 92), "there is little evidence to suggest that gains from problem solving research have been maintained in experimental settings or successfully generalised to other settings". Against this backdrop, it was felt that this study should be conducted in an attempt to produce results that would be practical and that could be generalised to the South African context.

The CBPSI presented in this study stimulates learner participation (see Dhlamini & Mogari, 2012a; Kasanda *et al.*, 2005). The reformed school curriculum in South Africa, as in many other developing countries, rests heavily on a learner-centred approach (DoE, 2006a; Engelbrecht & Harding, 2008). According to Kasanda *et al.* (2005), a learner-centred approach emphasises the need to: 1) match learners' interest and experience; 2) use learners' existing knowledge and skills; and, 3) include learners' everyday experiences in topics to be taught. Scholars such as Wertheimer (1959), Bruner (1960) and Hiebert *et al.* (1996) have urged teachers to challenge learners on problems that interest them.

Despite such importance in connecting mathematics to the learners' real world, the researcher observed that little was known about how and how often this actually happened in mathematics classrooms. Given this situation, it was envisaged that the current study would be useful in surveying the extent of the use of everyday context as an indicator of the ways that learner-centred approaches were implemented in South African mathematics classrooms.

1.9 DEFINITION OF KEY TERMS

The following are operational definitions of key terms used in the study:

1.9.1 Problem solving

In this study a problem solving activity is conceptualised as a cognitive process or activity in which there is a search for solution to a problem. In terms of the cognitive load theory, effective problem solving process involves the construction and activation of problem solving schemas. During a problem solving process, a schema helps the brain to search for an associated solution or finds a path to a given goal. Given that this study relied on cognitive science and schema theory (section 3.5), the following characterisation of a problem was adopted: A task is said to be a problem if its solution requires that a learner relates previously learnt knowledge to the task at hand. Meaning in this problem solving scenario, the learner uses previously acquired skills to respond to the demands of the new problem task.

1.9.2 Problem solving skills

Generally, problem solving skills are defined as "the learners' capabilities and abilities to solve problems from intellectual domains such as mathematics" (Renkl & Atkinson, 2010, p. 16). In terms of this study, problem solving skills are manifested when participants succeed in the application of previously learnt problem solving knowledge to novel problems. In experimental schools participants studied several worked-out problem solving examples by providing them as analogies for problem solving tasks that were later treated in class. When dealing with actual problem solving tasks participants in experimental schools were expected to demonstrate skills and abilities to relate a problem task to a worked-out example that was treated earlier in the mathematics lesson. An achievement test was used to measure participants' problem solving abilities and skills (section 6.3). Participants' scores in the achievement demonstrated their problem solving ability and performance, interpreted as their problem solving skills.

In addition, participants' problem solving skills were evaluated using a criterion developed for this purpose (Appendix F; see also section 7.5.3). According to this criterion, a learner who is a skillful problem solver: 1) analyses factors associated with the problems (Olowa, 2010); 2) masters rules for problem solution (Fuchs *et al*., 2004); 3) is aware that novel problems are

related to previously solved problems (Fuchs *et al*., 2004); 4) lines up numbers from text to perform mathematics operations (Fuchs *et al*., 2004); 5) verifies that their answers make sense (Fuchs *et al*., 2004); 6) predicts, plans, revises, selects, classifies and checks (Pugalee, 2004); 7) identifies useful information, can work strategically and can make connections (Schurter, 2002); and, 8) sustains problem solving actions (Gagatsis & Shiakalli, 2004).

1.9.3 Learning

The aim of this study was to investigate the effect of context-based problem solving instruction on the problem solving performance of Grade 10 learners, who performed poorly in mathematics problem solving (section 1.2). The achievement of this aim would give an indication of whether or not learning, which refers to the development of problem solving skills in this study, took place. Given this aim, it was important to define learning in terms of cognitive architecture and cognitive load assumptions (Sweller, 1988). According to Dhlamini and Mogari (2011), cognitive load assumptions were used in the current study to conceive learning as the construction of learners' problem solving schemata in the long-term memory (see section 3.4.3 & section 4.6.1). In terms of this definition, learning occurs when there is an alteration of problem solving information in the long-term memory as a result of the newly formed problem solving schemas (section 4.6.1). When successful learning has been accomplished, knowledge that is formed in the long-term memory can be recalled and applied later on demand (Cooper, 1998). With repeated application problem solving schemas can be automated (see section 3.6).

1.9.4 Real-life context

Participants in this study came from a disadvantaged township background (section 1.1). Section 6.2 provides some realistic background characteristics and general socioeconomic status of the participants' in the study sample (see also Table 6.1). The real-life context of participants in this study constituted the following variables: 1) generally poor parental care (section 6.2.2.); 2) generally poor employment status of the parents (section 6.2.3); 3) generally poor education status of the parents (section 6.2.4); 4) limited accessibility to computer at home (section 6.2.5); 6) generally poor schooling and poor performance in mathematics (see section 6.2.7 & section 6.2.8).

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Given the disadvantaged socioeconomic background of the study participants, most of the tasks were contextualized around their every township experiences. Location learning within familiar contexts was meant to promote comprehension and facilitate the development of problem solving skills (see also section 1.4). Song (2011, p. 11) noted that "learning that is situated in a familiar context activates learners' prior knowledge". In addition, Song (2011) shows that information appearing in more familiar contexts is better recalled because the familiar context makes it easier to arouse a learner's schemata and, in turn, these schemata play an important role in remembering and comprehending new material.

1.9.5 Disadvantaged learner

Most people living in townships earn a low income and their access to quality education is limited (see section 1.3, section 1.9.4, section 2.14 & section 6.2). Because of their generally poor income financially and poor education, most of the township dwellers achieve little in material terms. As a consequence, children from township schools are classified as "disadvantaged learners" (Tsanwani, 2009, p. 12). According to Tsanwani (2009), the term *disadvantaged learners* refers to a group of learners "from populations with low social status, low educational achievement, tenuous or no employment, limited participation in community or organization and limited ready potential for upward mobility" (p. 12). The analysis of demographic data in section 6.2 suggested that most participants in this study emerged from disadvantaged socioeconomic backgrounds, and were therefore disadvantaged learners.

1.9.6 Conventional problem solving instructions (CPSI)

In this study, conventional problem solving instruction (CPSI) refers to any form of classroom activities which characterised teachers' instructions in control schools during a two-week intervention. Generally, CPSI differed from CBPSI that was implemented by the researcher in experimental schools. Similar context-based problem solving tasks were prepared by the researcher and treated in experimental and control schools during intervention. However, the approach employed by teachers in presenting context-based problem solving tasks in control schools was different to the one employed by the researcher in experimental schools (see also section 1.9.7). When the researcher observed teachers' instructions, it was clear that in most control schools a *didactic teaching approach* was followed in which teaching is associated with

transmission of problem solving knowledge by the teacher, and learning associated with passive receiving of problem solving knowledge.

Generally the following patterns were observed: 1) learners listened passively to the problem solving information mainly delivered by the teacher; 2) problem solution examples were not emphasised to facilitate assimilation of new problem solving knowledge (in most cases, only one example was given to the learners); 3) new knowledge was seldom linked to learners' real-life experiences; 4) learners participated in limited whole classroom discussions (in most cases learners did not form discussion groups and desks were arranged in a conventionally linear format); 5) learners spent most of their learning time writing notes from either what was said by the teacher or written on the chalkboard; and, 6) learners were observed to be attempting to retrieve or recall the information for evaluation purposes. In most conventional approaches, the focus was more on the individual acquisition of information than on group-driven problem solving (Olowa, 2010).

1.9.7 Context-based problem solving instruction (CBPSI)

Context-based problem solving instruction refers to the researcher's teaching approach in which learners were exposed to problem solving activities that gave meaning to their everyday experiences (section 1.1; see also, Dhlamini, 2011). Exposing learners to problems that bore resemblance to their real-life experience was aimed to enhance the effective development of problem solving skills.

The implementation of CBPSI embraced the following instructional features: 1) learners worked in groups; 2) initial discussion of the lessons were aimed at adjusting the context of the problems to the real-life experiences of learners (for instance western names are changed to familiar local names; a name like *salary* was replaced with the name *wage*, the latter being more familiar in a township context); 3) problem solving activities were presented in such a way that the effect of cognitive load on learners' working memory was minimised (split-attention[12] is minimised); 4) a worked-out examples approach dominated and guided problem solving activities (learners were

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[12] Split-attention is the phenomenon that occurs as a result of physically separating problem solving information (Cierniak, Scheiter & Gerjets, 2009; see also section 4.4 & section 5.5.1.6).

provided with samples of worked-out step-by-step solutions to demonstrate solution process); 5) learners were given opportunities to verbalise and share their problem solving skills and strategies with their fellow group members (self-explanation[13]). The researcher also probed learners to guide and facilitate group discussions; 6) the researcher did not dominate instruction but rather monitored and guided problem solving discussions. The researcher asked questions to evaluate the level of problem solving schema construction; 7) after working in groups, and sufficient exposure to worked-out examples was achieved, learners were then given a chance to attempt context-based problem solving tasks individually to demonstrate development of problem solving skills. The summary of a context-based problem solving instruction and its developmental phases is discussed in section 8.4.1 (see also Figure 8.1).

1.10 LIMITATIONS OF THE STUDY

It is acknowledged that the research design followed in this study poses some challenges to external validity of the study (Roberts, 2003). Participants in this study were selected by the qualifying characteristics of their disadvantaged socioeconomic background and their low performance in mathematics (see Dhlamini & Mogari, 2011). The design of the study lacked random assignment of participants to experimental and control groups because intact classes were used. While the sample in the study approximated the target population, caution should be used when generalising beyond participants. Conclusions should, therefore, not be extended beyond the township disadvantaged socioeconomic environment in which the experiment was conducted. Furthermore, this study was undertaken to tackle problem solving performance in only one section of the Grade 10 mathematics syllabus, namely, Financial Mathematics. Lastly, the duration of the intervention was too short to claim substantial restructuring in learners' problem solving schemas in long-term memory (see more discussion in section 9.5)

1.11 ORGANISATION OF THE THESIS

Chapter 1 provides a general introduction to the study and includes contextual background to the study. A statement of the problem and the significance of the study are also presented in this chapter. *Chapter 2* reviews research relevant to the study. In this regard, both local and

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[13]Self-explanation is the process of explaining text to oneself either orally or in writing while reading (McNamara, 2004).

international scholarly works on problem solving are explored. In C*hapter 3*, the researcher discusses the components of human cognitive architecture important to this study. This discussion is critical as it provides useful information that explains certain problem solving behaviour exhibited by learners during context-based problem solving tasks.

Chapter 4 discusses Sweller's (1988) cognitive load theory (CLT) as a theoretical framework for the study. This theory of learning is used to explain and analyse the cognitive aspects that are said to influence learners' cognitive processes during problem solving activities. In *Chapter 5,* the research methodology followed in the study is outlined. Amongst the methodological issues dealt with in this chapter are: research methods, sampling techniques and procedures, data collection procedures and procedures used in analysing both qualitative and quantitative data.

Chapter 6 explores quantitative evidence of learners' enhanced problem solving performance. In the main, the results from the pre- and post-achievement tests are analysed. In *Chapter 7,* a qualitative analysis of the semi-structured interviews and classroom observations is provided. In *Chapter 8,* a summary and discussion of the findings are provided. In this chapter the findings of the study are discussed in terms of the research aim, research objectives, research questions and the theory that this study adopted. *Chapter 9* concludes the study. Limitations and recommendations of the study are also presented in Chapter 9. Areas for future research are also suggested in this chapter.

CHAPTER TWO

PROBLEM SOLVING

2.1 INTRODUCTION

Not only do education departments mandate the teaching of problem solving in the school curriculum, but problem solving is a necessary social skill that goes beyond academic, social, political and professional boundaries. The importance of mathematical literacy and problem solving has been emphasized by many researchers (see, for example, Baloyi, 2011; Dhlamini, 2011; Dhlamini & Mogari, 2011; Gaigher, 2006; Olowa, 2010; Poorya, Hassan & Farzad, 2011; Rockwell, Griffin & Jones, 2011, Robabeh, Hassan & Farzad, 2012; Sepeng, 2011; Sepeng, 2010). Problem solving is generally regarded as "the most important cognitive activity in an everyday and professional context" (Jonassen, 2000, p. 63).

Apart from problem solving, recent views suggest that mathematics instruction should be concentrated around tasks situated within real-life experiences of learners (Jitendra, Dipipi, & Perron-Jones, 2002; Jurdak, 2006; Lesh & Harel, 2003; Palm, 2006; Sepeng, 2011; Sepeng, 2010; see also section 1.1). In line with these views, the South African Department of Education (DoE) contends, "mathematical problem solving enables us to understand the world and make use of that understanding in our daily lives" (DoE, 2006a, p. 20). One of the general aims of the South African curriculum is "to ensure that learners acquire and apply knowledge skills in ways that are meaningful to their lives, and one way to achieve this is to ground knowledge in local contexts" (Department of Basic Education [DBE], 2011b, p. 2).

According to DBE (2011b, p. 7), learners should be exposed to both mathematical content and real-life contexts "to develop competencies such as problem solving, reasoning ability, decision making, etc." So in recent school curriculum programs, efforts are being made to use real-world context and the application of mathematics as a means of developing mathematical understanding and promoting learners' problem solving skills. Teaching in this way is often described as adopting a context-based approach (see section, 1.9.7, section 2.12 & section 2.13).

Although instruction that emphasises mathematics and problem solving through connection with a real-life context is considered critical by many, "procedures that emphasise memorization and completion of lengthy worksheets requiring rote practice are common in many mathematics classrooms" (Jitendra *et al*., 2002, p. 23). The dominance of instruction that emphasise memorization is evident when learners fail to apply problem solving knowledge in real-life situations that require them to do so. For instance, both national and international studies have revealed poor performance by South African learners in mathematical and problem solving skills in comparison to learners from other countries (Bansilal, James & Naidoo, 2010; Howie, 2001, 2006; Mji & Makgato, 2006; Reddy, 2006). Hence there is a need to design instruction that infuses real-life experiences in mathematics classrooms because many people involved in curriculum development have identified considerable benefits associated with a context-based approach. Lesh and Harel (2003) maintain that the kind of problem solving tasks that can be emphasised in mathematics classrooms are simulations of real-life contexts where mathematical thinking is useful in the everyday lives of the learners or their family and friends.

Given this background, the current study explored the use of everyday experiences to promote learners' problem solving skills in mathematics (see Dhlamini, 2011). Because problem solving is a cognitive activity, it is a complex skill to learn (Sweller, 1988, 2010). In this study, real-life experiences that are familiar to learners are used as instructional tools to facilitate the acquisition of problem solving skills. In this way, connections between mathematics and real-life contexts are explored in order to promote the acquisition of problem solving skills by learners. According to Verschaffel, Greer and De Corte (2000), the latter is achievable when learners are immersed in innovative learning environments that are radically different from conventional classroom practices.

In this chapter, the notion of problem solving as one of the critical skills in learning mathematics is explored. The chapter begins with a systematic description of problem solving. In doing this, various problem solving definitions are explored with a view to coining a working definition for the current study. Furthermore, the use of a real-life context to promote learners' problem solving skills acquisition in mathematics also forms part of this chapter.

2.2 PROBLEM SOLVING

Increasing evidence suggests that high levels of mathematical problem solving skills are needed for most jobs in the 21st century (Xin, Jitendra & Deatline-Buchman, 2005). There is a need to ensure that all learners have sufficient problem solving skills to meet the challenges of the 21st century. As such, curriculum that emphasises the teaching of problem solving skills should be emphasised in the schools. This is important because the inclusion of problem solving in mathematics instruction can provide "a learning environment for learners to explore realistic problems and thus invent ways to solve the problem - a skill that could be essential in later life" (Lee, 2007, p. 3). In this way, problem solving activities allow learners to facilitate connections between related ideas, to consolidate mathematical knowledge and to think creatively. So problem solving is a critical skill for learners to learn.

In the present study, the acquisition of mathematical problem solving skills by Grade 10 learners is conceptualised as acquiring knowledge of to deal effectively with complex, not fully understood and ever-changing problem contexts that relate to their everyday experience (Wuttke & Wolf, 2007; see also section 1.9.6). Problem solving skills are manifested when learners participate in the learning process by contributing problems, analysing the factors associated with the problem, developing possible solutions for the problem, placing the solution(s) into actions (execution of problem solution steps) and evaluating the results of the solution (Dhlamini & Mogari, 2011; Olowa, 2010).

Other studies have attempted to describe problem solving ability in mathematics and to highlight its importance in mathematics education. Jonassen (2004, p. XXI) noted that "learning to solve problems is the most important skill that learners can develop in mathematics". According to Cobb, Yackel and Wood (2011), problem solving is a necessary ingredient in mathematics instruction because: it promotes learners' conceptual understanding; it fosters their ability to reason and communicate mathematically; and can capture learners' interest and curiosity. Furthermore, various studies have highlighted the importance of exposing learners to problem solving tasks so that mathematical sense-making is promoted (Marcus & Fey, 2003; Muhren & Van de Walle, 2010; Huntley, Marcus, Kahan & Miller, 2007; Van de Walle, 2003). Given this background, it is possible to conclude that mathematics problems that are truly problematic and

involve significant mathematics have the potential to provide the intellectual context for learners'
mathematical problem solving development (National Council of Teachers of Mathematics
[NCTM], 2006).

As far as describing problem solving in mathematics is concerned, in his book "*How to solve it*",
Polya (1957) conceptualised problem solving as an activity that places emphasis on discovery.
When solving a problem, new ideas and knowledge are discovered. Using this conception, Polya
(1957) developed the following steps for problem solving: 1) understand the problem; 2) plan the
solution process; 3) carry out the problem solution steps; and, 4) looking backwards. Each of
these steps involves a variety of possible questions that should be addressed. These will vary
according to the problem and the type of problem solving knowledge possessed by the learner
who is attempting to solve the problem. Polya's (1957) four basic problem solving steps can be
practiced by anyone: no special gift or creative talent is needed to comprehend and execute them.
Using this model, Polya (1981) emphasised that the first duty of a mathematics teacher is to
develop learners' problem solving skills and ability in mathematics. So this model emphasises
the importance of cultivating problem solving skills and abilities in learners.

However, Polya's (1981) description of problem solving did not serve as an ultimate envisioned
model, but it provided a solid foundation to develop various problem solving models that are
used in modern times. For instance, in Dogru (2008, p. 9) problem solving is described as "a way
of finding or creating new solutions for the problem or to apply the new rules to be learned".
This approach parallels Polya's (1957) second step, in which the problem solver plans and
creates the new solution path for the problem. Wang and Chiew (2010) described problem
solving as the individual's effort toward achieving a situational goal for which there is no direct
solution path. The latter is achievable when Polya' first and second steps are considered.
Through understanding and planning, a situational goal for the problem can be formulated.
According to Jitendra *et al*. (2002, p. 25), problem solving refers to the selection and application
of appropriate mathematical operations based on the representation. It involves both solution
planning and execution of mathematical operations (Jitendra *et al*., 2002), which entail Polya's
(1957) second and third steps. So we notice that the recent definitions of problem solving are
largely influenced by initial works of Polya (1957) in mathematics problem solving.

In line with these definitions, it is possible to conceptualise problem solving as a set of problems that enhance the acquisition of numerical and computational skills by the learner. One way to facilitate acquisition of numerical and computational skills is by providing learners with real-life problems that generate learners' interest to solve problems. In this way, the attainment of problem solving competency locates learning in meaningful tasks that are real-life connected, such as case-based instruction and project-based learning (Hmelo-Silver, 2004). Therefore, a problem solving approach should encourage meaningful and experiential learning. According to Hmelo-Silver (2004), problem solving should be organised around "the investigation, explanation, and resolution of meaningful problems" (p. 236). It is clear that thought and skill are required to envision a functional outcome and to derive a solution to a problem situation.

From the above explanations, it is possible to formulate a definition for problem solving. Problem solving can be conceived as a situation that presents an objective or goal that must be achieved. However, the situation may not provide immediate or visible solution for the attainment of the objective or goal. In considering the work of Schrock (2000) and those of other researchers, such as those discussed above, it is suggested that mathematical problem solving must meet at least three criteria, i.e.: 1) individuals must accept an engagement with the problem; 2) they must encounter a block and see no immediate solution process; and, 3) they must actively explore a variety of approaches to the problem. When a learner is immersed in problem solving according to the three steps mentioned above, the learner can develop critical thinking and problem solving skills that are the ultimate goals of mathematics education (Jitendra *et al.*, 2002).

2.3 GENERAL PROBLEM SOLVING MODELS OF THE 1960's

Several problem solving models were generated in the 1960's, however in this section only two models are discussed. In the early 1960's and late 1970's researchers developed a variety of general problem solving models to explain problem solving processes (see, for example, Bransford & Stein, 1984; Newell & Simon, 1972; Polya, 1957). During this period, an assumption was made that by learning complex problem solving skills one could transfer these skills to any situation (context). Consequently, problem solving models for processing

information, such as the General Problem Solver (GPS) were designed (Newell & Simon, 1972). The GPS defines two sets of thinking processes associated with problem solving process, namely: 1) understanding processes; and, 2) search process. According to the two GPS steps, it is essential to acquire initial understanding of the problem solving situation in order to generate a search device for the solution. This model has always been considered a useful base to influence the design of problem solving models currently considered useful (see section 2.4). It is also influenced by Polya's (1957) problem solving model. Researchers, such as Alio and Harbor-Peter (2000), Galadima (2002) and Williams (2003), have recommended that Polya's (1957 problem solving model and strategies be used by secondary school mathematics teachers to teach mathematics.

Another example of a problem solving model, which was developed in the early nineties, is Bransford's IDEAL model (Bransford & Stein, 1993). As conceptualised by Bransford and Stein (1993), the IDEAL problem solving process constitutes the following steps: 1) **i**dentifying steps that others may have overlooked; 2) **d**eveloping at least two sets of contrasting goals for any problem and defining them explicitly; 3) **e**xploring strategies and continually evaluating their relevance to the goals; 4) **a**nticipating the effect of strategies before acting on them; and, 5) **l**ooking at the effects of their efforts and learning from them. This model is similar to many general problem solving models that were common in the nineties. The IDEAL model is thought to be more meaningful when it is contrasted with more typical and everyday problem solving tasks. It can become more useful in an instruction that promotes the functionality of everyday context to facilitate learning and transfer.

2.4 CURRENT PROBLEM SOLVING MODELS

Most problem solving models of our time have been influenced by research in cognitive science (Kirkley, 2003). Because of the classic empirical work done by cognitive science, today we know that "the problem solving process includes a complex set of cognitive, behavioural and attitudinal components" (Kirkley, 2003, p. 4). In most of the problem solving studies conducted in the name of cognitive science, the role of problem solving schemas has been emphasised (see section 3.5 & section 3.6).

Kirkley (2003) defined problem solving as "a multiple step process wherein the problem solver must find a relationship between past experiences and the problem at hand and then act upon a solution" (p. 4). Using this definition, Mayer (1983) suggested the three characteristics for problem solving as being: 1) problem solving is cognitive but is inferred from behaviour; 2) problem solving results in behaviour that leads to a solution; and, 3) problem solving is a process that involves manipulation of or operation on previous knowledge. Using Mayer (1983) problem solving characteristics, the problem solving model in Figure 2.1 is suggested:

Figure 2.1: A model of the problem solving process
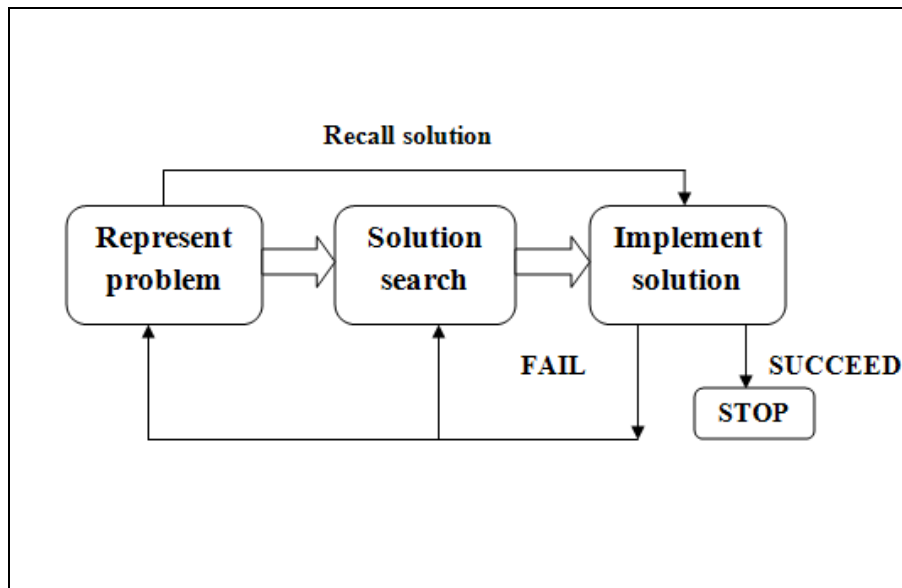
Figure 2.1 shows that there are three basic problem solving stages for a problem solving process. *Stage one* involves representation of a problem. According to Learning Plato (2003), this stage entails calling up the appropriate context knowledge and identifying the goal and the relevant starting conditions for the problem. *Stage two*, which involves a search for the solution, includes "refining the goal and developing a plan of action to reach the goal" (Learning Plato, 2003, p. 4). The final stage, *stage three*, is called implementing the solution (Learning Plato, 2003). The latter includes executing the plan of action and evaluating the results.

There is a short-cut route however: the recall solution process. If, for instance, a learner realises that he or she might have solved the problem in a previous encounter, the learner may move straight to implementing the solution. Of course, many problems are too complex and cannot be solved by this single iteration of this process (Figure 2.1). According to Learning Plato (2003), in these cases, the learner will have to break down the problem into intermediate goals and solve each one in turn, using the suggested process in Figure 2.1. This switching between smaller, intermediate goals and a larger, final goal is an example of a higher order thinking skill called a "cognitive strategy" (Learning Plato, 2003, p. 4).

As it appears that the modern problem solving model focuses more on the cognitive aspect of problem solving activity, there is a need to understand human cognitive architecture (see Chapter 3) to explain certain observed problem solving behaviour and actions. In that way, the current study is seen to be following the current trend of looking at problem solving from a cognitive perspective.

2.5 PROBLEM SOLVING INSTRUCTION

There is a concern that knowledge gained at school is hardly applied in working contexts. One response to this concern has taken the form of problem solving instruction. There is a belief that problem solving instruction can help to bridge the gap between the classroom and the professional world. This is because a number of faculty members in professional schools have noted that the knowledge acquired in the classroom does not transfer properly to a profession, whether it be medicine, engineering, social work or education.

In describing a problem solving instruction Yin (2011) noted that "problem solving instruction is not simply the addition of problem solving activities to otherwise discipline-centred curricula, but a way of conceiving of the curriculum which is centred around key problems in professional practice" (p. 14). In this teaching approach, efforts to make connections between classroom knowledge and out-of-school knowledge should be fore-grounded. One way to achieve this is to formulate problem solving tasks that relate directly to learners' everyday experiences. In that way, mathematics is brought to the level of the learners.

Furthermore, problem solving instruction in mathematics refers to a teaching approach in which problem solving tasks are used to promote mathematics learning. Most of these tasks have a direct connection with a real-world context. In this approach: the teacher begins the lesson by posing a problem; then the teacher teaches a skill that helps learners to solve the problem (NCTM, 2006). The newly acquired skill should help the learner to find a solution to the problem. In this context, problem solving becomes both the start and the end point for a mathematics lesson.

According to Sutton (2003), the objectives of problem solving instruction are: 1) to strengthen problem solving skills; 2) to expand the scope of the problem domain that the learner works on; 3) to expand the range of problem solving skills of the learners; and, 4) to identify and analyse problems that are personal, social, or non-academic and problems that do not have a single answer. In this way, problem solving becomes the process by which learners experience the power and usefulness of mathematics in the world around them (NCTM, 2006).

In simple terms, a problem solving approach to teaching mathematics can be seen as an approach that emphasises the importance of real-life connections as a starting point for learning. In this way, teaching and learning is built around everyday experiences that bear meaningful relevance to the life of a learner. In such an instructional environment, it is assumed that the motivation of a learner is heightened by the realisation that mathematics is grounded in real-life issues that connect to his or her everyday experience.

2.6 TEACHERS' VIEWS ON PROBLEM SOLVING

As curriculum implementers, teachers are the agents of change. Therefore, the extent to which the aspirations of the new curriculum are realised can be influenced by the variable of teacher behaviour. Problem solving is a new area of focus in the mathematics curriculum in South Africa. Hence several efforts are made to influence teachers to teach mathematics through problem solving. The success of these attempts can only be realised when teachers conceive rich and constructive views on problem solving. Teachers' views are considered in this study for their role in influencing teacher's method of instruction. The method of instruction influences learners' performance. This study aimed to improve the problem solving performance of Grade

10 learners who performed poorly in mathematics. Understanding teachers' views may provide a useful framework to trace causes of poor performance in a subject.

Several studies have explored teachers' views and conceptions about problem solving (see, for example, Freitas, Jiménez & Mellado, 2004; Lang & Namukasa, 2010; Näveri, Pehkonen, Hannula, Laine & Heinilä, 2011; Sivunen & Pehkonen, 2009). When curriculum reforms are proposed, it is essential to ascertain teachers' views because, according to Freitas *et al*. (2004), "teachers do not change their conceptions easily" (p. 114). This is possible because their conceptions are the fruit of many years they themselves spent at school. According to Freitas *et al*. (2004, p. 115), "many teachers use instructional approaches that are very similar to those they preferred when they were learners, or simply teach in the same way as they themselves were taught". In other cases, it is because teachers feel satisfied with certain teaching strategies that have been consolidated by professional experience, or because they do not have any teaching strategies readily available to replace the existing ones. Or it may be that in the educational system and in the teaching community itself there exist "situations that reinforce the traditional model and represent barriers to educational change" (Freitas *et al*., 2004, p. 115).

As far as teachers' views and conceptions about problem solving are concerned, Freitas *et al*. (2004) found that most teachers view problem solving as favouring motivation; aiding learners to learn; clarifying, applying and reinforcing the principles that are being taught. They also see problem solving as being "a process that develops learners' cognitive skills" (Freitas *et al*., 2004, p. 116). According to Freitas *et a*l. (2004), motivation comes in when learners make the problem their own, so that it ceases to be a schoolwork problem that they see as external to themselves. In that way, the problem becomes an intrinsic motivation and the desire to find a solution is generated.

Other researchers have found that teachers see problem solving as an innate ability in every individual. For instance, Freitas *et al*. (2004) note that some of the teachers usually explain problem solving as if it is something that one knows how to do and that neither poses any doubts nor requires any sort of "let's see if this works" approach. So in the latter instance, the teacher views learners as capable beings who can solve problems independently. This view of

mathematics problem solving can be associated with progressive or reformed methods of teaching mathematics, in which learners are made to realise that there are many alternatives to problem solving. The method the teacher applies in the classroom is just but one method amongst many methods that can be used to derive the solution.

According to Kramarski and Revach (2009), when a teacher enters the teaching field unprepared to teach mathematics problem solving his or her views of mathematics will be limited. Such a teacher will view mathematics problem solving as an instrumental way of teaching that should follow a prescribed set of teaching procedures. Kramarski and Revach (2009) add that a teacher who enters a teaching profession unprepared will perceive mathematics as an unrelated set of facts, rules and skills, to be used as required, rather than a process of reasoning and generalising. Studies that have been examined in this section provide a framework to conceptualise teachers' views of problem solving. As indicated earlier, exploring teachers' views is useful to benchmark their levels of commitment in fostering problem solving ideas in learners. In all, the few studies that have been examined in this section seem to suggest that there is a need to train teachers properly to ensure they teach mathematics problem solving skills and abilities effectively.

2.7 LEARNERS' VIEWS ON PROBLEM SOLVING

Learners form a significant part of teaching and learning. Understanding learners' problem solving views may help to influence the way problem solving instruction is implemented. In most cases, learners' views about mathematics problem solving are influenced by what goes around in the classroom. Some of the learners view problem solving skills as a gift that is only possessed by teachers. According to Freitas *et al*. (2004), some learners see problem solving strategies as a cookbook recipe to be given by the teacher and are therefore trapped in conventional problem solving strategies. For these learners, "conventional problem solving models could be a major cause of learners' difficulties in learning" (Freitas *et al*., 2004, p. 116), especially when they fail to emulate their teachers.

In their study, De Hoyos, Gray and Simpson (2002) distinguish between two types of learners' views and approaches when solving a mathematics problem:

- problem solving ideas to be *discovered* to solve the problem (discover a solution);
- problem solving ideas to be *invented* to solve the problem (invent a solution).

In the first category, learners view problem solving ideas and solutions as pre-existing, already invented and must be discovered. Learners in this category do not think they can contribute in finding a solution for the problem at hand. A teacher is seen as the one who comes to the classroom with solutions. The learner's task would be to uncover what already exists or what the teacher brings to class (De Hoyos *et al*., 2002). On the other hand, "a learner whose aim is to invent a solution either does not believe that a solution is out there, or believes that if this is the case he or she can create his or her own solution" (De Hoyos *et al*., 2002, p. 2).

In this section of the thesis, only two types of learners' views are presented and it should be noted that numerous other views reflected by learners have not be discussed. However, the two sets of learners' views that are presented highlight the importance of the teacher's role in influencing learners' problem solving views. For instance, in the second model of learners' views discussed in this section, a teacher can have a role in influencing learners to conceptualise mathematics problem solving as a process of searching for an already invented solution path; which means it is rather important to influence learners to be solution inventers. However, how learners view problem solving will depend on the method of instruction the teacher chooses to employ to teach mathematics problem solving. In an interactive environment, where learners are continuously encouraged to express problem solving views, it is possible for learners to invent new problem solving solutions.

2.8 PROBLEM SOLVING ERRORS BY LEARNERS

Learners' problem solving errors are considered in this study for their link with poor performance in mathematics (Prakitipong & Nakamura, 2006). Prakitipong and Nakamura (2006) conducted a study to show that poor performers in mathematics made more problem solving errors than good performers. The study of learners' problem solving errors can be a powerful tool to diagnose learning difficulties and consequently help to design adaptive instruction to improve learners' performance.

In mathematics problem solving learners' actions often contain errors (Schlöglmann, 2007). In the last few decades, several studies have highlighted the nature and types of errors made by learners when solving mathematics problems (Muir, Beswick & Williamson, 2011; Schlöglmann, 2004, 2007). However, only a few studies have examined the nature and causes of these errors in depth.

Naturally, it is expected that learners may turn to make errors when they tackle problem solving tasks in mathematics. Schlöglmann (2007) noted that errors are a permanent component of human thought and action. In mathematics, most of learners' problem solving work is replete with errors (Schlöglmann, 2004, 2007). While there are many reasons for learners' problem solving errors, only a few will be discussed in this section. Schlöglmann (2007) distinguished between two types of learner problem solving errors in mathematics, namely: 1) errors that are based on the incorrect application of a formula; and, 2) errors whose origin is a misconception or inadequate understanding of the mathematical problem. According to Schlöglmann (2007), errors in the first category would not appear if the learners were to use the formula or do the calculation in isolation, rather than as a stepping-stone in a more complex calculation. Such errors are often called "careless mistakes" or "slips" (Schlöglmann, 2007, p. 360).

It is often difficult to decide the category to which learner problem solving errors belong. Usually one needs more information about the problem solver, his or her learning history and performance or mark in mathematics and so on (Schlöglmann, 2007). The second type of Schlöglmann (2007) error is linked to a misconception or inadequate understanding of the concept. This type of error brings the teacher to the fore-front, as the teacher is the main source of information directed to the learners. This means that teachers need to design instruction in such a way that it is misconception-free: it should provide adequate information for learners to understand the concept.

Yeo (2009) conducted a study with 13 to 14 year-old secondary school learners in Singapore (n = 56). The purpose of the study was to explore difficulties faced by secondary learners when engaging in problem solving tasks in mathematics. Semi-structured interviews were used to collect data for the study (Yeo, 2009). From the interviews the following difficulties were

identified as causing learners' problem solving errors: 1) lack of comprehension of problem task; 2) lack of strategy knowledge; 3) inability to translate the problem into mathematical form; and, 4) inability to use the correct mathematics.

The problem solving errors discussed by Yeo (2009) relate to those documented by Schlöglmann (2007). Both studies emphasise correct knowledge base for successful problem solving. Both studies highlight the importance of effective instruction in the treatment of learners' problem solving errors. The link between learners' problem solving errors and instruction has been emphasised by many researchers.

Aspects of learner problem solving difficulties have been emphasised by many researchers. For instance, White (2010) considered that problem solving errors may occur at one of the following phases: 1) reading; 2) comprehension; 3) strategy know-how; 4) transformation; 5) process skill; and, 6) solution. On the other hand, Schoenfeld (1985) suggested four aspects that contribute to problem solving errors, namely: 1) mathematical knowledge; 2) knowledge of heuristics; 3) affective factors that affect the way the problem solver views problem solving; and, 4) managerial skills connected with selecting and carrying out appropriate strategies. Furthermore, Lester (1994) said that errors depicted during the problem solving process could be caused by problem solver characteristics, such as: 1) traits (spatial visualisation ability and ability to attend to the structural features of problems); and, 2) dispositions (beliefs and attitudes and experiential background, such as instructional history and familiarity with types of problems).

McGinn and Boote (2003) conducted a study in which four primary factors that affected learners' perceptions of problem difficulty were identified. These factors were identified as leading to learners' problem solving errors. Identified factors were: 1) categorisation, which refers to the ability to recognise that a problem fits into an identifiable category of problems, which run along a continuum from easily *categorisable* to *uncategorisable*; 2) goal interpretation, which refers to figuring out how a solution would appear, which runs along a continuum from well-defined to undefined; 3) resource relevance, which refers to referring to how readily resources were recognised as relevant (from highly relevant to peripherally relevant); and, 4) complexity, which refers to performing a number of operations in a solution.

The review of literature on learners' problem solving errors suggests that the problem solver's characteristics are the most important determinants of a learner's problem solving errors. However, the issue of learners' background knowledge and familiarity to the problem have also been emphasised in the literature. On the whole, research highlights the following causes of learners' problem solving errors: 1) misconceptions (Schlöglmann, 2007); 2) lack of comprehension of problem task (White, 2010; Yeo, 2009); 3) incorrect application of formula (Schlöglmann, 2007); 4) inability to translate problem into mathematics form; and, 5) inability to use correct mathematics. The following treatment strategies are suggested: 1) strategy know-how (White, 2010; Yeo, 2009); 2) categorisation (McGinn & Boote, 2003); and, 3) resource relevance (McGinn & Boote, 2003). It is therefore important for teachers to understand the fundamental causes of problem solving errors to design instruction that minimises the rate of their occurrence.

2.9 RESEARCH ON PROBLEM SOLVING

Problem solving is generally regarded as the most important cognitive activity in an everyday and professional context (Jonassen, 2000, p. 63). At school, problem solving strategies are a prerequisite for success in mathematics. Various studies have been conducted on the role of problem solving in influencing learners' performance and teachers' strategies in curriculum delivery. These studies have been conducted both locally (Van Loggerenberg, 2000; Gaigher, 2006) and internationally (Jurdak, 2006; Maccini & Hughes, 2000; Yan, 2003; Yan & Lianghuo, 2000).

Jurdak (2006) studied problem solving and its integration to real-life problems and provided four reasons for integrating real-life problems in mathematics, namely, "enhancement of the learning of mathematics; development of competent citizens; development of general problem solving competencies and attitudes; and the utility of mathematical application in solving problems in extra-mathematical areas of everyday life" (p. 283).

Maccini and Hughes (2000) developed a problem solving STAR[14] strategy (model), which was successfully administered, to improve problem solving skills of learners with learning disability at secondary level. One of Maccini and Hughes (2000) research questions was: "Will students improve their performance on representing and solving word problems involving addition, subtraction, multiplication and division of integers?" (p. 11). The participants had experienced "problems with 'past mathematics courses' and 'consequently were either placed in the resource room for basic skills' in mathematics or enrolled in a 'slow-paced' algebra course taken over two years" (Maccini & Hughes, 2000, p. 11). The treatment group, who were subjected to the STAR problem solving strategy, improved their understanding of mathematics concepts. In addition the treatment group were helped to "feel better about their introduction in algebra skills" (Maccini & Hughes, 2000, p. 18). The treatment group scored higher on the tasks given to them compared to the control group.

The STAR problem solving strategy had two distinguishing features: 1) it was specifically designed for learners with learning disability in higher classes; and, 2) it focussed on algebra word problems. The present study focussed on the following aspects: 1) participants were Grade 10 learners who were low-performing in mathematics, not with learning disabilities; 2) the focus was on the topic of Financial Mathematics, not necessarily on algebra word problems. Hence, because of these differences the STAR problem solving strategy could not be adopted for use in the present study.

The study which explored the influence of integrating problem solving strategies with learners' real-life context and the influence of such an instruction on learners' performance in mathematics has not been reported in South Africa. Jurdak (2006) stated that "few theory-grounded studies were conducted on the perspectives of high school students towards problem solving in school and its link to problem solving in the real work" (p. 283). Gaigher, Rogan and Brown (2006) investigated the effect of a structured problem solving strategy on performance and conceptual understanding in South African schools. In a seven-step problem solving strategy, administered to Grade 12 higher grade physics learners, they reported enhancement of

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[14] In the STAR strategy: S stands for 'Search the word problem'; T stands for 'Translate the words into an equation in picture form'; A stands for 'Answer the problem'; and R for 'Review the solution' (Maccini & Hughes, 2000).

problem solving skills and conceptual understanding of physics in the group that participated. The experimental group outperformed the control group by 8% in the mid-year examination (Gaigher *et al*., 2006). Although the Gaigher *et al*. (2006) problem solving strategy succeeded in accelerating the performance of learners in certain topics of Grade 12 physics it could not be adopted for use in the present study because it was inconsistent with the aim of the current study. The aim of the present study places heavy instructional reliance on the integration of real-life context and mathematics instruction, which is not quite explicit in the Gaigher *et al*. (2006) problem solving strategy. Furthermore, the study by Gaigher *et al* is on physics which is completely different from financial mathematics among others from the epistemological and ontological point of view. Nevertheless, Gaigher *et al*'s study does provide evidence that learners' problem solving skills can somehow be improved. Hence, the current study seeks to investigate the use of a context-based problem solving instruction to improve learners' problem solving skills in financial mathematics.

The choice of suitable tasks that link to the learners' contextual settings has also been deemed important. Jurdak (2006) highlighted the challenges of selecting suitable 'situated problem solving' tasks that are authentic to meet the mathematical requirements of the curriculum. Jurdak emphasised "the need for a mathematics problem task to lend itself to multiple approaches and different levels of treatment" (p. 291). The current study observed that a situated mathematics problem task could encourage learners to employ different problem solving strategies that are linked to their everyday contextual background. These types of tasks can encourage learners to reflect and draw from real-life experiences. As Jurdak (2006) acknowledged, "situated problem solving may provide an opportunity for appreciating the power and limitations of using mathematics in the real world" (p. 298).

The present study provided opportunities for learners to develop self-generated or 'self-regulatory' (Perels, Gurtler & Schmitz, 2005) problem solving skills for mathematics. These problem solving skills should be informed by one's contextual background. The researcher observed that such skills should be developed in line with the cognitive demands of the task at hand. Wu and Adams (2006) emphasized the need to link "the demands of problem solving tasks

to the cognitive processes involved" (p. 94). All of these issues need to be considered when reality (context) is brought to class as a tool to enhance teaching and learning.

2.10 FACTORS INFLUENCING MATHEMATICS PROBLEM SOLVING ABILITY

Individual differences in mathematical problem solving ability are difficult to explain. However, there are indications that the ability is not necessarily an in-born or an inherent quality. For instance, Hauser, Santos, Spaepen and Pearson (2002) argued that solving a problem involves using prior experience, observation and insight to find the solution. All of these attributes can be cultivated and nurtured with time, rather than being considered as the products of genetics. An example can be made of someone who walks into a dark room: he or she will solve the problem (bring light to a dark room) by searching for a light switch, even if the room had not been previously visited (Hauser *et al*., 2002).

In this case, the solution to the problem is clearly linked to the fact that the problem solver might have been involved in a similar problem solving situation in previous experiences. The problem solver then uses previously gained problem knowledge and experience to deal with the new problem at hand. In this context, it can be argued that a problem solving schema could have been activated to guide a problem solution process.

Others have also contended that beliefs learners hold about their mathematical capabilities have a strong influence on task performance and problem solving (Leder & Forgasz, 2002, 2004; Malmivuori, 2001). According to Cifarelli, Goodson-Espy and Chae (2010, p. 207), "a student's mathematical beliefs are viewed as conceptions the student holds about mathematics and ideas of how he or she can act within a mathematical context". There has been much research conducted on the essential role of beliefs in learning and teaching mathematics (Goldin, Rösken & Törner, 2009; Philipp, 2007). Consequent to these studies are strong suggestions that there are direct and indirect factors, which influence mathematical problem solving skills, such as: learners' attitude towards mathematics, learners' self-esteem and teachers' teaching behaviour, motivation and self-efficacy (Olowa, 2010; Pimta, Tayruakham & Nuangchalerm, 2009).

Bloom's theory of learning behaviours (Bloom, 1956) specifies three domains of learning, namely: cognitive, affective and psychomotor. According to Pimta *et al.* (2009, p. 382) Bloom's: cognitive domain involves "students' own background knowledge and skills"; the affective domain involves learners' "attitude on the subject, school and learning processes, interest, motivation, self-efficacy, self-esteem, etc."; and the psychomotor domain encompasses "teaching quality factors, namely, instruction acknowledgement, participation in class activities, teacher's sanction system and giving feedback".

Olowa (2010) has argued that the teaching approach used by teachers is very important to the success of the teaching process. Olowa (2010) distinguishes between problem solving instruction and subject matter instruction. According to Olowa (2010), in problem solving instruction "students participate in the learning process by contributing problems, analysing factors associated with the problem, developing possible solutions to the problems, placing the solution(s) into actions, and evaluating the results of the solutions" (p. 34). This is in sharp contrast to the subject matter approach (Olowa, 2010), which "is a teacher-centred approach to teaching where students are more passive participants in the learning process". Students listen to the information, participate in limited discussions, take notes, and retrieve or recall the information for evaluation purposes. With the subject matter approach, the focus is more on acquisition of information than on group-driven problem solving.

2.11 DEVELOPING EFFECTIVE SKILLS FOR PROBLEM SOLVING

Noushad (2008) has argued that "learners can improve their problem solving skills when they become aware of their own thinking as they read, write, and solve problems in school" (p. 1). In their instruction teachers should promote learners' awareness directly by informing learners about effective problem solving skills and discussing cognitive and motivational characteristics of thinking. In terms of cognitive load theory, problem solving skills can be developed when instruction is designed to construct problem solving schemas. In turn problem solving schemas allow learners to relate novel problem solving tasks to the one that were treated in the past.

One of the goals of learning mathematics should be to promote learners' problem solving skills. Therefore teachers must be empowered with instructional techniques that help them to become

effective problem solving instructors. Many researchers have argued that learning by worked examples is an effective method of initial skill acquisition (Renkl, 2005; Schwonke, Renkl, Salden & Aleven, 2010). Worked-out examples have been recommended for their reduction of problem solving demands by providing worked-out solutions (Salden, Aleven, Schwonke & Renkl, 2010; see also section 4.3 for more discussions).

2.12 THE ROLE OF REAL-LIFE CONTEXT IN PROBLEM SOLVING INSTRUCTION

Several studies have explored connections within and across the mathematics curriculum (see, for example, Adler, Pournara & Graven, 2000; Dhlamini, 2009; Dhlamini & Mwakapenda, 2010). Connections within mathematics refer to the integration of topics and units within mathematics as a subject, while connection across mathematics refers to the integration of mathematics with other school subject or with the out-of-school world or the real-life context. Real-life contexts provide another avenue to connect mathematics instruction to learners' experiences. The use of context is emphasised in teaching and learning of mathematics in the new curriculum in South Africa. When properly integrated, the context can "enable the content to be embedded in situations that are meaningful to the learner and so assist learning and teaching" (DoE, 2006a, p. 12). However, to achieve the integration of mathematics with real-life context "the teacher should be aware of and use local contexts, not necessarily indicated in curriculum documents, which could be more suited to the experiences of the learner" (DoE, 2006a, p. 44).

Given that teachers are the implementers of the new curriculum, it is important to orientate them properly with the content of the curriculum. For teachers to be proficient in a context-based curriculum, they need proper training. According to Khumalo (2010, p. 16), "A context-based approach requires educators to accept the notion of a context as the starting point for their instruction in science and mathematics". Therefore teachers must understand issues that constitute a context that could be related to mathematics teaching.

Beasley and Butler (2006) defined context as covering a wide range of issues, such as drugs, medicine, the air we breathe, fertilizers and pesticides, rivers, shops, etc. When these

socioeconomic issues are properly integrated in a mathematics problem solving instruction, the teaching of mathematics is simplified and relevant to the learner. These examples of socioeconomic issues can be adopted by teachers and used as a starting point for designing the units of mathematics work at school.

The use of real-life experience to promote mathematics instruction is not very common (Gaoseb, Kasanda & Lubben, 2002; Khumalo, 2010). For instance, Gaoseb *et al.* (2002) conducted a study in which they examined and compared the use of everyday contexts by mathematics and science teachers. Participants in this study were the teachers who were in the final stage of the Mathematics and Science Teachers Extension Project (MASTEP) in-service training program. The findings of this study indicated that science educators use out-of-school experiences more than mathematics teachers do (Gaoseb *et al.*, 2002). This study shows that mathematics teachers were more reluctant to include real-life experiences in their instruction as compared to the science teachers.

Mathematics teachers must realize that problem solving skills are not only needed in classrooms settings, but, they may also prove to be an important attribute in situations beyond classroom. In real-life world people are constantly expected to do estimations, to predict relationships and patterns, to construct organised list of items, and so forth. Efficiency in these real-life tasks may require a certain level of expertise in problem solving abilities. Unfortunately, what is happening in many mathematics classrooms is that many learners are being taught their basic skills without ever having to apply them in everyday problem solving situations (Anderson, Olson & Wrobel, 2001). This lack of connection may lead learners to look at mathematics as separate from the real-world issues (Anderson *et al.*, 2001).

Recently, South Africa developed a rigorous curriculum which encourages connection within school subjects, and also connections between subjects and real-life contexts (Dhlamini, 2009; Mwakapenda & Dhlamimi, 2010; Adler, Graven & Pournara, 2000). In addition, the curriculum has mandated the teaching of problem solving skills in mathematics (DBE, 2011b). The Curriculum and Assessment Policy Statement (CAPS) states that "problem solving should be central to all mathematics teaching" (DBE, 2011b, p. 7). Furthermore, the importance of

incorporating real-life contexts in mathematics instruction is also receiving special focus in the new curriculum documents (DBE, 2011b). As part of its general aims, mathematics curriculum should "promote the idea of grounding knowledge in local contexts" (DBE, 2011b, p. 3).

Against this backdrop, there is a need to encourage learners to formulate and solve problems that relate to real-life situations so that they can see the significance of mathematics to their lives. This form of instruction will help learners to "create their own way of interpreting an idea, relating it to their own personal life experience, seeing how it fits with what they already know, and how they are thinking about related ideas" (Anderson *et. al*., 2001, p. 29). Making and encouraging these connections in mathematics classrooms will improve learners' interest in the subject and subsequently the desired productivity.

2.13 CONTEXT-BASED AND PROBLEM SOLVING APPROACH IN A SOUTH AFRICAN CONTEXT

In recent times, curriculum reforms have been observed in various countries across the world. Countries like Finland, Australia, China, Singapore, United States and United Kingdom have recently reshaped their education systems (Acharya, 2003; Atweh & Clarkson, 2003; Huang, 2004; Yu & Davis, 2007). Each of these countries had hoped to increase labor productivity and promote economic development and growth through expanded and improved education (Sahlberg, 2006). In South Africa, when the new Government of National Unity (GNU) took over in 1994, it also initiated a political programme aimed at transforming all aspects of the education system, including the curriculum (Aldous, 2004; Bansilal *et al*, 2010).

The rationale for curriculum change in South Africa was shaped by a growing public concern that: school knowledge was seen as failing to make a meaningful connection with the out-of-school context; and the fact that many learners participating in the school system were not acquiring problem solving or critical thinking skills (DoE, 2002; Mji & Makgato, 2006; Mullis, Martin & Foy, 2008). Curriculum 2005 (C2005[15]), which was based on the philosophy of

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[15] In 1997 the Council of Education Ministers (CEM) made the decision to replace the old apartheid curriculum with a progressive Outcome Based education (OBE) system. In 1998 OBE was introduced into all South African schools in General Education and Training (GET). The new certificate, which replaced the Senior Certificate, is called a

Outcomes-Based Education (OBE), was introduced in South African schools for the first time in 1998; later its revised model (the National Curriculum Statement [NCS[16]]) followed in 2003 (Bansilal *et al*., 2010; C2005 Review Committee, 2000; Lombard & Grosser, 2008). Amongst other things, implementation of the new curriculum was guided by the view that school knowledge be constructed on the basis of learners' everyday context - be it real or 'fantasy' (Ainley, Pratt & Hansen, 2006) - in order to enhance learning experiences by learners. Everyday experience then became a unifying basis to facilitate the education of learners (DoE, 2005; see also DoE, 2006a & DBE, 2011b).

This would mean that in order to facilitate learners' understanding of a particular topic in mathematics, a teacher would have to draw from a familiar context that appealed to learners. This idea is also emphasised in the DoE (2006a) curriculum document, which emphasised that "tasks and activities should be placed within a broad context, ranging from the personal to home, school, business, community, local and global" (p. 19). The NCS envisages learners who actively take part in learning experiences tailor-made for the context in which they find themselves (Reyneke, Meyer & Nel, 2010), with realistic contexts an essential tool for learning in OBE-oriented instruction.

Further analysis of OBE also reveals that, among other things, cultivation of problem solving skills has prominence in the mathematics curriculum. For instance, the Curriculum Statement for mathematics emphasizes that "mathematical problem solving ability enables us to understand the world and make use of that understanding in our daily lives" (DoE, 2006a, p. 20). As a subject, mathematics includes both knowledge and skills as focal areas. The domain of knowledge includes numbers and relationships, patterns and algebra, space and shape, measurement and

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Further Education and Training Certificate and was awarded for the first time in 2005. Because of this, the new curriculum became known as Curriculum 2005 (C2005).

[16] The introduction of OBE in South African schools generated tension that was linked to a range of concerns held by educators and other stakeholders - both government and civil society. Among other things, there were complaints that it was not understandable at classroom level because of use of language that was not understood by teachers (Cross, Mungadi & Rouhani, 2002). The tension led to the national curriculum review and the revision process of C2005 in the light of recommendations made by a Ministerial Review Committee appointed in 2000 (Chisholm, 2005). The review process culminated in the birth of the currently espoused National Curriculum Statement (NCS) model, and with its emergence the notion of C2005 faded into the background.

data handling, as areas of importance; skills include representation and interpretation, calculation, reasoning, problem posing and solving (DoE, 2002).

From this background it can be argued that one of the goals of teaching mathematics is to develop the mathematics problem solving skills of the learners. Mathematics teachers should create realistic contexts to enable learners to achieve OBE-related educational outcomes. Despite the introduction of the OBE curriculum, poor performance in both Grade 12[17] results and FET mathematics remains persistent in South Africa (Reddy, 2007; South African Institute of Race Relations [SAIRR], 2011; Van der Berg, 2007). Researchers have noted that OBE curriculum has not succeeded in assisting learners to acquire the fundamental problem solving skills and envisaged conceptual knowledge (Carnoy & Chisholm, 2008; Cross, Mungadi & Rouhani, 2002; Howie & Plomp, 2002). When using Grade 12 end-of-the-year examination results (matric[18] results) as a basic measure to assess the effectiveness of the implemented OBE curriculum it appears that our education system, together with our learners' mathematics problem solving performance, is currently in crisis.

For instance, despite an impressive 73.3% senior certificate pass rate in 2003 (an improvement from 47% in 1997) from 2004 onwards, there has been a slight drop in the pass rate each year (Education Foundation, 2010; see also Table 2.1). In 2008 only 62.5% of candidates prepared for the final NCS external examination passed, and in 2009 the pass rate dropped to a disappointing 60.7% (Reyneke *et al*., 2010). There is a worrying downward trend in the Grade 12 pass rate each year, despite countless efforts to improve the education system.

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[17] It must be noted that at the time of conducting this study, a standard examination was only written at the end of Grade 12 in South Africa, and it is at this level where learners' acquired knowledge and skills are evaluated through standardised national examination. The Grade 12 examination results have been used as an indicator of SA learners' performance at school level (Howie & Plomp, 2002).

[18] A matric is a national examination that South African secondary school learners have to pass in order to be admitted to a university.

Table 2.1: Grade 12 pass rates from 2003 to 2009

Year	2003	2004	2005	2006	2007	2008	2009
% pass	73.3	70.7	68.3	66.5	65.2	62.7	60.6

Source: Education Foundation (2010)

In mathematics, the trend is no different. For instance, after analysis of 2008 Grade 12 mathematics and science results, Maths Excellence (2009) reported that "recently *The World Economic Forum* ranked South Africa 120th for mathematics and science education, well behind our troubled neighbour Zimbabwe (ranked 71st)" (p. 1). It is also observed that many learners desist from taking mathematics as a subject at FET level (see Table 2.2).

Table 2.2: Grade 12 mathematics performance trends from 1995 to 2006

Year	Grade 12 candidates who wrote mathematics	Candidates who passed mathematics	% of learners who passed mathematics
1995	531 453	29 475	5.5
1996	513 868	22 416	4.4
1997	558 970	19 575	3.5
1998	552 384	20 130	3.6
1999	511 159	19 854	3.9
2000	489 298	19 327	3.9
2001	449 332	19 504	4.3
2002	443 765	20 528	4,6
2003	440 096	23 412	5.3
2004	467 890	24 143	5.2
2005	508 180	26 383	5.2
2006	351 503	25 217	7.2

Source: Education Foundation (2010)

The matric results seen in Table 2.2 suggest that very few learners passed mathematics in South Africa between 1995 and 2006. Consequently, very few learners are being prepared to skillfully apply mathematical problem solving skills in real life situations. It also seems that few learners who pass mathematics are not adequately prepared in terms of mathematics knowledge and problem solving skills. Howie and Plomp (2002) note that "much of the basic mathematics knowledge expected of pupils leaving school has not been attained by them" (p. 23). There is an urgent need to address these educational problems, particularly from a mathematics perspective.

Furthermore, international and cross-national studies have raised serious concerns about the state of mathematics problem solving in South Africa (Trends in International Mathematics and Science Study [TIMSS]; the Monitoring Learning Achievements [MLA] initiative; the Southern Africa Consortium for Monitoring Educational Quality [SACMEQ]-initiated studies; and Performance in International Student Achievement [PISA]; Reddy, 2007). South Africa participated in TIMSS in 1995, again in 1999 (TIMSS-Repeat or TIMSS-R) and also in 2003, and the problem solving performance of South African learners has continued to reveal poor mathematics skills when compared with other participating countries (Bansilal et al., 2010; Howie, 2001, 2006; Reddy, 2007). In 1995, South Africa participated in TIMSS, which is conducted under the auspices of International Association for the Evaluation of Education (IEA), alongside 41 countries, and South African Grade 8 mathematics learners came last, with a mean score of 351 points out of 800 points (Howie, 2001). This mean was significantly lower than the international benchmark of 513 (Howie, 2001; Mji & Makgato, 2006).

The repeat of a dismal performance by South African Grade 8 mathematics learners was manifested in the TIMSS-R 1999: the mean score of 275 achieved against the international mean of 487 generated major concerns in education circles. This mean of 275 was lower than that of Morocco, Tunisia and other developing countries, such as Chile, Indonesia, Malaysia, and the Philippines (Howie, 2001; Mji & Makgato, 2006). Results from the TIMSS 2003 showed no improvement. For instance, out of the six African countries that participated in TIMSS 2003, South Africa came last. Egypt, Botswana and Ghana made their debut in 2003, but successfully outperformed South Africa, which had participated in previous studies (Reddy, 2007).

It seems that efforts to improve our education standard have not yielded positive outcomes. Some researchers have noted that learners' inability to translate their problem solving school knowledge to everyday living is a great concern in education circles (Khuzwayo, 2005; Van der Berg, 2007). Poor teacher training, teachers who lack content knowledge and low levels of confidence when teaching mathematics and science, and the fact that most teachers were trained in specific subject fields, have all been cited as reasons for teachers' inability to integrate school knowledge with out-of-school knowledge and to instil problem solving skills in learners (Adler *et al*., 2000; Howie & Plomp, 2002; Onwu & Mogari, 2004; Pretorius, 2008; Reddy, 2007). Currently there are calls to replace the new NCS curriculum and for schools to revert to conventional ways of teaching and learning in South Africa. For example, the current Minister of Basic Education, Angie Motshekga, in her public address to the National Assembly on the 5th of November 2009 declared:

> "The question on everyone's lips is why we do not, as Mamphela Ramphele[19] always wants us to do, declare the death certificate of outcomes-based education, OBE? I must say that we have, to all intents and purposes, done so. So if anybody asks us if we are going to continue with OBE, we say that there is no longer OBE. We have completely done away with it." (Equal Education, 2010).

Non-governmental organisations (NGO), like SAIRR, have recently denounced the new curriculum's inability to assist school leavers to progress rapidly into the job market as a result of a deficiency in basic literacy and numeracy skills (SAIRR, 2011).

Given these calls, the NCS curriculum has recently been replaced by the Curriculum and Assessment Policy Statement (CAPS) (DBE, 2011b). The CAPS curriculum for mathematics emphasizes the need to teach problem solving strategies at school level. For instance, it emphasizes that "mathematical problem solving enables us to understand the world (physical,

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[19] Dr. Mamphela Ramphele is the Managing Director of Human Development Network at The World Bank Group. She has worked as a Medical Doctor, Civil Rights Leader, Community Development Worker, Academic Researcher, and a University Administrator. She joined the University of Cape Town as a Research Fellow in 1986, and was appointed as the Deputy Vice-Chancellor five years later. In September 1996 she took up her post as Vice Chancellor, becoming the first black woman to hold this position at a South African university. She holds a Ph.D. in Social Anthropology from the University of Cape Town, a B.Com in Administration from the University of South Africa and diplomas in Tropical Health and Hygiene and Public Health from the University of Witwatersrand.

social and economic) around us, and, most of all, to teach us to think creatively" (DBE, 2011b, p. 6). However, there are no clear guidelines on how learners' problem solving abilities can be evaluated and assessed (Wuttke & Wolf, 2007). Wuttke and Wolf (2007, p. 86) have further noted that:

- "most teachers are unsure of how learning environments can be structured in order to increase a person's ability to solve complex problems (lack of known methods);
- teachers think that rudiments and basic skills have to be taught first before they can move on to more demanding topics like problem solving;
- while a person's ability to solve problems is a learning objective in curricula, it is unclear how it can be evaluated".

CAPS further highlights the significance of grounding mathematical knowledge in a local context, hence, in this study, the ability of a context-based problem solving instruction method to enhance learners' problem solving skills is tested. According to Gainsburg (2008), context-based problems are expected to have many benefits in education settings, such as:

- enhancing learners' understanding of mathematical concepts;
- motivating mathematics learning; and,
- helping learners apply mathematics to real problems, particularly those arising in the workplace.

From the discussion provided, it is possible to conclude that attempts must be made to assist learners to develop their problem solving skills in mathematics. It also seems that these attempts have to be made as soon as possible.

2.14 DISPARITIES IN MATHEMATICS PROBLEM SOLVING PERFORMANCE BETWEEN LEARNERS OF DIFFERENT SOCIOECONOMIC STATUS

The last decade has seen issues of socioeconomic disadvantage and mathematics performance dominating policy-making agenda and academic debate in South Africa (Baloyi, 2011; Tsanwani, 2009). Township schools have always been described as under-achieving in

mathematics when compared to schools in the urban areas. According to Tsanwani (2009, p. 17), "under-achievement in mathematics is particularly recognised as a major problem in schools serving disadvantaged communities in South Africa".

Performance disparities in mathematics performances by schools in township and urban backgrounds have generated a lot of questions. The aim of this section is to investigate how the literature explains observed mathematics performance disparities amongst learners from different socioeconomic locations – defines as black and white learners - which are served by the same education system.

There is abundant evidence to suggest that schools in disadvantaged communities lag behind when compared to schools in economically advantaged communities. Several studies have shown that "historically white and Indian schools, located in economically advantaged communities, still outperform black and coloured schools by far in the matriculation examination and performance tests" (Van der Berg, 2007, p. 2). This view is corroborated by the Gauteng Department of Education (GDE) (2010) report on Gauteng schools' performance in mathematics and science in secondary schools, which conceded, "the majority of mathematics and science passes are still from independent and former model C schools" (GDE, 2010, p. 12).

Evidence of this is also demonstrated in a study conducted by the Consortium for Research on Educational Access, Transitions and Equity (Create) in township schools in June 2009. The study involved 12 township schools from two South African provinces (Gauteng and the Eastern Cape) in which: 487 Grade 5 learners wrote the Grade 4 mathematics tests; 662 Grade 7 learners wrote the Grade 6 mathematics tests (Create, 2010). Both tests were administered in English and had been designed as achievement tests with some diagnostic elements (Create, 2010). According to Create (2010), the tests had been aligned to the National Curriculum Statement assessment requirements. Each contained items that would assess numeric skills in each of the five mathematics Learning Outcomes[20] (LOs).

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[20] According to DoE (2002), the Learning Outcomes (LO) for mathematics at both the intermediate (Grade 4 – 6) and senior (Grade 7 – 9) phases are grouped as follows: **LO1**: Numbers, Operations and Relationships; **LO2**: Patterns, Functions and Algebra; **LO3**: Space and Shape (Geometry); **LO4**: Measurements; and, **LO5**: Data Handling.

Results from this study suggested that township school learners are struggling to master basic competences and fundamental skills in mathematics. This was observed from their test scores obtained from achievement tests that were below their actual grade level. For instance, the average score achieved by Grade 5 learners on the Grade 4 test was 23.5% (Create, 2010, p. 4). The results were equally disappointing for the Grade 7 test subjects. At this grade, "an equally low mean score of 28.1% was achieved by learners on the Grade 6 test" (Create, 2010, p. 4). In Figure 2.2 and Figure 2.3 the mean performance of learners, tested on their ability to demonstrate competency in different numeracy and mathematics skills, is presented.

Figure 2.2: Mean percentage scores per numeracy skill by Grade 5 learners
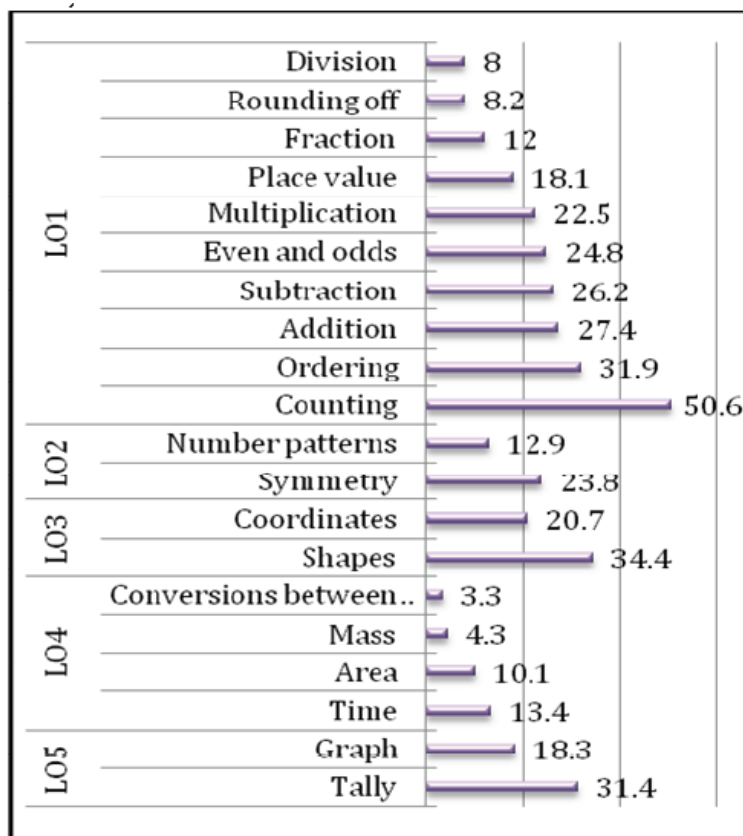
Source: Create (2010, p. 3)

According to Figure 2.2, Grade 5 township learners could only achieve a respectable mean percentage in the counting skill in which they achieved a mean percentage of 50.6%. However, these learners struggled to perform as well in skills involving division, rounding off and making conversions, in which they achieved 8.0%, 8.2% and 3.3%, respectively. The results were also not impressive for the Grade 7 learners. Learners in this grade performed averagely in mathematics skills requiring them to deal with number patterns and perspectives: they scored 55.5% and 57.4%, respectively. However, the performance is clouded by the demonstrated average inability to perform other related Grade 6 mathematics skills. They are unable to perform mathematics skills relating to rounding off, adding and subtracting, ordering of fractions and problems dealing with central tendencies, etc. (see also Figure 2.3).

Figure 2.3: Mean percentage scores per numeracy skill by Grade 7 learners

	Skill	Score
LO1	Ordering Whole..	42.3
	Fractions, Decimals,...	24.6
	Multiply & Divide	24.3
	Place Value	19.3
	Ordering Fractions	17.6
	Add & Subtract	14.4
	Rounding Off	5.6
LO2	Number Patters	55.5
	Geometric Patters	34.1
	Equations	27.2
LO3	Perspective	57.4
	2-D Objects	32.9
	Transformation	30
LO4	Mass	36.1
	Length	24.8
	Time	23.8
	Capacity	19.1
LO5	Central Tendencies	7.5
	Data Interpretation	27.3
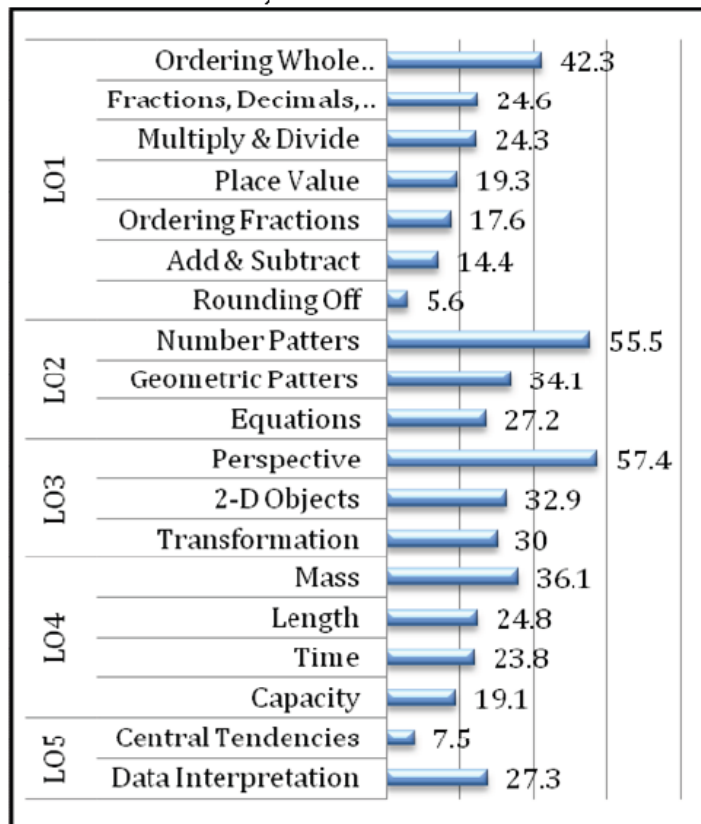
Source: Create (2010, p. 3)

These results in Figure 2.2 & Figure 2.3 suggest that most learners in township schools fail to achieve learning outcomes as expected by the NCS. On average, their performance in mathematics and numeracy is below expectation. This may mean that many learners in disadvantaged communities are failing to learn mathematics in the topics that are indicated in Figure 2.2 and Figure 2.3.

On the other hand, the performance of learners in former model C schools is well beyond that of their township counterparts. In this regard, Van der Berg (2007) noted that the white population has education levels similar to those of developed countries. The same cannot be said of black learners attending schools in township areas. According to GDE (2010, p. 12), the challenges faced at primary and high schools in respect of mathematics and science education have predictable consequences in higher education. This report further demonstrate that former white universities continue to outperform former black universities in science, engineering and technology (SET) related fields (GDE, 2010). The statistics in Figure 2.4 confirm these assertions.

Figure 2.4: The performance of learners in mathematics and science subjects in former black and white schools[21]
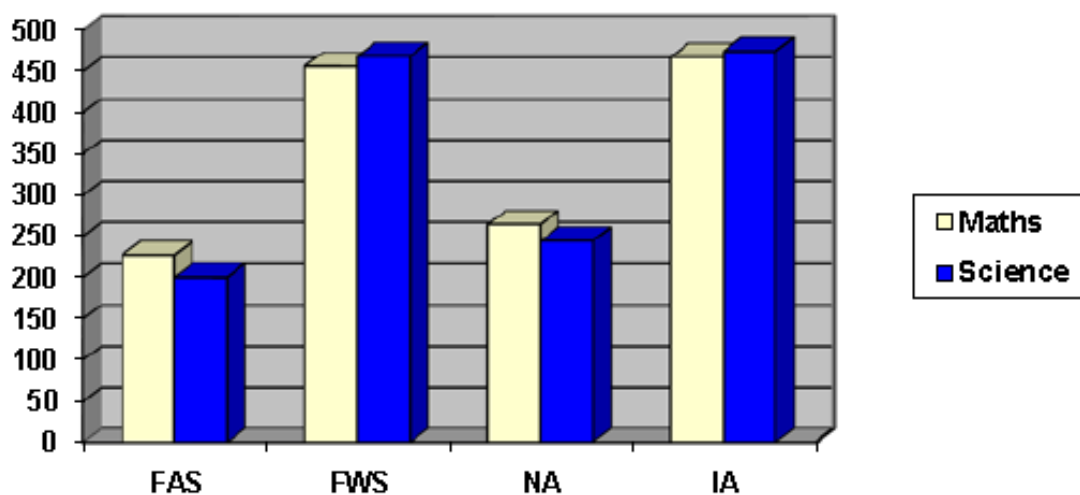
Source: GDE (2010, p. 12)

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[21] In figure 2.4, the following codes have been used: **FAS** = Former African schools; **FWS** = Former White schools; **NA** = National Average; and, **IA** = International Average.

The statistics in Figure 2.4 suggest that the former white universities continue to produce more than double the number of SET graduates compared to the former African universities (GDE, 2010). Learners from former white schools (FWS) perform at a level comparable to that of international average (IA). It seems the gap between the performance of FWS and FAS learners is too large to be considered negligible.

Since 1994, there have been several attempts to transform the education system in South Africa (Baloyi, 2011). These attempts have been received with mixed feelings, while in some sectors they have been described as being slow-paced. In terms of these changes, Baloyi (2011) has noted, "Not enough has been done to address educational inequalities inherent in the system and in particular, to equalize learner performance between former white and former black schools" (p. 11). In section 1.3, background to this problem was provided. With its 1948 victory, the National Party (NP) government did not hesitate to impose race-conscious laws of which black citizens became the primary victims (Beinart, 2001; see also section 1.3).

In 1994, the African National Congress won the democratic elections, after which a Government of National Unity was formed. The new government also wasted no time in repealing all race-conscious laws propagated by the NP regime. The reforms also led to the formation of a new curriculum. With the introduction of the new curriculum, there was renewed interest in the politics of performance gaps between black and white schools in South Africa (see, for example, Baloyi, 2011; Brodie, 2004; Jansen, 2001; Tsanwani, 2009). In particular, Jansen (2001) has explored issues around performance gaps between former white (model C) and former black (township) schools.

Jansen (2001) explored issues of autonomy, accountability and assessment. In the Jansen article, the state's rush to focus on teachers' and learners' performance, without giving priority to the issues of curriculum innovation, is questioned. According to Jansen (2001), the state must first address critical issues of performance imbalance between schools in different socioeconomic locations before focussing on educational outputs. Jansen argues that the latter "diverts attention from making the required educational input needed to redress the historical inequalities of an apartheid education system" (Jansen, 2001, p. 555). According to Baloyi (2011, p. 16), Jansen's

argument is that the state's rush to focus on performance is premature because "there are still huge investment gaps between former white (model C) and former black (township) schools". Given this reality, the performance comparability between the two school groups is not possible. What comes up from both Baloyi (2011) and Jansen (2001) is that issues of performance disparity amongst learners from different races cannot be resolved within a short space of time. The state should invest most of its educational resources in trying to address observed issues of performance disparity. Other researchers have explored this issue by investigating possible variables that are likely to influence learners' performance in mathematics. For instance, Jansen (2001) identified the following factors as influencing learners' mathematics performance: 1) lack of educational resources; 2) poor school infrastructure and upgrading; and, 3) poor teacher training and curriculum development. Unfortunately these conditions are more prevalent in township schools where a majority of black learners receive their education (Baloyi, 2011). Conditions in former white schools are relatively better. Hence performance disparities between these school groups will perpetuate.

In 2000, the Southern African Consortium for Monitoring Education Quality (SACMEQ) conducted a study in which it evaluated the mathematics ability of grade 6 mathematics learners in 14 countries. The SACMEQ results showed that South Africa fell into the bottom half of the group and that the difference in scores between socioeconomic classes (SES) was almost 100 points in both categories (Gerard, 2011; see also section 1.3 and Table 1.3). Following these findings, Van der Berg and Louw (2007) conducted a study to investigate factors relating to poor performance by South African grade 6 mathematics learners in general and the learner disparities between learners from middle and low-income groups. The following factors were identified as the main causes of under-performance by South African learners, particularly in township schools: 1) monitoring of learners' progress by school principals; 2) teacher absenteeism; and, 3) teacher quality. According to Baloyi (2011), these factors were largely influenced by socioeconomic status, which puts learners from richer families at an advantage over learners from poor families (see also, Van der Berg, 2005).

Several studies, including TIMSS studies, have confirmed that many learners in South African schools do not sufficiently master the knowledge and skills underlying learning and problem

solving (Maree, Aldous, Hattingh, Swanepoel & Van der Linde, 2006). Maree *et al.*, (2006) have also raised concerns about a vast gap between the quality of schooling provided and the achievement of white and black learners. According to Maree *et al*. (2006), "since the Grade 12 national examination results still largely determine whether a learner will be accepted to sought-after fields of study at tertiary institutions, technological and scientific fields of study in particular are, by large, out of reach for black learners" (p. 229).

As in the previously cited studies, there are a number of variables associated with poor performance in black schools. Some of these are worth mentioning in this report, e.g.: poor socioeconomic background of learners, lack of appropriate learner support materials, general poverty of school environment, general poor quality of teachers and teaching, language of instruction often not the same as learners' mother tongue, and inadequate study orientation (Maree *et al*., 2006). Studies that have been discussed in this section seem to suggest that socioeconomic variables are important factors to consider when studying learners' performance.

2.15 SUMMARY OF THE CHAPTER

In this chapter, an attempt was made to describe concepts such as *problem solving* and *problem solving ability*. In section 2.3 and section 2.4, an explanation was provided of the two types of problem solving models, namely the traditional and the current models. In section 2.4 the significance and relevance of the current model of problem solving to the current study was clearly elucidated. The discussion on the role of teachers' views on problem solving, as it is discussed in section 2.6, played an important part in explaining the role of teachers' influence on learners' problem solving performance.

The role of real-world contexts in influencing learners' problem solving performance was discussed in section 2.12 and section 2.13. In section 2.12, the role of real-world context in influencing problem solving was explored. The chapter closes by providing a discussion on the influence of context-based problem solving instruction on the South African learner. This discussion was extended by exploring problem solving performance disparities between learners of different socioeconomic backgrounds (see also section 2.14).

Because problem solving is a cognitive activity, in the next two chapters, discussion on the relation between problem solving activity and cognition are provided. These discussions begin with a useful description and explanation of human cognitive architecture (Chapter 3) and how this knowledge can be used as a framework to explain human problem solving processes. In Chapter 4, a theoretical framework for the study is presented and further used to explain human cognitive assumptions that influence complex problem solving processes by learners.

CHAPTER THREE

COMPONENTS OF HUMAN COGNITIVE ARCHITECTURE

3.1 INTRODUCTION

In this chapter, the structure of the human cognitive system or cognitive architecture is discussed. For this purpose, cognitive science is used to explain components of the human cognitive system that are said to influence learners' problem solving behaviour and performance. This explanation is necessary because cognitive load theory (CLT) (Sweller, 1988) was used to frame this study (see Chapter 4). CLT suggests that learning, which in the current study constitutes learners' acquisition of problem solving skills, happens under conditions that are aligned with human cognitive architecture (Paas, Renkl & Sweller, 2004). The chapter also examines some properties of cognitive architecture that influence learners' problem solving performance and learning in general.

3.2 HUMAN COGNITIVE ARCHITECTURE

The term *cognitive* refers to perceiving and knowing (Rockwell *et al*., 2011). Cognitive scientists seek to understand the science of mental processes, such as: perceiving, thinking, remembering, understanding language and learning (Sorden, 2005). Cognitive architecture is defined as "an underlying infrastructure that influences the thinking and learning processes in an intelligent system, such as a human being" (Langley *et al*., 2007, p. 1). In terms of this definition, all human mental life and behaviour involve the cognitive system or cognitive architecture. For instance, perceiving everything around us involves using our cognitive system to recognise and categorise what we see, hear, taste, touch or smell.

In order to see, hear, taste, touch or smell, the cognitive system relies on its internal components, such as working memory and long-term memory. Human cognitive architecture can thus be described further as the concept of the human mind comprising cognitive structures such as working memory, long-term memory and schemas (Khateeb, 2008; Song, 2011). The structural arrangement of cognitive components and the interplay between them constitute the cognitive

architecture of the human mind. Cognitive architecture can provide a principled way to examine the extent to which mechanisms other than knowledge may influence learning and problem solving skills development. In the next section, the researcher explores the historical background to human cognitive architecture, or memory, and the models designed to explain its functionality.

3.3 MODELS OF MEMORY

Over the years, several approaches or paradigms have been used to describe the concept of memory. For instance, in 1890 Hermann Ebbinghaus[22] proposed that memories were simply associations of ideas. The *associationist paradigm* suggested by Ebbinghaus attempted to determine how new associations were made by presenting new information (Bower, 2000). Ebbinghaus was able to demonstrate that the more often a list of items is repeated, the less time is needed to re-learn the items, and that if a delay is imposed then more are likely to be forgotten.

It is clear that the *associationist approach* conceptualised memory as a passive process, in which we simply take in, store and recall. Bartlett's (1932) *constructivist approach,* on the other hand, conceptualised memory as an active process. The latter approach claimed that meaningfulness and understanding are critical to memory. Yet another (alternative) view characterised memory as a flow of information (discussed in section 3.4). This information-processing attribute of memory has been the most accepted paradigm since the 1950s, and has resulted in many significant research theories and memory models, such as those discussed in the following section.

3.3.1 Memory model proposed by Waugh and Norman

Waugh and Norman (1965) proposed a memory model that is shown in Figure 3.1.

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[22]It is assumed that Hermann Ebbinghaus lived between the years 1884 and 1964 (Hoffman, Bamberg, Bringmann & Klein, 1985). According to Hoffman *et al*. (1985, p. 57), "little has been written about Ebbinghaus in English, or in German, and there is no biography in his name". However, it is claimed that Ebbinghaus left a few autobiographical notes, especially notes that referred to the important period he spent travelling in England and France. Despite there being little information about him, his 1885 classic work, *On Memory*, has distinguished him as a research icon in the field of psychology. This work is regarded as a major accomplishment in the application of the experimental method to psychological questions. He is generally credited with founding the experimental psychology of the "higher mental processes" (Hoffman *et al*., 1985, p. 58).

Figure 3.1: Waugh and Norman's memory model
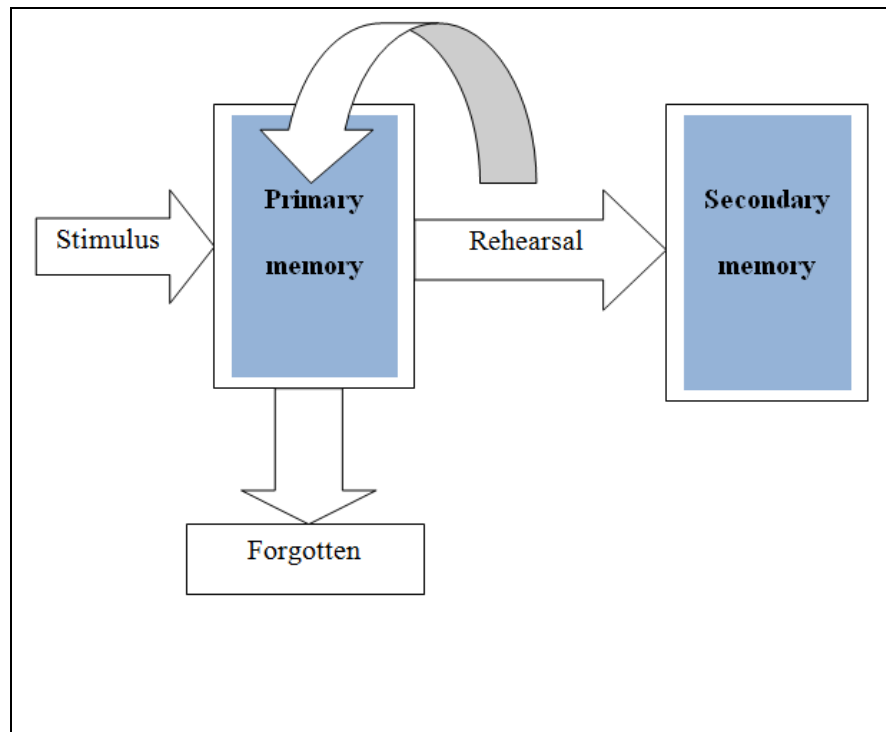
Source: Khateeb (2008, p. 5)

The model distinguishes between two kinds of memory, i.e. the primary memory and the secondary memory. This model assumes that a stimulus entering the primary section of the memory system must be rehearsed quickly, otherwise it would be lost or forgotten (Khateeb, 2008). As more stimuli enter the primary memory, the old stimuli are 'pushed out' because it has limited capacity. The new stimulus has to be rehearsed to enable storage in the permanent section of the memory (known as the secondary memory) otherwise it gets forgotten (Waugh & Norman, 1965). Once knowledge is kept in the secondary memory, there is no need for further rehearsal processes.

In Cooper's (1998) model (Figure 3.3), the primary memory is represented by the working memory. Cooper's long-term memory is equivalent to secondary memory in Waugh and Norman's model. These models conceptualise almost identical memory models for the human cognitive system.

3.3.2 Memory model proposed by Atkinson and Shiffrin

Atkinson and Shiffrin (1968, cited in Khateeb, 2008) suggested a memory model very similar to that of Waugh and Norman (1965) and Cooper (1998). However, Atkinson and Shiffrin (1968, cited in Khateeb, 2008) model is a more complex and integrated version. This model is represented in Figure 3.2:

Figure 3.2: Atkinson and Shiffrin (1968) multi-store memory model
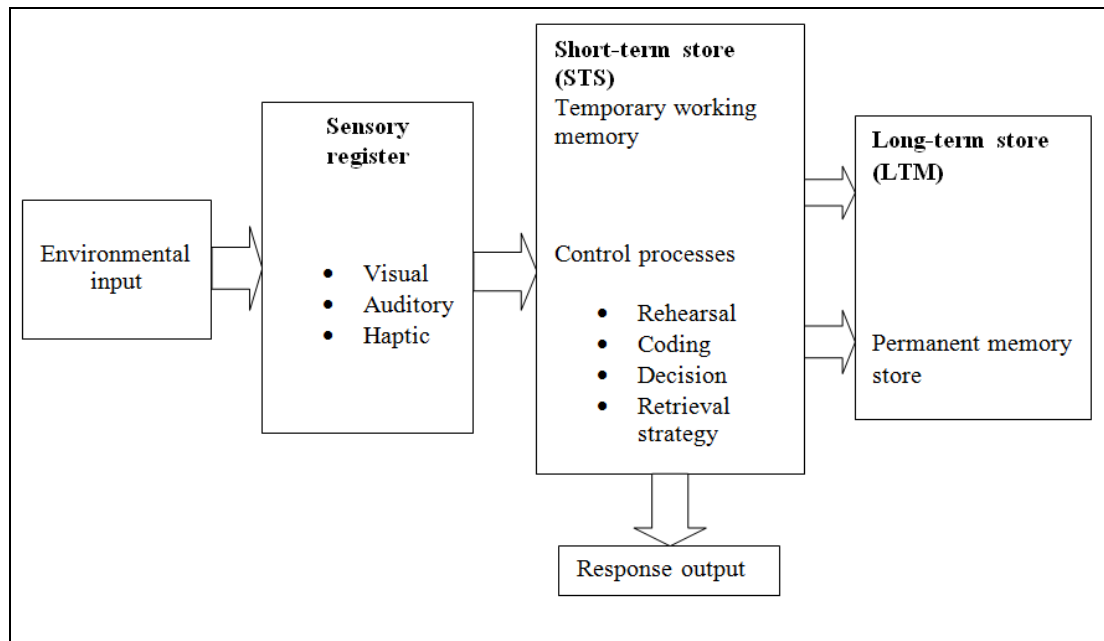
Source: Khateeb (2008, p. 6)

Most studies of human cognitive architecture have relied on the Atkinson and Shiffrin (1968, cited in Khateeb, 2008) model as a basis for argument. This model is different from that of Waugh and Norman (1965) in that it adds a third component, namely, the sensory register. The concepts of short-term storage and long-term storage were first introduced by Atkinson and Shiffrin (1968, cited in Khateeb, 2008), who conceptualised how information flows through the *sensory register*, the *short-term memory* and the *long-term memory*.

3.3.2.1 The sensory register

According to Atkinson and Shiffrin's (1968, cited in Khateeb, 2008) model, information from the surrounding environment enters the memory system through the sensory register. This is achieved through a number of transitory memories (in the form of visual, auditory and haptic sensory systems) before the incoming information is passed to the short-term store. According to Khateeb (2008), "in Atkinson and Shiffrin model, the sensory register acts as a pathway for the short-term store" (p. 7).

3.3.2.2 The short-term store

Khateeb (2008) explained that a short-term store is a temporary section in which information is kept for a period of time, which is usually under the control of the subject. During this period, information is consciously processed and stored in the short-term store by rehearsal. In this model, Atkinson and Shiffrin (1971) also assumed the capacity of the short-term store to be extremely limited. Despite this major shortcoming, the short-term store was considered a critical component of the memory system, where activities such as decision making and problem solving occurred.

Using this framework, Atkinson and Shiffrin (1971) proposed the following definition for the short-term store: "A system in which decisions are made, problems are solved and information flow is directed" (p. 3). These actions they regarded as output responses of the long-term store. Atkinson and Shiffrin (1971) observed that the output response of the short-term store is dependent on the long-term store.

3.3.2.3 The long-term store

This section of the memory is regarded as a long-term or permanent memory store (Khateeb, 2008). After information has been processed in the short-term store it is transferred to the long-term store to be stored for a longer time or permanently. However, this can only be achieved through rehearsal (Khateeb, 2008). According to Atkinson and Shiffrin (1971), the longer an item has been maintained in the short-term store by rehearsal, the more likely it is to be transferred to the long-term store. Unlike the short-term store, "the long-term store is assumed to

be unlimited, both in its capacity and in its duration" (Khateeb, 2008, p. 7). It can hold huge chunks of information for a very long period.

Using this knowledge, one can assume that the quality of rehearsal taking place at the short-term level determines the manner in which knowledge is eventually stored at the long-term level. Using these models, Figure 3.1, Figure 3.2 and Figure 3.3, it is possible to discuss each of the components of the memory system.

3.4 MEMORY TYPES AS CONCEPTUALISED TODAY

The model presented by Cooper (1998) is the most recently adopted to represent human cognitive architecture (see Figure 3.3). Figure 3.3 illustrates how we learn through remembering. Memory has components that help us to remember information. However, what we see and remember depends more on what we already know than on what is actually presented to us (Cooper, 1998). What we already know is stored in the long-term memory in the form of schemata. The two arrows pointing in opposite directions between the working memory and the long-term memory sections in Figure 3.3 illustrate the interaction between the two memory modes. According to this arrangement, knowledge and skills stored in the long-term memory can be sent back to the working memory as and when required. Cooper's (1998) example below can be used to illustrate this point.

1. THE CAT

Source: Cooper, 1998

When we look at the phrase we read it as "*THE CAT*" even though the middle letter "*H*" between the words "*THE*" and "*CHT*" is the same. However, we tend to read the part of the phrase that is written as "*CHT*" as "*CAT*" because our memory allows us to remember a familiar association

with this phrase, irrespective of what is presented to us. The fact that the same letter is sandwiched between the two letters in each word is overlooked. This is because we have already invented a mental picture associated with these words. According to Figure 3.3, this process occurs in the long-term memory.

Figure 3.3: Three modes that are integrated to define an information processing model of human cognitive architecture
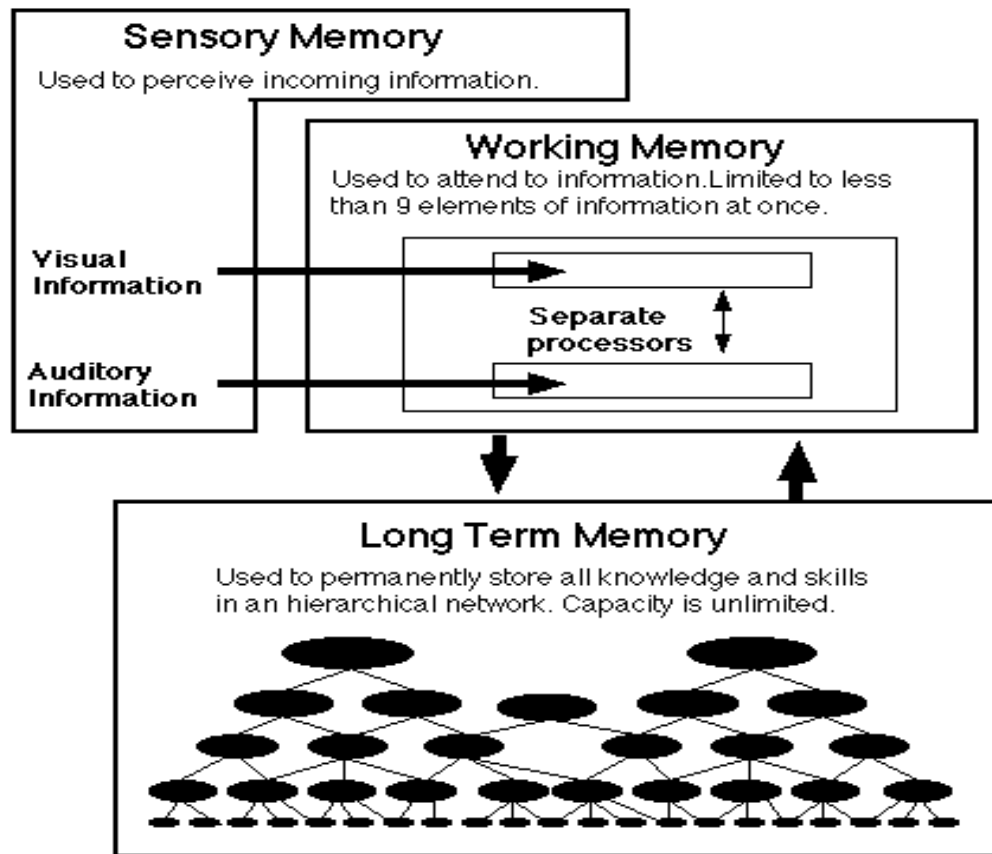
Source: *Cooper (1998)*

This experience is true of many objects we process on a daily basis. We see and remember different items belonging to the same category as if they were identical. For instance, we recognise literally millions of different trees, as trees, even though no two are identical. Given this background, it is clear that in order to understand the process of learning and problem

solving skills development, it is essential to understand how the human memory system functions and how this understanding developed.

3.4.1 The sensory memory

This is the part of the memory system that is responsible for the delivery of information to the working memory prior to it being processed (see Figure 3.3). It deals with stimuli that are processed through our senses, which may be taste, smell, sight or sound. The manner in which information enters the working memory is dependent on these memory systems (sensory memory). We thus transmit information to our cognitive system when we see or hear something. Such sensory memories are extinguished very quickly: in about half a second in the case of visual information and three seconds for auditory information (Cooper, 1998). It is thus vital that this sensory information is recognised and attended to quickly, lest it be forgotten.

3.4.2 The working memory

Working memory is a concept that grew out of the former model of short-term memory, which was viewed as a structure for temporarily storing information before it was transferred to long-term memory (Sorden, 2005). By the late 1960s and early 1970s, dissatisfaction with the assumptions used to explain the short-term memory had developed and this led to a re-examination of the notion of short-term memory. A proposal was made for "a more robust model of short-term memory", which is called working memory (Sorden, 2005, p. 265). This new model of working memory represented a system with sub-components that not only held temporary information, but also processed it so that several pieces of verbal or visual information could be stored and integrated (Sorden, 2005).

The working memory is the section of the memory that deals with conscious processing of information entering the cognitive system through the sensory memory (see Figure 3.3). It is conceptualised as a location where many cognitive operations are carried out. Working memory can be equated to consciousness, and because of this quality, humans can monitor only the contents of working memory (Grossberg, 2010; Koch & Tsuchiya, 2007). Paas, Van Gog and Sweller (2010) believe that "humans are only conscious of the information currently being held

and processed in working memory and are essentially oblivious to the enormous amount of information stored in the long-term memory" (p. 115).

Another very important attribute of working memory is the severe limitation of its processing capacity and duration (Bethel & Borokhovski, 2010; Khateeb, 2008; Song, 2011). As far as its processing duration is concerned, "almost all information stored in working memory and not rehearsed is lost within 30 seconds" (Paas *et al*., 2010, p. 117).

Also, because of capacity limitations, it cannot deal simultaneously with information comprising more than about seven elements. In 1956 George Miller presented the idea that the working memory could only hold 2 + 7 chunks of information that it could process at a given moment. A chunk is any meaningful unit of information, which could be digits, words, chess positions, peoples' faces or trees (also compare section 3.4). Chunks can vary in size. The idea of grouping information in chunks is the basis of grouping numbers such as phone numbers or social security service numbers into small groups to make them easier to remember and work with. For instance, it is common to group telephone numbers in chunks rather than attempting to remember or process them individually. According to Miller, if the telephone numbers had to be processed individually, the working memory capacity would be exceeded and some of that information would be lost (Paas *et al*., 2010).

This limitation is necessary, however, because when the working memory is dealing with novel elements, like problem solving, for which full knowledge is not available, there is no alternative to "a random generate-and-test procedure" that considers how various elements should be combined (Paas *et al*., 2010, p. 117). This occurs because novel information may present unfamiliar elements to the working memory with which it is unable to cope. According to Paas *et al*. (2010), novel information results in combinatorial explosions that prevent adequate processing.

The limitations of the working memory only apply to new, yet to be learned information. Previously organised and stored information in the long-term memory is not prone to combinatorial explosion, and thus the limitations that must be imposed on novel information do

not apply to familiar information. While novel information can be stored only for brief periods with severe limitations on the amount of such information, when dealing with previously learned information stored in the long-term memory, these limitations disappear (Paas *et a*l., 2010). In this way, large amounts of information can be transferred with ease from long-term to working memory over indefinite periods of time. This means that the capacity and limitations of working memory do not apply to information that has already been acquired.

Lastly, the limitations of the working memory mentioned above are further constrained by the fact that the working memory capacity is distributed over two partially independent processors (De Jong, 2010; Fang, Xu, Brzezinnski & Chan, 2006; Van Merriënboer & Sweller, 2010). This dual-processing assumption is based on Pavio's "dual-coding theory" (Artino, 2008, p. 427) and Baddeley's "theory of working memory" (Artino, 2008, p. 427). Both these theories propose that there are two separate channels for processing visual and auditory information. The implication of this dual-processing system is that the limited working memory capacity can be effectively increased by utilising both visual and auditory channels, rather than using one processing channel alone. Given this knowledge, CLT proposes that the constraints of the working memory can help to determine what kinds of instruction are effective (Chong, 2005). Therefore, instruction that makes efficient use of limited working memory will increase learning possibilities.

3.4.3 The long-term memory

Unlike the working memory, long-term memory provides for limitless storage of information (Paas *et al*., 2010). Given this ability, long-term memory can be described as the immense body of knowledge and skills that we hold in a more or less permanently accessible form (Cooper, 1998). Everything we know is held in long-term memory awaiting activation. Examples are: knowledge of our names, knowledge of how we read and write, knowledge of how we drive, etc. Activation occurs when working memory submits a query to the long-term memory; the interplay between the two is thus very important.

As implied by our definition, problem solving skills are also stored in long-term memory. These skills can be applied spontaneously. With extended practice, problem solving can be performed

without high levels of consciousness. In terms of cognitive load theory, this process is called "automation" (Khateeb, 2008, p. 25). What this means is that when problem solving skills are stored in the long-term section of the memory they can be automated when needed for application (see section 3.6).

3.5 SCHEMA THEORY

In section 3.3.3 long-term memory is described as "a section of the memory system where huge amounts of knowledge are stored" (De Jong, 2010, p. 105). Knowledge is stored in long-term memory in the form of schemata. A schema (plural *schemata* or *schemas*) is a cognitive construct that is able to organise the elements of information according to the manner in which they will be applied (Ayres & Van Gog, 2009). A schema is defined as "a knowledge structure that represents a class of things, events and situations" (Song, 2011, p. 16). Put simply, a schema can be anything that has been learnt and is treated as an entity.

Schema theory is a theory of "how knowledge is structured, and of how knowledge structures facilitate the use of knowledge in particular ways" (Song, 2011, p. 16). According to schema theory, problem solving schemata provide the fundamental framework for understanding, learning, and understanding ideas relating to problem solving (Song, 2011). The amount of problem solving knowledge stored in an individual's long-term memory determines the level of problem solving performance by that individual.

What is remembered is partly dependent on the information itself. In section 3.2, the act of remembering was discussed, and an example of trees was used. We see different types of trees that are not necessarily identical, simply as trees. In terms of schema theory, this is possible because in our minds a generalised tree schema has already been constructed.

When new information is presented it is altered so that it becomes congruent with knowledge of the subject matter, such as a tree. Knowledge of subject matter is organised into schemata and it is these schemata that determine how new information is dealt with. According to Sweller (1994, p. 296), if we are asked to describe a tree from memory, "our description will rely heavily on the tree schema rather than entirely on the particular tree's elements that we see, such as leaves,

branches and colour". A schema organises information and knowledge according to the manner in which it will be applied.

Problem solving schemas should act in the same way. These schemas allow the "classification of problems into categories according to how they will be dealt with, that is, according to solution mode" (Sweller, 1994, p. 296). A schema enables a person to deal effortlessly with a potentially infinite variety of objects. This is possible because schemata are able to store and organise huge amounts of knowledge. Schemata can be brought from long-term memory to working memory. Whereas working memory might, for example, only deal with one element (for example, a cognitive load that can be handled easily), that element may consist of a large number of lower level, interacting elements. These interacting elements would far exceed working memory capacity if each element was to be processed. But because a schema can put together a large number of interacting elements and present them as one element in the working memory, the cognitive load is reduced in the working memory. This is possible because even a complex schema can be dealt with as one element in working memory (Van Merriënboer & Sweller, 2005).

So, schemas reduce the amount of mental effort or working memory capacity needed for the performance of a particular task, especially when they become automated (section 3.6). This process can serve as a valuable tool to enhance problem solving performance. When learners are continually exposed to problems of the same type they develop problem solving schemata that relate to a particular type of problem. The more problems learners encounter, the broader the resulting schemata. According to Fuchs, Fuchs, Finelli, Courey & Hamlett, (2004), "the broader the schema, the greater the probability that individuals will recognise connections between familiar and novel problems and will know when to apply the solution methods they have learned" (p. 419). That is when the notion of automation becomes important.

3.6 SCHEMA AUTOMATION AND PROBLEM SOLVING PERFORMANCE

Automation has been defined as the ability to process information without conscious working memory control (Sweller, 2003) and has been identified as an important factor in human cognitive architecture. According to Khateeb (2008, p. 26), "the process of learning automation

of skill execution is gradual", meaning, it is not a once-off accomplishment but it is rather achieved over time. This is because schemas are not static structures but are in a continuous process of refinement and restructuring, and can be formed over a long period of time. So the nature of automation associated with each schema gradually changes from one state to another.

Mathematical problem solving requires learners to apply skills to novel problems. A major challenge in executing problem solving skills is the development of schemata for grouping problems into types that require the same solution (Fuchs *et al*., 2004). We have seen that continued practising of problem solving can help learners to develop problem solving schemata that can be automated over time. Even highly controlled and complex tasks, such as problem solving, can be automated with sufficient practice (Van Merriënboer & Ayres, 2005). Khateeb (2008) suggests that "once automation has occurred, the solution is obtained very rapidly and one becomes an expert problem solver" (p. 26).

Expert problem solvers differ from novice problem solvers in that the former have automated their problem solving moves; their problem solving schemas better enable them to recognise a problem as belonging to a certain class of problems. On the other hand, novice problem solvers possess deficient problem solving schemata and are unable to recognise problem states. They rely instead on "generalised problem solving strategies, such as means-and-ends approaches" (Jonassen, 1997, p. 67). According to Jonassen (1997), problem solving schemata allow learners to become familiar with problem solving attributes for each problem type. In a problem solving task, learners are thus able to respond spontaneously to the demands of the problem because their existing schemata for that problem present it as a familiar exercise.

Given this explanation, it seems that a problem may be a challenge to one solver, while being a matter of pure routine to another, more experienced solver. The latter has automated the problem solving skills that relate to the particular problem. It is by this process that human cognitive architecture handles complex material, such as problem solving, that appears to exceed the capacity of working memory.

3.7 SUMMARY OF THE CHAPTER

This chapter explained human cognitive architecture. The important role played by each component of the memory system was emphasized. As the incoming information enters the memory system through the *sensory memory* it is processed in the *working memory*. However, the working memory is limited in its processing capacity, and can handle only a few elements or units of information. When a complex task, such as problem solving, is presented, the working memory could be overwhelmed by the interactivity of elements in the task, and its processing capacity will be affected. The *long-term memory* provides a solution to this shortcoming as it can store limitless amounts of information in the form of *schemata* or *schemas*.

Given that each schema is presented as a single unit of information, these can easily be processed in the working memory. The processing of schemas in the working memory occurs spontaneously or through a process called *automation*. Automation frees the working memory capacity and reduces the working memory load. After extensive practice, schemas become automated. When the schemas are automated they allow learners to further bypass the limitations of working memory.

From an instructional design perspective, it follows that designs should encourage both the construction and the automation of schemas. In the next chapter, discussions on these designs are presented. This is achieved by presenting a theoretical framework for the study. This theory is useful in demonstrating instructional methods to compensate for the shortcomings of working memory during problem solving. Furthermore, this theory is used to introduce the notion of *cognitive load* that is said to hamper the processing ability of the working memory during problem solving. However, mechanisms to counteract the hampering effects of cognitive load are also presented in this chapter.

CHAPTER FOUR

COGNITIVE LOAD THEORY

4.1 INTRODUCTION

Human cognitive architecture provides a basis for cognitive load theory (CLT) (Chapter 3). CLT is an instructional theory based on some aspects of human cognition. Since its conception in the early 1980s, CLT has been used to develop several instructional strategies that have been demonstrated empirically to be superior to those used conventionally (Paas *et al*., 2004; Salden *et al*., 2010). The fundamental assumption of CLT is that for instructional methods to be effective, instruction designers need to take human cognitive architecture into account (Khateeb, 2008; Paas *et al*., 2004). It also emphasises the necessity for instructional techniques to be aligned with the basic operational principles of the human cognitive system (Kalyuga *et al*., 2004; Plass *et al*., 2010; Sweller, 2010; Sweller *et al*., 2011). In effect, the basic premise of CLT is that learning will be severely hindered if instructional materials overwhelm a learner's cognitive resources.

In this chapter, CLT is presented as a theoretical framework for the current study, mainly because CLT focuses primarily on the effects of learning by studying worked-out examples, and also the fact that CLT provides useful options for designing effective instructions to develop learners' problem solving skills in mathematics. In order to enhance the beneficial effects of worked-out examples approach, a variety of instructional techniques that are suggested by CLT are also discussed in this chapter. Amongst these are the *split-attention* effect and *self-explanation* by learners during problem solving process. In this chapter the split-attention effect and self-explanation effect are presented as effective instructional techniques to enhance the effect of worked-out examples approach on learners' problem solving performance. In this regard, empirical evidence is provided to substantiate the claim that the worked-out example approach is superior to conventional methods in assisting novice learners to construct problem solving schemas.

4.2 COGNITIVE LOAD THEORY

During the past few years, problem solving research has captured the attention of all those concerned with education, particularly classroom practitioners and curriculum designers. Most of the results obtained from this research have recently been synthesized into various theoretical formulations. They have also been used to generate novel instructional techniques that can enhance learning outcomes in subjects such as mathematics. In particular, reference is made to the classical experimental work of John Sweller, who contributed to the understanding of the importance of schema acquisition in successful learning and problem solving in mathematics (see Sweller, 1988).

In the 1980s, John Sweller[23] developed a cognitive load theory (CLT) that underwent substantial expansion in the 1990s by researchers around the globe (Paas, Renkl & Sweller, 2003, Rikers, 2006; Sweller, 1988). CLT had a theoretical precedence in the educational and psychological literature well before Sweller's ground-breaking article of 1988 (see, for example, Beatty, 1977; Marsh, 1979). Baddeley and Hitch (1974) for instance, introduced the notion of concurrent memory load. They showed that "a concurrent memory load of six items produced impaired performance in a number of cognitive tasks" (Davies & Logie, 1993, p. 224). However, it was Sweller's cognitive load theory that was among the first to consider working memory as the key component of the human cognitive system in relation to learning.

CLT has been adopted in this study because it provides a plausible theoretical framework for investigating cognitive processes and instructional designs linked to problem solving activity. CLT uses interactions between information structures and knowledge of human cognition to determine such instructional design. It can be utilized to increase the effectiveness of learning and also to decrease unnecessary effort that is not directly related to learning itself (Khateeb, 2008). According to CLT, for effective learning to occur, the structure of human cognitive architecture should be understood (section 3.2). Recognizing Miller's (1956) information processing research, which demonstrated that working memory is limited in the number of

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[23] John Sweller is an Australian educational psychologist who formulated the cognitive load theory (CLT). CLT is an instructional theory based on some aspects of human cognition (see section 4.2). Sweller is currently a Fellow of the ASSA (Academy of the Social Sciences in Australia) and is an Emeritus Professor of Education at the University of New South Wales. His research is focused on cognitive processes and instructional design, with specific emphasis on working memory limitation and the consequences for instructional designs (ASSA, 2011; Sweller, 2003).

elements it can contain simultaneously, Sweller was able to build CLT (see section 3.4.2). In terms of this study the theory treats schemas, or a combination of elements, as the cognitive structures that make up an individual's problem solving knowledge base (Sweller, 1988).

To date, several definitions have been offered, which are aimed at explaining CLT. Only two are presented in the current study. According to Van Gerven, Paas, Merriënboer, Hendricks and Schmidt (2003), cognitive load theory is an instructional theory that starts from the idea that our working memory is limited with respect to the amount of information it can hold and the number of operations it can perform on that information. According to this definition, it is important for instructional designers to acknowledge that every human being, inclusive of learners, operate using a limited working memory (section 3.4.2). So instruction should be designed to encourage learners to utilize their limited working memory efficiently, especially when learning a difficult task such problem solving. In the discussions that follow it will be demonstrated how this can be achieved.

Paas *et al*. (2010) define CLT as the theory that is "concerned with the learning of complex cognitive tasks, in which learners are often overwhelmed by the number of interactive information elements that need to be processed simultaneously before meaningful learning can commence" (p. 115). The term "overwhelmed" refers to a stage where the working memory is unable to process information presented to it. It was explained in section 3.4.2 that there is a limit to the number of information elements that the working memory is able to process at a given time. For instance, during problem solving, learners may be bombarded with information and, if the complexity of their instructional materials is not properly managed, the working memory limit will be exceeded and cognitive overloading will result. This process may be overwhelming to a learner who might be a novice problem solver.

In light of these definitions, it is possible to describe CLT as simply an instructional theory that is based on our knowledge of human cognitive architecture (Clark, Nguyen & Sweller, 2006). In both definitions, it is clear that certain problem solving tasks can impose cognitive load on learners' working memory. Cognitive load refers to the mental burden and efforts that an individual experiences while executing a task, an assignment or a mission. Chang, Sung and

Chen (2001) define cognitive load as the state of loading on human cognitive system, particularly memory operations, created by the level of mental capacity and the resources required to perform a given task. According to this definition, there are two important components that can elevate the load in a human mind, that is: 1) the fact that the capacity of human working memory is extremely limited (see section 3.3.2); and, 2) the type and quality of instructional material that is given to the learners (instructional design).

Sweller (2005) defines cognitive load as the workload imposed on the human cognitive system by a particular task. When instructional designers, or teachers, prepare instruction for learners, they intentionally design the means to present information. It is the instructors' mode of presenting the information that determines the level to which cognitive load is imposed on learners. For instance, if the instructional material is badly organized, it has the potential to heighten the cognitive load, and vice versa. So in terms of CLT, a teacher needs to design an effective instructional strategy to present information to learners.

There are various strategies to present information. They may range from organizational strategy to sequencing, cues, feedback, orienting or question techniques, etc. (Fleming & Levie, 1993; Lohr, 2000). These instructional strategies may have different impacts on learning, also depending on the media and the presenting strategy used during instruction. A fundamental claim of CLT is that these strategies are likely to be ineffective unless they consider the underlying cognitive architecture of the learner during instruction (Clark *et al*., 2006).

In the next subsection, the relation between CLT and human cognitive architecture is demonstrated by discussing three types of CLT: intrinsic cognitive load (ICL), extraneous cognitive load (ECL) and germane cognitive load (GCL).

4.2.1 Intrinsic cognitive load

This load refers to the complexity of the learning material that a learner intends to learn mentally (Van Gog & Rummel, 2010). Intrinsic cognitive load is due to "the natural complexity of the information that must be processed and is determined by levels of element interactivity" (Sweller, 2005, p. 27). The complexity is dependent on the intrinsic nature (difficulty level) of

the learning material and upon the learner's amount of prior knowledge. Learner's prior knowledge has been considered in this definition because the size of meaningful information chunks that a learner can handle without taxing his or her working memory capacity is dependent upon it (Van Gog & Rummel, 2010). Thus a learning problem solving task that is complex for a beginner may indeed be simpler for an expert. Therefore, to compensate for the deficiency in the learner's prior knowledge, learning material of high complexity is enhanced when the interacting elements are taught in isolation and the relevant interactions are instructed later; this suggests that intrinsic load can be manipulated by instruction (Pollock, Chandler, & Sweller, 2002; Van Merriënboer, Kirschner, & Kester, 2003; see also Moreno, 2006, p. 171).

In terms of the assumptions of cognitive load theory, when the arrangement of elements in the task is such that the interaction between them is high, then the intrinsic load gets higher as well, and vice versa. According to Sweller (2010, p. 124), "Low element interactivity materials allow individual elements to be learned with minimal reference to other elements and so impose a low intrinsic load". An element can be anything that needs to be or has been learned, such as a concept or a procedure (Sweller, 2010). Problem solving tasks present such typical elements. Working memory, as a processing system of our minds, plays an important role in processing these elements. Problems cannot be solved if sufficient information or elements cannot be retained in the working memory and integrated.

An example is learning numerical symbols in a mathematics class or learning certain words in a language class. Both of these learning experiences constitute low element interactivity tasks because "each element can be learned without reference to any other elements" (Sweller, 2010, p. 124). When one learns chemical symbols in a chemistry class, for instance, working memory is only assigned to processing the cognitive elements associated with the chemical symbol at hand, without experiencing load associated with the neighboring symbol.

High element interactivity material consists of elements that interact heavily and so cannot be learnt in isolation. The closer the elements interact with each other, the heavier the working memory load (Sweller, 2010). For instance, in a mathematics problem equation all elements could be associated with the equation. Hence the problem equation must be solved

simultaneously because of high element connectivity in the equation. A novice problem solver might struggle to deal with the following algebraic problem:

$$a(b + xy) = y, \quad \textit{Solve for "x".}$$

The problem solver might struggle as each of the symbols in the equation above may act as an element. As a result, all elements in the equation must be processed simultaneously in working memory to comprehend the equation. However, the elements of the equation are closely connected and are likely to present the equation as a higher element interactivity task than learning the chemical symbols of the periodic table. Consequently, the algebraic task might impose a relatively high intrinsic cognitive load on a learner than a task in a chemistry class would do.

4.2.2 Extraneous cognitive load

Unlike intrinsic cognitive load, which is dependent upon element interactivity, extraneous cognitive load (ECL) is defined as the load caused to the working memory (WM) as a result of poorly designed instructional procedures that interfere with schema acquisition and schema automation (Paas *et al*., 2010; Schnotz & Kürschner, 2007). This occurs when learners are required to engage in activities "that are not directed at schema acquisition or automation" (Sweller, 1994, p. 299). In sections 3.5 and 3.6 it was emphasised that schema acquisition promotes learning (Sweller, 1988; Sweller *et al*., 2010).

It seems that this type of load is mainly dependant on the goal of instruction. For instance, when the goal of instruction is to construct problem solving schemas, the ECL is imposed if instructional materials contain texts and graphics that are difficult to integrate with each other (Chong, 2005). In this case learners may be forced to use much of their WM resources trying to establish coherence between the two sources of information. Consequently, little or no cognitive capacity will remain to foster learning and skill acquisition.

In many of the conventional instructional designs, instructional procedures are developed without any consideration or knowledge of the structure of information or cognitive architecture. The result is that conventional instructional procedures are guilty of imposing ECL on learners' working memory, to the detriment of actual learning. According to Paas *et al*. (2010), "When instructional material is poorly constructed, extraneous load is generated because the learner is diverted away from schema acquisition and uses up precious working memory resources by trying to deal with a suboptimal learning environment" (p. 115).

In the literature, a number of general sources of ECL are mentioned. One such example is the "split-attention" effect (De Jong, 2010, p. 108; see also section 4.4). According to De Jong (2010) split-attention effect refers to the separate presentation of domain elements that require simultaneous processing. In this case, learners must keep one domain element in memory while searching for another element in order to relate it to the first (De Jong, 2010). An example is a teacher who can use two ways to describe a triangle. She can either provide a verbal description of the triangle or draw a (triangle) diagram on the chalkboard. The first method is likely to impose more ECL than the latter, because in the former the learner will have to embark on an extensive visual or mental search process, whereas in the latter, the teacher makes provision for the visual demands of the problem. From a "split-attention" perspective, we can argue that in the former the learner' attention is split into searching for a visual puzzle that correlates with the concept of a triangle, whilst at the same time the learner has to contend with the processing activity of the concept of triangle in the working memory.

To minimize the "split-attention" effect instructional material should be presented to learners in an integrated manner (see, Van Gog, Kester, Nievelstein, Giesbers & Paas, 2009; Van Merriënboer & Sweller, 2005; Van Merriënboer & Sweller, 2010). The second method that is used by the teacher (drawing a diagram on the chalkboard) seems to minimize the "split-attention" effect (see also section 4.4).

A second identified source of extraneous cognitive load is when learners must solve problems for which they have no problem solving schema-based knowledge (De Jong, 2010). Here, learners' problem solving schemas for the problem at hand have not been developed. In general, this refers

to conventional practice problems (Artino, 2008; Paas *et al*., 2010). In this scenario, learners are more likely to resort to general problem solving strategies, such as the use of the means-ends analysis, as a solution procedure (De Jong, 2010; Jones & Langley, 2005). Using a version of means-ends analysis, which is "a constrained architecture for problem solving" (Jones & Langley, 2005, p. 480), requires one to search for problem solving operators to reduce the difference between the current problem state and the goal state. This search, in terms of CLT, can impose ECL on WM, thus making it difficult or impossible for effective learning to be optimised. To remedy this, learners can be offered *goal-free problems*, *worked-out problems* or *completion problems* instead of traditional problems (Atkinson, Derry, Renkl & Wortham, 2000; De Jong, 2010; Renkl, Hilbert & Schworm, 2009; Rourke & Sweller, 2009).

According to De Jong (2010), a third source of extraneous load is evoked when "the instructional design uses only one of the sub-systems of working memory" (p. 108). This is referred to as the "modality principle" (De Jong, 2010, p. 108). During instruction, it is essential to address the visual and the auditory parts of the working memory. According to the "modality principle", material is more efficiently presented as a combination of visual and auditory material (see Low & Sweller 2005; Mayer, 2008; Sorden, 2005; Van Merriënboer & Sweller, 2010).

The last source of extraneous load is when learners must coordinate materials that have the same information (De Jong, 2010). Using this form of instruction puts a heavy load on learners' cognitive resources because these resources have to be allocated into processing multiple pieces of information simultaneously. This is analogous to giving a computer multiple commands at once. The speed with which the computer processes all of this information declines as a result of it having to perform different tasks concurrently. The same happens with working memory capacity, which is limited and fixed (Bethel & Borokhovski, 2010). If the information to be stored and processed in the working memory exceeds its capacity, that is, germane load is minimized, learning ceases to take place.

This assumption points to an inextricable link between the working memory and learning and evidence from both neuroscience and cognitive science research has confirmed a direct and strong link between working memory and learning capacity (see, for example, Buhner, Kroner &

Ziegler, 2008; Colom, Abad, Quiroga, Shih & Flores-Mendoza, 2008). Based on the results of these studies we can argue that increase in working memory capacity, by optimising the germane load, should translate into increase in learning capacity. An increase in working capacity allows learners to manage greater cognitive load during problem solving tasks. So teachers must design instruction that promotes schema construction.

4.2.3 Germane cognitive load

Germane cognitive load (GCL) is a third kind of cognitive load, which is encouraged to be promoted in educational settings. GCL is the load dedicated to the processing, construction and automation of schemas (De Jong, 2010; Paas *et al*., 2010; Sweller, 2010). CLT sees the construction and subsequent automation of schemas as the main goal of learning. According to De Jong (2010, p. 109), the construction of schemas involves processes such as interpreting, exemplifying, classifying, inferring, differentiating and organizing. The load that is evoked by these processes is regulated through the GCL.

Therefore, the teacher should maximize efforts to stimulate and guide learners to engage in schema construction and automation during instruction and in this way increase GCL (De Jong, 2010). One way, for instance, of maximizing the germane load in order to achieve learning (schema acquisition) is to organise content in a manner that integrates it with the learner's prior knowledge and experience (Bethel & Borokhovski, 2010). Mayer (2008) has also noted that GCL processing can be fostered by asking learners to engage in activities such as self-explanation of the to-be-learnt material (see section 4.5).

4.2.4 Additivity of cognitive loads

Cognitive load theory assumes that the three types of cognitive load discussed above are additive (Gerjets, Scheiter & Cierniak, 2009). The sum of the load is "the sum of the three kinds of cognitive load" (Schnotz & Kürschner, 2007, p. 477). However, the sum cannot exceed the limits of the working memory capacity if learning is to occur (Bethel & Borokhovski, 2010). Intrinsic cognitive load provides a base load that is irreducible other than by constructing additional schemas and automating previously acquired schemas. According to Paas *et al*. (2003), "Any

available working memory capacity remaining after resources have been allocated to deal with intrinsic cognitive load can be allocated to deal with extraneous and germane load" (p. 2).

From a cognitive load perspective, it is important to realize that the total cognitive load associated with an instructional design, or the sum of intrinsic cognitive load, extraneous cognitive load and germane cognitive load, should stay within working memory limits. Hence "cognitive overload results if the sum of the three cognitive load types requires more working memory resources than the learner has at his or her disposal during learning" (Gerjets *et al.*, 2009, p. 45). In Figure 4.1 techniques to manipulate cognitive load in order to foster effective learning are demonstrated.

Figure 4.1: The relationship between cognitive load and learning[24]
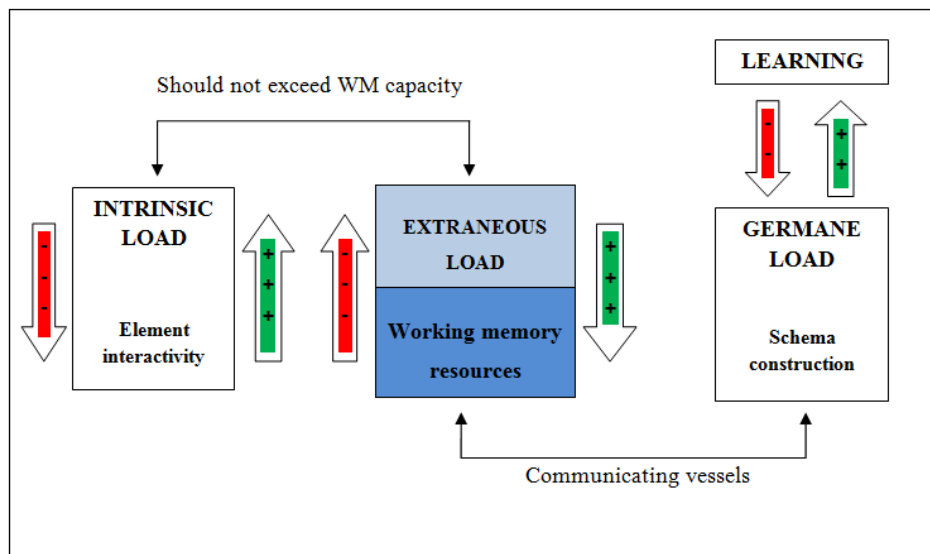
Source: Dhlamini and Mogari (2011)

According to Figure 4.1, if intrinsic cognitive load is high, extraneous cognitive load must be lowered. On the other hand, if intrinsic cognitive load (ICL) is low, levels of extraneous cognitive load (ECL) may be less important because total cognitive load may not exceed

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[24] In Figure 4.1 green arrows represent cognitive processes that support learning and skills development, and red arrows represent cognitive processes that defeat learning and skills development.

working memory capacity. As a result, "instructional designs intended to reduce cognitive load are primarily effective when element interactivity (ICL) is high" (Paas *et al*., 2003, p. 2). When element activity is low, designs intended to reduce cognitive load on working memory are not effective.

The three loads can work in tandem: for example "a reduction in extraneous cognitive load (by using a more effective instructional design) can free capacity for an increase in germane cognitive load" (Paas *et al*., 2003, p. 2). If learning is improved by an instructional design that reduces extraneous cognitive load, the improvement may have occurred because the additional working memory capacity freed by the reduction in extraneous cognitive load has now been allocated to germane cognitive load (Paas *et al*., 2003).

In the current study, the additivity principle of cognitive loads was applied in the following manner. *Firstly*, instruction must be designed in such a way that intrinsic load is optimized. This means a context-based problem solving task should be at an appropriate level of complexity for the learner's processing ability. As stated to earlier, this is achieved through sequential presentation of learning material, thus reducing the amount of element interactivity that a novice memory has to simultaneously process at an instance. *Secondly*, extraneous load must be minimized. In terms of our study, this is achieved by presenting learning material located in learners' everyday experience. According to CLT, learning that takes place in familiar settings reduces the effects of cognitive load or the extraneous load. So for effective learning to happen, extraneous load must be kept at a minimum (Van Gog & Rummel, 2010).

Thirdly, germane load should be optimized so that working memory resources are optimally used. The germane load is optimized by keeping both intrinsic and extraneous loads at manageable levels. Once the extraneous load is effectively managed, it can influence the levels of germane load. Hence the two loads are like communicating vessels. This 3-step instructional process that supports learning is represented by green arrows (with "+" insertions) in Figure 4.1. The implication is that instructional design for novice learners should increase germane cognitive load and decrease extraneous cognitive load (Paas *et al*., 2003).

In the 1990s, CLT was used almost exclusively to study instruction intended to decrease extraneous cognitive load. Some of the major effects that yield better problem solving schema construction and higher transfer learning are summarized in the last two sections of this chapter.

4.3 WORKED-OUT EXAMPLES APPROACH

Cognitive load theory has initiated many empirical studies to develop principles that foster effective learning process that promote learning outcomes. The key assumption in cognitive load theory is that working memory is severely limited (see section 3.4.2). In the previous discussion (section 4.2), it was mentioned that there are three types of cognitive load that impact on the working memory. The three types of cognitive load are additive (section 4.2.4). This means that the enlargement of one type of cognitive load reduces the working memory capacity and resources that will be available for processing the other two types of cognitive load. Therefore, the types of cognitive load can be managed. Given this background, the overall recommendation is that an instructional design should reduce extraneous load (i.e. information processing hindering learning) and increase germane load (i.e. information processing supporting learning) (Van Gog & Rummel, 2010).

Several other empirically validated instructional techniques for eliminating cognitive overload have been suggested. One such technique is learning through worked-out examples (Koedinger, Pavlik, McLaren & Aleven, 2008; Paas *et al*., 2004; Van Gog & Rummel, 2010). Research within the framework of cognitive load theory has demonstrated that it is effective to combine worked-out example study and problem solving in the initial acquisition of problem solving skills (Artino, 2008; Van Gog & Rummel, 2010). According to Renkl, Atkinson and Grobe (2004, p. 59), "Worked-out examples should be provided initially, followed by to-be-solved problems, in order to foster problem solving skill acquisition in structured domains such as mathematics".

A worked-out example is an instructional device that provides a model for solving a particular type of problems. It typically includes a problem statement and a procedure for solving a problem (Atkinson *et al*., 2000; Van Gog, Ericsson, Rikers & Paas, 2005). A worked-out example provides a learner with an expert's model of solving a typical problem that the learner

can learn from and emulate. A worked-out example typically presents a solution in a step-by-step fashion (see Figure 4.2 & Appendix J). Together, the steps are meant to show how other similar problems might be solved.

Figure 4.2: Worked-out example from Renkl, Atkinson and Maier (2000)

PROBLEM TEXT: From a ballot box containing 3 red balls and 2 white balls, two balls are randomly drawn. The chosen balls are not put back into the ballot box. What is the probability that a red ball is drawn first and a white ball second?

SOLUTION:
 STEP 1:
 Total number of balls: 5
 Number of red balls: 3
 Probability of red ball on first draw: 3/5

 STEP 2:
 Total number of balls after first draw: 4
 Number of white balls: 2
 Probability of white ball on second draw: 2/4

 STEP 3:
 Probability that a red ball is drawn first and a white ball is second: 3/5*2/4 = 6/20 = 3/10

ANSWER: The probability that a red ball is drawn first and a white ball is second is 3/10.

Source: Atkinson et al. (2000, p. 182)

In a worked-out example approach, the idea is to provide the learner with resources needed to solve that problem, and then encourage the learner to solve novel problems. But what does empirical research say about the combination of worked-out examples approach and problem solving? Evidence shows that problem solving research has relied on the worked-out examples effect to foster learners' problem solving skills (see, for example, Artino, 2008; Koedinger *et al*., 2008; Paas *et al*., 2004; Sweller & Cooper, 1985; Van Gog, Paas & Van Merriënboer, 2008; Van Gog & Rummel, 2010). Most of these studies have demonstrated that learning from worked-out examples leads to superior learning outcomes when compared to problem solving.

In this line of research, the first study was conducted by Sweller and Cooper (1985). They investigated the effect of using worked-out examples to develop learners' problem solving schemas, which are needed to categorize and solve problems more easily. During problem solving a schema helps to categorize problems according to their characteristics (Sweller, 1994; see also section 3.5 & section 3.6). Problems are then solved by classifying them according to categories to which they belong. Each time a problem solver comes across a problem, a problem solving action, for solving problems to which a new problem belongs, is executed. Therefore the goal of learning should be to develop problem solving schemas to help learners solve novel problems efficiently.

In the Sweller and Cooper (1985) study participants were year nine learners. In the course of the study participants were given two worked-out example problems to study and were then allowed to ask questions. Thereafter, participants were divided into two groups, consisting of those using conventional practice problems and those working on a worksheet with worked-out examples. The results of the study showed that participants in the example-enriched condition spent less time in the acquisition phase and made fewer errors than the conventional group.

The Sweller and Cooper (1985) study is of particular interest in the current study. The current study aims to develop problem solving skills of learners who were low-performing in grade 10 mathematics (section 1.1). Sweller and Cooper (1985) study provides a useful framework to improve learners' problem solving performance. The study of worked-out examples provides a useful foundation in the development of learners' problem solving skills. When learners have developed problem solving skills: 1) their problem solving performance is improved; 2) the time they spend in solving a problem reduces, and, 3) the rate at which they do problem solving errors reduces.

Studies that have reported the beneficial effect of the worked-out examples approach have been reported in other domains: geometry (Salden *et al*., 2010; Schwonke, Renkl, Krieg, Wittwer, Aleven & Salden, 2009), chemistry (McLaren, Lim & Koedinger, 2008), and algebra (Anthony, 2008). Anthony (2008) conducted a classroom study wherein a conventional Cognitive Tutor was compared with an instructional version that included example-problem pairs, consisting of

annotated worked-out examples presented with problem solving tasks. Although no significant differences were observed in the immediate retention, but participants in the example-enriched condition attained significantly better long-term retention scores (Anthony, 2008). The study of Antony adds another component of empirical evidence in support of the beneficial influence of worked-out examples approach.

The studies on that have reported on the benefits of a worked-out example approach positively tested the hypothesis that replacing conventional problem solving techniques with worked-out examples would enhance learner outcomes by reducing instructional time and/ or increasing learner outcomes in terms of retention and transfer performance (Salden *et. al*., 2010).

So what could account for the beneficial effects of worked examples in problem solving conditions? From a cognitive load theory perspective (Sweller, 1988), the answer is that human working memory, which has a limited capacity, is taxed by strictly solving problems, which requires thinking styles such as setting sub-goals. Such mental work can consume cognitive resources that could be better used for learning and schema construction (McLaren & Isotani, 2011). However, worked-out examples are believed to lessen *extraneous* load because the problem solver can associate the problem at hand with the one that was treated during the worked-out example phase (Salden *et al*., 2010; McLaren & Isotani, 2011). Upon meeting a novel problem the problem solver is not overwhelmed by the demands of the novel problem because there is already a problem solving schema to solve the problem. In that way the working memory can only use a small portion of its resources to process the problem, meaning, the extraneous load has been reduced.

While search methods such as means-ends analysis may be critical for problem solving, such techniques may exhaust learners' cognitive resources that are needed for learning. By providing learners with worked-out example solutions to study, which worked-out examples do, the need for an extensive search for correct solution steps is avoided and learners can concentrate on building problem solving schemas, so they can more readily solve similar problems in future (McLaren & Isotani, 2011). Later on, when solving a problem, instead of grappling with many new and unfamiliar details, as well as searching through memory, the learner can easily recall a

similar example while engaging in active cognitive processing to strengthen his or her understanding of the new problem (McLaren & Isotani, 2011).

Moreover, it is assumed that "studying worked-out examples focuses learners' attention on information that is relevant to problem solving schema construction" (Gerjets *et al*., 2004, p. 34). For instance, "studying worked-out examples might draw learners' attention to structural problem solving features that indicate the problem category a particular problem type belongs to, or it might draw learners' attention to the solution rationale behind a category-specific solution procedure" (Gerjets *et al*., 2004, p. 34).

However, exploiting the potential of effective learning with worked-out examples means that several worked-out examples are provided before problem solving tasks are given to learners. Giving learners several problem solving examples helps them: to compare different problem structures; to familiarise them with different problem types and to foster problem solving understanding (McLaren & Isotani, 2011). Sweller and his colleagues found that providing learners with many worked-out examples is more effective than providing them with a few worked-out examples followed by conventional instruction (Sweller & Cooper, 1985; Cooper & Sweller, 1987). According to Gerjets *et al*., (2004, p. 40), "provision of multiple worked-out examples with different surface features might further improve example comparisons", that is, worked-out examples may improve learners' ability to compare and distinguish between different problem types. Also, Stark (1999) and Renkl (1997) suggested that profitable example processing can be enhanced by sequentially presenting problem states. According to Stark and Renkl, this type of presentation encourages learners to explain the worked-out examples to themselves by anticipating the next step in a worked-out example solution; then checking to determine whether the predicted step corresponded to the actual step (Salden *et al*., 2010).

In an attempt to further strengthen the effectiveness of worked-out example study, the following questions are explored: 1) to what extent do learners profit from the study of worked-out examples when they are given an opportunity to explain the solutions of the worked-out examples to themselves and to others (self-explanation effect)?; and, 2) what happens when a worked-out example contains separate sources of information that need to be integrated mentally

in order to understand the worked example (split-attention effect)? These questions are explored in the next sections of this chapter.

4.4 SPLIT-ATTENTION EFFECT

One of several instructional design recommendations derived from cognitive load theory suggests integrating separate but mutually referring information sources physically (such as text and pictures), when both sources are required for understanding complex issues (Ginns, 2006; Van Merriënboer & Sweller, 2010). Tarmizi and Sweller (1988) were the first to show that in some cases the profitable effects of example studies on problem solving schema construction can fail to occur. In their study, Tarmiz and Sweller (1988) examined a number of worked examples and observed that all examples contained separate sources of information. This means that the diagram and the explanatory text of the problem were not physically integrated and, as a result, the learner's attention is split between two sources of information. This phenomenon creates what Sweller (1999) called a split-attention effect.

Split-attention occurs when learners are presented with multiple sources of information that have to be mentally integrated before they can be understood. From a cognitive load theory, learners with integrated formats of information experience a lower cognitive load than learners with split-sources formats, because of a reduced extraneous load in learning with an integrated format (Cierniak *et al*., 2009). Cognitive load research has shown that split-attention instructional formats hamper learning, whereas integrated formats foster learning (see Cierniak *et al*., 2009; Sorden, 2005; Van Gog *et al*., 2009). Cierniak *et al*. (2009), Tarmizi and Sweller (1988), Ward and Sweller (1990), and Sweller and Chandler (1991), also demonstrated that worked-out examples without split-source information led to better learning results than split-source worked-out examples and conventional problems.

From an instructional design perspective, it is evident that instruction should not be designed so that it causes the learner to divide attention between two tasks, such as searching for information to solve a problem while solving the problem. In the current study, a problem solving split-source task was administered to learners in the experimental group (see, Appendix H; section 5.5.1.6). The aim of the task was to detect the influence of split-attention sources on learners'

problem solving performance. Results of this investigation showed that learners in less split-attention induced conditions performed better than those in split-attention enriched conditions.

4.5 SELF-EXPLANATION

Renkl (2002) suggests that "the extent to which learners profit from the study of examples depends heavily on how well they explain the worked-out example problem solution to themselves and to others" (p. 530). This is called the "self-explanation effect" (Renkl, 2002, p. 530). Self- explanation is a way of providing learners with an opportunity to explain problem steps to themselves or to others (Ainsworth & Loizou, 2003; Paas & Van Gog, 2006; Rittle-Johnson, 2006), in that way demonstrate whether or not they understand the solution steps in the worked-out example. According to Renkl and Atkinson (2002), learners who are successful in self-explanation: 1) will be able to apply their acquired knowledge in related problem tasks; 2) will be motivated to achieve the problem solving goals, that is, find the solution to the problem; 3) more frequently apply knowledge that is domain-specific when solving a problem task (principles-based explanations); 4) are less likely to suffer from an illusion of understanding components of the problem; and, 5) are able to devote more time to the study of worked-out examples (more learning time) to guide future learning.

In another experiment Renkl (1997) investigated the effect of self-explanation when the learning time for each individual was fixed. Renkl (1997) found that the quality of self-explanation was significantly related to learning outcomes even when learning time was kept constant. In this study, Renkl (1997) used cluster analysis and participants were classified as either successful or unsuccessful learners (Renkl & Atkinson, 2002). According to Renkl & Atkinson (2002), the successful and unsuccessful learners differed in terms of the following aspects: 1) frequently assigned meaning to operators by identifying the underlying domain principle (*principle-based explanations*); 2) frequently assigned meaning to operators by identifying the sub-goals achieved by these operators (*explication of goal-operators combinations*); and, 3) tended to anticipate the next solution step instead of looking it up (*anticipative reasoning*).

These studies suggest that it is crucial that teachers and curriculum makers should search for instructional interventions that can foster self-explanation activities and, eventually, positive

learning outcomes. Of concern though, are the instructional techniques for fostering profitable self-explanation in learning environments. It is this that the current study intends to investigate. Indeed, sometimes learners are not able to provide correct and satisfactory self-explanation. When learners struggle to generate effective self-explanations it is reasonable to guide learning further with other instructional techniques such as *instructional explanations* and *prompting self-explanations* (Renkl, 2002). However, it is also necessary to balance the extent to which instructional explanations are incorporated in a lesson because "instructional explanations can have the effect that learners reduce their self-explanation effort" (Renkl, 2002, p. 534). Also, prompting learners to self-explain is considered to be an effective tool to foster profitable self-explanation. In this case learners are encouraged to externalize their views and understanding of the problem.

According to Gerjets *et al*. (2004), rather than expecting self-explanation to occur spontaneously, learners should be prompted to engage in self-explanatory activities. Renkl and Atkinson (2010) and Hummel and Nadolski (2002) prompted learners to encourage profitable self-explanation. In both studies, learners worked with examples in the field of statistics (probability). In the prompted group, learners were asked to explain each step and the rule they applied at each step. The researchers found higher transfer test performance in the prompted group (Van Merriënboer & Sweller, 2005).

Moreover, according to Renkl & Atkinson (2002), there are two ways to foster self-explanation as an effective learning strategy, namely, *direct intervention* and *indirect intervention*. Direct intervention occurs when learners are trained directly to do self-explanation. Renkl, Stark, Gruber and Mandl (1998, cited in Renkl & Atkinson, 2002) showed in their experiment that "a short training session effectively fostered the explication of goal-operator combinations and principle-based explanations in a subsequent learning phase" (p. 107). Indirect intervention occurs when self-explanation techniques are not trained directly. Instead, the learning materials are structured in a way that fosters self-explanation (Renkl & Atkinson, 2002). For example, Catrambone (1998, cited in Renkl & Atkinson, 2002) found that "designing worked-out examples in a way that makes each sub-goal salient within an example fostered self-explanation

about what these steps accomplished" (p. 107). Consequently, learning outcomes were heightened.

In sections 4.4 and 4.5, instructional techniques to help learners benefit from example studies have been provided. Based upon the discussion, an assertion made by Trafton and Reiser (1993) that "the most efficient way to present material to acquire a skill is to present an example, then a similar problem to solve immediately following" (p. 1022), is supported. Hence in the current study, a framework that integrates the design of context-based problem solving instruction (CBPSI) with the worked-out example study was adopted (see Appendix I; section 8.3 & Figure 8.1). In addition, to enhance the effectiveness of CBPSI, the effects of *split-attention* (see Appendix H & Example 8.1) and *self-explanation* (see section 8.4 & Figure 8.1) by learners were also incorporated in the lesson (see section 5.6.2.2.1). The beneficial effects of cognitive load theory, which are mentioned in this section, were enforced in the CBPSI lesson until participants in experimental schools were able to solve context-based problems on their own.

4.6 LEARNING AND UNDERSTANDING IN TERMS OF COGNITIVE LOAD THEORY

It is now possible to describe learning and understanding in terms of cognitive load theory.

4.6.1 Learning

In this section *learning* is defined in terms of cognitive load theory (CLT) assumptions as "An increase in expertise due to an alteration in long-term memory" (Schnotz & Kürschner, 2007, p. 477). According to this definition, if nothing has been altered in the long-term memory, then learning has not taken place or been achieved. It seems that in terms of the discussion in sections 3.5 and 3.6, the major mechanisms of learning are schema acquisition and schema automation. Schema acquisition changes what individuals treat as an element (Schnotz & Kürschner, 2007). If this treatment is appropriate and effective, cognitive load is reduced in the working memory and learning can occur (see section 4.3.4).

According to sections 3.5 and 3.6, if a schema is acquired, then the set of previously existing elements that were integrated into the schema can now be treated as a single element that can be

dealt with effectively in the working memory (Schnotz & Kürschner, 2007). So, schema acquisition reduces the number of interacting elements in the working memory. This information can be processed consciously or automatically. Extended practice allows schemas to be processed automatically. This process is called schema automation (section 3.5). Schema automation allows cognitive processes to occur without control and thus allows for providing working memory reserves for other kinds of processes (Sweller, 2005). According to CLT, this is the ultimate goal of learning.

4.6.2 Understanding

According to CLT, understanding occurs when all relevant elements of information are processed simultaneously in working memory (Marcus, Cooper & Sweller, 1996). Material is considered to be too hard to understand if it consists of too many interacting elements that cannot be held simultaneously in working memory (Sweller, Van Merriënboer & Paas, 1998). Schnotz and Kürschner (2007, p. 477) posit that "understanding cannot occur until schema construction and automation have progressed to the point where working memory can hold and process essential elements". In addition, CLT assumes that understanding requires changes in long-term memory besides processing in working memory. This position is in line with the view of Schnotz and Kürschner (2007, p. 455) who posit that "without changes in long-term memory, nothing has been understood". In terms of this line of reasoning, there seems to be a thin line between *learning* and *understanding* in CLT terms.

4.7 SUMMARY AND CONCLUSION OF THE CHAPTER

In this chapter a theoretical framework for the study was presented. The current study dealt with problem solving from a cognitive perspective. Hence a cognitive load theory was used as a theory to frame the current study. Different types of cognitive loads were also presented and used to explain the limitations of working memory, which is the processing unit of the human memory system. Most importantly, in this section it was demonstrated how different types of cognitive loads can be manageable to enhance effective problem solving performance.

In section 4.2.4 a diagram was used to explain the additivity of three types of cognitive load (see Figure 4.1). The chapter concluded with a discussion of the different effects of cognitive load

theory in terms of the role they play in influencing problem solving performance. In this regard, the worked examples effect was presented and used to design context-based problem solving activities. Self-explanation and the split-attention effect have also been discussed.

In the next chapter, a research methodology is presented. In this chapter, it is demonstrated how cognitive load assumptions are used to design context-based problem solving tasks.

CHAPTER FIVE

RESEARCH METHODOLOGY

5.1 INTRODUCTION

The purpose of a research study has an influence on the type of research design the researcher chooses to follow (Welman, Kruger & Mitchell, 2005). The design selected influences the data collection methods as well as the techniques and instruments used to collect the data (Welman *et al.*, 2005). In this chapter, the study design is described; this is followed by a discussion of the population, sample and sampling methods used and the instruments used to collect data. Issues of reliability and validity are also discussed. The data collection plan and the way in which the researcher addressed ethical issues in the study are also explained.

5.2 RESEARCH HYPOTHESIS

The aim of this study was to investigate the effect of context based problem solving instruction on the problem solving performance of Grade 10 learners who performed poorly in mathematics problem solving, and were from a disadvantaged socio-economic background. The null hypothesis and an alternative hypothesis for the study are expressed below (see also section 5.8.1.3).

Null Hypothesis (H_0): The implementation of context-based problem solving instruction does not enhance learners' mathematical problem solving skills, and hence their performance.

$$H_0: \mu_{\text{context-based problem solving instruction}} = \mu_{\text{conventional instruction.}}$$

Alternative Hypothesis (H₁): The implementation of context-based problem solving instruction enhances learners' mathematical problem solving skills, and hence their performance.

$$\textbf{H}_1: \mu_{\text{context-based problem solving instruction}} \neq \mu_{\text{conventional instruction}}.$$

5.3 RESEARCH DESIGN

The current study employed a mixed-methods approach, consisting of a *quasi-experimental design*[25]*,* using a non-equivalent control group design to test the effect of context-based problem solving instruction (CBPSI) on learners' problem solving skills, and a *descriptive survey design* to observe and interview participants regarding the implementation of the instruction. The latter was used to account for the outcomes of the quasi-experimental study.

5.3.1 Non-equivalent control group design

According to Arzi and White (2005, p. 141), "Random selection is rarely convenient or even possible in educational research". Cook (2002) observes that "random assignment is rare in research on the effectiveness of strategies to improve student performance" (p. 42). Several researchers rate the non-equivalent control group design as well worth using in many instances in which true experiments are impossible (examples include, Blessing & Florister, 2012; Cohen, Manion & Morrison, 2007; Delamont, 2012; Hancock & Mueller, 2010; Jackson, 2012; Johnson & Christenson, 2012).

True experiments are probably most common in a pre-test post-test group design with random assignment (Gall, Gall & Borg, 2007). It was observed in this study that a lack of randomness would pose a threat to internal validity. For this reason, certain factors in the participating schools were considered (see section 4.3.1). Schools with similar socioeconomic and academic

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[25] Quasi-experiments are experiments that lack random assignment of participants to groups (Gall, Gall & Borg, 2007).

backgrounds participated in the study. The pre-test results of the schools were compared to determine the equivalence before intervention (see section 6.3).

A non-equivalent control group design has been used in several studies. Gaigher *et al*. (2006) employed this design to investigate the effect of a structured problem solving strategy on 189 Grade 12 learners' problem solving skills and their conceptual understanding of physics. The rationale for non-randomized assignment of learners into groups was an "attempt to exclude diffusion, contamination, and rivalry" (Gaigher *et al*., 2006, p. 9). Claire and Michael (2003) used the design in a study in which the effectiveness of a Social Skills Training (SST) programme on 28 learners from four secondary schools was evaluated. They opted for this design "due to practical constraints of time and resources" (p. 241). In this study, two schools formed an experimental group and the other two formed the control group.

Turner and Lapan (2005) employed this design because "it was only feasible to randomly assign intact groups with similar characteristics (i.e. students from the same grades, from the same type of school, and from a similar socio-economic status) to experimental (n = 107) and control (n = 53) groups, rather than individuals being assigned to these groups" (p. 518). Turner and Lapan (2005) acknowledged that this was "because intact classes are already formed before the research is begun" (p. 518). This design has been used widely in educational research in recent years (see, for example, Baker & White, 2003; Chih-Ming & Yi-Lun, 2009; Liu, 2005; Ozmen, 2008). For this study, the researcher therefore found a non-equivalent control group design appropriate because it was not possible to randomly assign participants to either the experimental or control group since intact classes were used: reorganizing participants into experimental and control groups would have disrupted the systematic arrangement and normal running of the participating schools.

5.3.2 Descriptive survey design

In survey studies, information is assessed on attitudes, opinions and behaviour (Gay, Mills & Airasian, 2011). The present study explored the behaviour, views and opinions of learners and teachers about the implementation of CBPSI. This was achieved through purposive semi-structured interviews and classroom observations. These were used to ensure that the "research

does not become over-reliant on one instrument and thus, disconnected from everyday life" (Harries & Brown, 2010, p. 2).

According to Malderez (2003), "observation is one of the two common ways of getting information which can help make sense of educational situations, gauge the effectiveness of educational practices, and plan attempts for improvements" (p. 179). In the current study, the researcher developed a classroom observation schedule to collect data on the use of context-based problem solving instruction (see section 5.3). In the observation of teachers and learners, the researcher ensured uniformity by using the same observation schedule in all classrooms at the various schools at different visitation times.

In order to follow up on observed problem solving behavior and to probe participants' views on the use of context-based problem solving instruction in mathematics, semi-structured interviews were conducted with a purposive sample of learners and two teachers. In purposive sampling, the researcher selects a sample based on his/her experience and knowledge of the group to be sampled (Gay *et al*., 2011). In the context of this study, the researcher gained experience of and knowledge about the participants over a two-week intervention period, during which context-based problem solving tasks were treated in classrooms where observations were conducted. Using this knowledge and experience, the researcher identified a set of criteria for selecting teacher and learner samples for the interviews (see section 5.4.3; Appendix K & Appendix L).

For instance, two teachers, T1 and T2[26], from schools C2 and C3[27] respectively, were sampled for the interviews. The two teachers presented interesting profiles and contrasting teaching approaches. T1 was in possession of a three-year teaching diploma (STD[28]) plus an advanced teaching diploma (FDE) (refer also to Table 4.2). T2 possessed a BEd (section 5.4.4) degree with mathematics as a major. The teaching experience of the two teachers differed significantly; 23 years in the case of T1 and six years in the case of T2.

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[26] See the explanation of T1 and T2 notations in section 5.8.2.2.
[27] See section 5.4.4 for an explanation of C2 and C3 notations. Also see Table 5.2 for the profiles of these schools and those of their respective mathematics teachers (section 5.4.4).
[28] See section 5.4.4 for an explanation of STD and FDE abbreviations.

Given the background on teachers T1 and T2, a set of criteria were established for the selection of teachers for participation in semi-structured interviews. The sampling of teachers for the interviews was made on the basis that:

- They presented contrasting teaching approaches, while implementing context-based problem solving tasks;
- They manifested contrasting opinions on the use of real-life contexts in mathematics problem solving;
- They held different implicit views on the extent to which learner participation should be encouraged and permitted in context-based problem solving lessons;
- They were likely to reveal possible challenges that the incorporation of context-based problem solving instruction posed in mathematics classrooms. (If probed further, comments such as the one from T1, that *".... these learners are different ..."* would probably shed some light on the envisaged pedagogical challenges).

Using this tool, the researcher selected T1 and T2 for the interviews. It was decided that choosing teachers who apparently belonged to different schools of thought would elicit data that would represent a diversity of opinions.

Procedures to select learners for the interviews are discussed in section 7.5 (see also Appendix L for the selection tool used to sample learners for the interviews).

As with the classroom observations, semi-structured interviews were conducted by the researcher with teachers and learners. The purpose of these interviews was to elicit participants' views and opinions on the use of CBPSI. Interviews and observations have been used in numerous educational studies. For instance, Onwu and Mogari (2004) used observations, amongst other techniques, to evaluate the impact of a teacher development project on teachers' classroom instruction. Bansilal *et al*. (2010) used both interviews and observations in a case study involving five learners in which they elicited information on learners' understanding and expectations of their teachers' assessment feedback. Other studies have also employed these data collection

techniques (see, for example, Mogari, 2004; Vithal & Gopal, 2005; Demircioglu, Demircioglu & Calik, 2009; Kramarski & Revach, 2009).

5.4 SAMPLING

Sampling refers to the process and techniques used to select participants. Sampling reduces the cost of collecting data by working with a manageable and accessible group that is representative of the population (Welman *et al*., 2005).

5.4.1 Population

The targeted population in this study was Grade 10 mathematics learners and Grade 10 mathematics teachers from historically socioeconomically disadvantaged township schools in the Gauteng province of South Africa. Prior to the experimental intervention, data was collected to establish participants' demographic information and their suitability for participation in the study (see section 5.2; Appendix D).

In South Africa, the National Party (NP) government advocated a system of unequal distribution of social and educational resources (see section 1.3). Consequently, schools in township areas have experienced the following educational challenges over the decades: 1) inadequate allocation of resources, such as learning and teaching support materials (LTSM); 2) a legacy of inadequately qualified teachers, particularly in the fields of mathematics and science; and 3) challenges in dealing with domain-specific teaching and learning facilities (Khuzwayo, 2005; Van der Berg, 2007). Furthermore, research demonstrates that: most learners who do not perform well in mathematics come from black township schools (see section 1.3); most schools with poor mathematics performance at Grade 12 level are situated in townships; and most teachers considered to be under-qualified or inadequately trained to teach mathematics are also found in township schools (see, for example, Khuzwayo, 2005; Van der Berg, 2007).

Given this background, schools from this population pool were considered for participation in the current study on the basis that: 1) they were located in disadvantaged township settings; 2) they had performed poorly in mathematics in recent years; 3) they had poorly trained mathematics teachers (see section 5.4.4); and, 4) they showed similar school features in terms of

infrastructure, learner enrolment, matriculation results, classroom practice and management, school discipline code and whole school management approach.

5.4.2 Sample

The sample in the study consisted of 783 Grade 10 mathematics learners drawn from nine township high schools. Of these learners, 413 (from five schools) formed an experimental group and 370 (from the remaining four schools) formed the control group. Learners in the control group were taught by their incumbent teachers. There was one teacher from each of the control schools in the sample; hence, four teachers participated in the study. Learners in the experimental schools were taught by the researcher.

The 783 learners were selected to ensure that the mean of the sample ($\bar{x}$) would be representative of the population mean (μ). Johnson and Christensen (2012) note that "larger samples result in smaller sampling errors, which means that your sample values (the statistics) will be closer to the true population values (the parameters)" (p. 481). The number of schools in each group (i.e. experimental and control groups) was decided upon to reduce the effects of inherent differences among the schools as far as possible. Even though similarities among participating schools were identified to ascertain equivalence, there were always inherent differences among these schools. It was hoped that by limiting the number of participating schools to nine the effect of these inherent differences would be minimised.

The researcher focused on Grade 10 mathematics learners because: 1) any change (intervention) implemented at Grade 10 level has the potential to make an impact on future performance in Grade12; 2) it was easier to gain access to Grade 10 learners than to senior Grades, who were preparing for the trial[29] and final national examinations at the time of the study; and, 3) it would be easier to influence Grade 10 learners' mathematical problem solving skills than to achieve similar results with Grade 12 learners.

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[29] Trial or mock examinations in Grade 12 are usually written during the month of September to ascertain the level of preparedness of learners for the final national examination written at the end of the year.

Dacey (1989) identified six critical stages in the growth of human creativity across the lifespan. Among these, the first three stages include both pre-school and school years. The most important stage is the period from 10 to 16 years old. According to Dacey (1989), at this stage learners are attempting to define their self-concept and they are open to new ideas as they intensify their search for identity. In other words, children within this age range are in the best state to learn new things, such as problem solving skills, through context-based problem solving instruction. According to Yan (2000), the period is the optimal stage at which to develop their abilities and skills in problem solving.

Some researchers have discovered that learners' problem solving skills become more systematic and logical as they grow older and that a marked change in their problem solving skills occurs between the ages of 11 and 14 (see, for example, Proctor, 2010; Zhu & Fan, 2006). It was on the basis of these studies that the current study focused on Grade 10 mathematics learners who generally fall within the age range of 16 to 17 years in the South African educational context (Department of Education [DoE], 2006b). According to Lianghuo and Yan (2000), this is the most important stage for learners to develop their skills in problem solving.

All participating schools were public schools (i.e. schools that are government-funded to some extent). In such schools, the government provides a minimum and parents contribute to basics and extras in the form of school fees (Education Foundation, 2010). Five of the participating schools are located in townships in the Ekurhuleni Region in Gauteng; the other four are in the Tshwane[30] Region or Pretoria, also in Gauteng. All schools are governed by the same educational policies, rules and regulations (Department of Basic Education [DBE], 2010; DoE, 1998).

5.4.3 Sampling techniques

A convenience sample was used for this study. This sampling technique has been used in various studies. For instance, Gainsburg (2008) used convenience sampling to select 62 teachers from 28 middle schools and 34 high schools for participation in a study in which he questioned teachers about "their understanding and use of real-world connections" (p. 199). The use of this sampling

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[30] Tshwane is the name used for the Pretoria area.

technique is favoured in studies conducted in naturalistic education settings (see, for example, Lombard & Grosser, 2008; Mji & Makgato, 2006; Mogari, 2004; Ozsoy & Ataman, 2010).

Allocation of schools to either the experimental group or the control group was based on their geographical location. The five schools from the Ekurhuleni Region formed the experimental group, while the four schools from the Tshwane Region formed the control group. The control schools and experimental schools were therefore separated by a distance of about 80 kilometres or 50 miles. According to Gaigher (2006, p. 37), such separation effectively "prevents diffusion, contamination, rivalry and demoralisation". Contamination can occur when learners in different groups talk to each other or borrow each other's study tools (Shea, Arnold & Mann, 2004).

In the current study, this could have occurred when the control group was exposed to a new context-based problem solving instruction that was intended for the experimental group. Results of a study conducted by Howe, Keogh-Brown, Miles and Bachmann (2007) to establish expert consensus on contamination in a naturalistic education setting, suggested that "geographical overlaps are at the highest risk of contamination" (p. 196). According to Howe *et al*. (2007, p. 197), contamination can reduce the "statistical significance and precision of effect estimate" needed to make a statistical conclusion that the observed difference between two groups is due only to intervention.

5.4.4 School and teacher profiles

All schools participating in the study were coded for anonymity. Schools in the experimental group were designated E1, E2, E3, E4 and E5, where the capital letter "E" was a categorical representation for experimental schools. The number following the letter "E" represented the numerical sequence in which school visits were conducted by the researcher. For instance, school E1 was visited first, school E2 second and so on. Similarly, schools in the control group were designated C1, C2, C3 and C4. The letter "C" denoted schools in this category while the numbers 1, 2, 3 and 4 represented the sequence in which schools in this category were visited by the researcher for classroom observations and subsequent semi-structured interviews.

Prior to the commencement of the study, information required from these schools was collected with the help of the teachers (see Appendix E for the form used for this purpose). The form was used to elicit information, such as status of the school, specification of the area in which the school is located, number of learners currently enrolled in Grade 10, school's mathematics performance at Grade 12 level in previous years and so on. This data was used by the researcher to determine each school's suitability for participation in the study and to compare the extent of equivalence demonstrated across schools (see section 6.2; Table 5.2).

As far as the teachers in the sample were concerned, information on their qualifications and experience was also obtained. The qualifications structure for teacher education is subject to the Minister of Education's policy on qualifications in terms of the Higher Education Act of 1997 (DoE, 2006b, p. 14). This policy is expressed in the Higher Education Qualifications Framework (HEQF), which provides the basis for integrating all higher education qualifications into the National Qualifications Framework (NQF). It therefore spells out clear specifications for recognised teaching qualifications.

Generally, teachers' qualifications vary from a three-year college diploma[31] to a degree qualification (DoE, 1996; DoE, 2006b; DoE, 2007; Education Labour Relations Council [ELRC], 2003). Teachers with only a three-year college diploma have since been urged to upgrade their qualification to a bachelor's degree or equivalent. The aim is to develop a high academic standard of education for prospective teachers. The government provided financial support to these teachers to enable them to enrol for a two-year Further Diploma in Education (FDE), which was later replaced by an Advanced Certificate in Education (ACE) qualification (DoE, 2006b; see also DBE, 2011c & ELRC, 2003). Teachers' qualifications, together with their relative years of teaching experience, were considered in this study for their association with the

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[31] Within the high school context, a three-year college diploma was offered as a Secondary Teacher's Diploma (STD), which was the equivalent of a Senior Primary Teacher's Diploma (SPTD), and a Primary Teacher's Diploma (PTD) for senior primary schools and junior primary schools, respectively. Teachers who hold these qualifications have been advised to improve their teaching qualification to a bachelor's degree qualification, and most teachers have opted to add either an FDE or ACE (see section 5.4.4) to their three-year teaching diploma to elevate it to the required teaching level. Others have acquired a Bachelor of Education (BEd) degree, which is a three-year university teaching qualification. Mathematics and science teachers have the option of doing a Bachelor of Science (BSc) in Education, with either mathematics or one of the science subjects as a major.

teacher's method of instruction (Kramarski & Revach, 2009; Smith, Desimone, Zeidner, Dunn, Bhatt & Rumyantseva, 2007).

Given this background, a tool was designed to classify participating teachers according to their teaching qualifications (see Table 5.1). Data in Table 5.1 were provided by teachers when a *"school and teacher profile"* questionnaire was administered (Appendix E). For the purpose of this study a mathematics teacher with only a three-year college diploma, for instance a Secondary Teacher's Diploma (STD), was considered inadequately qualified to teach mathematics at Grade 10 – 12 level. The classification of an STD teacher as being inadequately qualified is in line with the Government Gazette (2011), which places an STD qualification at the National Qualifications Framework (NQF) level 6 or NQF level 6. Most teachers in this category have been urged by the Department of Education to improve their qualifications to meet the demands of the new OBE-oriented curriculum (DoE, 2006b; see also DBE, 2011c).

For the purpose of this study, a teacher with a bachelor's degree qualification or equivalent (for example, STD plus ACE) was considered to be moderately qualified, because in terms of the NQF categories a bachelor's qualification is placed at level 7. A teacher with an honours qualification (NQF level 8) in mathematics, or higher, was considered to be adequately qualified to teach mathematics at Grade 10 – 12 level (Government Gazette, 2011). In order to classify teachers' qualifications, the following three categories were established: "INADEQUATELY QUALIFIED", "MODERATELY QUALIFIED" or "ADEQUATELY QUALIFIED" (see Table 5.1).

Table 5.1: Classification of participating teachers by qualification[32]

Inadequately qualified	Moderately qualified	Adequately qualified
E2: STD	E3: STD + ACE	E1: BSc Hon
E4: STD	E5: STD + FDE	
C1: STD	C2: STD + FDE	
C4: STD	C3: BEd	

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[32] The notation E2: STD in Table 5.1 (for instance), represents the teacher's qualifications in school E2. All other notations in Table 5.1 can be interpreted in the same way. For instance, C3: BEd implies that the mathematics teacher in school C3 has a BEd qualification (a degree). Also, E5: STD + FDE refers to a teacher of mathematics at school E5 with two teaching diplomas in mathematics, and so forth.

At the time this study took place, the official teacher-learner ratio in South African high schools was 1:32 (see DoE, 2006b; DoE, 2009). Table 5.2 presents data on the profiles of each school and each participating teacher. Data in Table 5.2 were collected from all participating schools, through the teachers, prior to the commencement of the study (see Appendix E). The data in Table 5.2 confirmed the equivalence of the participating schools in terms of their socio-economic status and their suitability for participation in the study. The 2010 Grade 12 end-of-year mathematics results from all schools were comparable and suggested serious problems in mathematics instruction in all schools.

Table 5.2: School[33] and teacher profiles

Group Type	School Status	School Code	Teacher Qualification	Years of experience	Number of maths learners in grade 10	Grade 12 maths pass rate in 2010
Experimental	Public	E1	Degree + honours	13	90	38,7%
	Public	E2	Diploma	21	74	27,4%
	Public	E3	Advanced Diploma	08	101	31,6%
	Public	E4	Diploma	18	67	33,4%
	Public	E5	Advanced Diploma	14	81	32,8%
					n = 413	
Control	Public	C1	Diploma	17	133	25,0%
	Public	C2	Advanced Diploma	23	71	34,5%
	Public	C3	Degree	06	80	39,2%
	Public	C4	Diploma	13	86	45,7%
					n = 370	

5.5 Instrumentation

Data was collected mainly through an *achievement test, semi-structured interviews* and *classroom observations* (see Appendices A, Appendix B & Appendix C). However, other data-enriching sources that complemented this data were also used for triangulation purposes. The other sources included: 1) context-based problem solving worksheets (see Appendix I); 2) a

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[33] The enrolment shown in Table 5.2 above reflects the number of learners who were registered in the grade and who were initially sampled for the study. However, some learners were absent during intervention periods and others missed one or both test sessions (see section 7.2 & Table 7.1).

split-attention context-based problem solving task (see Appendix H); 3) a problem solving skills evaluation form (see Appendix F); 4) learner demographic details form (see Appendix D); 5) school and teacher profiles (see Appendix E); and, 6) a cognitive load identification tool (see Appendix G). In the next section, all instruments, including the supplementary instruments and their purpose in this study are discussed.

5.5.1 Purpose of instruments

5.5.1.1 Achievement test

The achievement test was developed by the researcher to measure learners' problem solving skills before and after the intervention. The topic of the test was Financial Mathematics (section 5.5.2.1). The selection of this aspect was intended to explore the influence of real-life context in mathematics problem solving. Principally, the test was administered to evaluate learners' problem solving skills before and after intervention. Financial Mathematics presents numerous opportunities to connect mathematics to a real-life context. The test was administered to both the experimental group and the control group (see Appendix A).

5.5.1.2 Classroom observations

According to Gay, Mills and Airasian (2006), classroom behaviour – behaviour of the teacher, behaviour of the student, and the interactions between teacher and student – can best be studied through naturalistic observation. Mulhall (2003) supports this, noting that observation is an excellent instrument with which to gain a rich picture of any social phenomenon, such as the behaviour of learners in a classroom. Accordingly, the purpose of classroom observations in the current study was to determine what transpired in class during lessons on Financial Mathematics in both the experimental and the control schools. Classroom observations provided useful data on how context-based problem solving instruction could be used in mathematics.

5.5.1.3 Semi-structured interviews

Semi-structured interviews were conducted with learners and teachers. Semi-structured interviews are generally favored in research studies because they are flexible and can be used to follow up on incomplete and unclear responses (Harries & Brown, 2010). Data from classroom observations formed the basis for subsequent semi-structured interviews. Gestures and

expressions that were observed in learners and teachers were probed during interview sessions. Interviews also provided respondents with an opportunity to verbalise and externalise their problem solving thoughts and ideas (see section 7.3).

5.5.1.4 Video recording

Video recording is listed as an essential ethnographic approach in research conducted in naturalistic contexts (DuFon, 2002), because: 1) it allows the researcher to obtain dense data (Heidet, Tate, Divirgilio-Thomas, Kolanowski & Happ, 2010); 2) video recorded data can provide the researcher with more contextual data (Heidet *et al*., 2010; Heath, Hindmarsh & Luff, 2010); 3) it provides information about the posture, facial expressions and gestures of the respondents (DuFon, 2002), especially those with limited linguistic means, may rely extensively on extra-linguistic means to convey their responses to the researcher; 4) it provides the researcher with denser linguistic information (DuFon, 2002; Heath *et al*., 2010); and; 5) video recorded data can be preserved permanently (Heidet *et al*., 2010), which allows the researcher to watch an event repeatedly by playing it back.

5.5.1.5 Context-based problem solving worksheets

Context-based problem solving worksheets were designed and implemented during instruction (see sample at Appendix I). The worksheets contained similar problem solving tasks to those in the achievement test. Topics in the worksheets covered *simple and compound interest, hire purchase, inflation* and *exchange rates* (compare with section 5.5.2.1). Examples 5.1, 5.2 and 5.3 are some of the context-based problem solving tasks contained in the worksheets:

Example 5.1: An example of a simple and compound interest problem task

> Andile invests R200 at 12% per annum (p.a.) simple interest for 3 years. Use the simple interest (SI) formula to calculate:
> 1. the interest which her money accumulates;
> 2. the total amount she will have at the end of 3 years.

The main purpose of these worksheets was to drive the lesson by immersing learners in context-based problem solving exercises. They were also used to familiarize learners with the context-based problem solving approach.

Example 5.2: An example of a problem solving task dealing with different types of interest rate

Suppose interest is compounded for 5 years at 16% p.a. Complete in blocks where the answers are not provided.

Interest description	Interest rate	Number of times compounded
1. if it is compounded annually		$n = 1 \times 5 = 5$
2. if it is compounded half-yearly	$i = \dfrac{0.16}{2} = 0.008$	
3. if it is compounded quarterly		$n = 4 \times 5 = 20$
4. if it is compounded monthly	$i = \dfrac{0.16}{12} = 0.013$	

Example 5.3: An example of a hire purchase problem solving task

A car radio costs R960. Thandi buys a radio on hire purchase and agrees to pay a deposit of R100 and 24 monthly payments of R45. Calculate;
1. the total simple interest paid;
2. the rate of simple interest.

5.5.1.6 Split-attention task

The split-attention task was designed and implemented in experimental schools at the beginning of the intervention (see Appendix H). Split-attention is the process of attending to two distinct

sources of information (Dhlamini & Mogari, 2011; Paas *et al*., 2010; section 4.4). Because split-attention creates unnecessary visual search, it may heighten learners' cognitive load (Paas *et al*., 2010). Hence the purpose of the split-attention task in the current study was to observe the influence of the split-attention effect, if any, and its associated cognitive load on learners' problem solving performance. To examine this influence, two conditions were created for learners, as detailed below.

First condition

In the first condition, the split-attention effect was maximized by writing two parts of the context-based problem task on both sides of the task sheet page (see Appendix H). Half of the learners in the class were subjected to the first condition. Learners subjected to the first condition were required to search for two mutually referring information (information belonging to the same problem task but differently positioned) of the problem, appearing on different sides of the *same* page (see Example 5.4).

According to Example 5.4, learners in the first condition were subjected to a visual search when comparing problem information appearing on both sides of the page. In terms of cognitive load theory, the resulting visual search in the first condition was expected to heighten learners' cognitive load (Paas et al., 2010; Sweller, 2010; Sweller, 1988). The cognitive load theory argues that in the first condition, the splitting effect may create problems for the working memory. In the first condition the problem task information appearing on different sides of the page will have to be processed differently in the working memory. Each time the learner moves from one page to another, pieces of information belonging to the problem solving task in the previous page must be held and processed separately in the working memory. The other problem solving information in the second page will also have to be processed separately. In the first condition the working memory is seen to be executing a dual task of processing the problem information, the process which is likely to heighten cognitive load.

Example 5.4: Example of context-based split-attention task to demonstrate the first condition of split-attention

Side 1 of page 1	Side 2 of page 1
Problem The table below shows the exchange rate of the Rand (R) against other countries. Use the information below to answer the questions that follow.	**Questions** Sipho won a competition where he can fly to three international destinations free of charge with spending money. The destinations he chose were Germany (€), Hong Kong ($) and England (£). He was allocated €9 000, $30 000 and £2 500 for Germany, Hong Kong and England respectively.

Side 1 of page 1 table:

Currency	One foreign unit = R
Euro €	9.178
UK £	14.484
US $	9.925
Australia $	5.556
Botswana Pula	1.621
Canadian $	6.452
Hong Kong $	1.274

Side 2 of page 1 questions:

1. Use the exchange rates in the previous page to calculate the total amount Sipho had been allocated in Rands.
2. If Sipho were to fly to Botswana, Canada and Australia with allocations of 9 500 Pula, $15000 and $21 500, respectively. How much will be his total allocation for this trip?

Second condition

In this condition, the same context-based problem solving task was given to the remaining half of the class. However, in this case, the problem statement, the accompanying diagram and the questions all appeared on the same page, that is, all information appeared on one side of the page (see Example 5.5).

Example 5.5: Example of a context-based problem solving task in which the effect of split-attention is reduced

<div style="background-color:#b8cea0">

Side 1 of page 1

Problem

The table below shows the exchange rate of the Rand (R) against other countries. Use the information below to answer the questions that follow.

Currency	One foreign unit = R
Euro €	9.178
UK £	14.484
US $	9.925
Australia $	5.556
Botswana Pula	1.621
Canadian $	6.452
Hong Kong $	1.274

Questions

Sipho won a competition where he can fly to three international destinations free of charge with spending money. The destinations he chose were Germany (€), Hong Kong ($) and England (£). He was allocated €9 000, $30 000 and £2 500 for Germany, Hong Kong and England respectively.

1. Use the exchange rates in the previous page to calculate the total amount Sipho had been allocated in Rands.

2. If Sipho were to fly to Botswana, Canada and Australia with allocations of 9 500 Pula, $15000 and $21 500, respectively. How much will be his total allocation for this trip?

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According to cognitive load theory, in the second condition, the split-attention effect has been reduced. Learners are not subjected to a visual search of information that is separately positioned but belong to the same problem. According to Cierniak *et al*. (2009), unnecessary visual search during problem solving should be avoided as it may result in heightening of extraneous cognitive

load (Paas *et al*., 2010; Schnotz & Kürschner, 2007; see also section 4.2.2). Extraneous load hampers learners' problem solving development (Chong, 2005).

5.5.1.7 Problem solving skills evaluation form

This tool was designed by the researcher and administered to the learners (n=50) at the experimental schools at the beginning of the study (see Appendix F & section 7.5.3). The purpose of this tool was to evaluate learners' problem solving status prior to the intervention (see section 7.5.3). Learners were given a context-based problem solving task on *Financial Mathematics* and were evaluated as they attempted to solve the problem.

5.5.1.8 Learners' demographic details form

The sample in the study consisted of Grade 10 learners who were from a disadvantaged socio-economic background and who were performing poorly in mathematics. Many learners found in township schools fit this description. Although the researcher was able to conveniently secure the participation of nine of schools such schools, their suitability for participation had to be verified. For this purpose, a tool was designed to collect data on learner demographic background (see Appendix D).

The following information was collected from each learner: *learner's age*; *learner's parents' status*; *learner's parents' employment status*; *learner's parents' education status*; *learner's accessibility to a computer at home* (also see section 6.2). Data were collected from both groups: by teachers in the control schools; and by the researcher in the experimental schools. Data for this instrument were collected throughout the intervention period to compensate for learner absenteeism (see section 6.2).

5.5.1.9 School and teacher profiles

Similarly, the status of the participating schools had to be verified. In terms of this study, to label schools as disadvantaged, the previous year's Grade 12 mathematics results, teachers' qualifications, teachers' years of experience and teacher-learner ratio were explored (see Table 5.2). In order to collect demographic details of schools and teachers a tool was designed and

administered to Grade 10 mathematics teachers in the participating schools (see Appendix E). The results of this exercise are presented in Table 5.2 and discussed in section 6.2.6.

5.5.1.10 Cognitive load measuring tool

The focus of this study was the development of learners' problem solving skills. Given that problem solving is a cognitive activity (Chapter 3 & Chapter 4), cognitive load theory (CLT) (Sweller, 1988) was used to frame the study. CLT is based on the assumption that the development of learners' problem solving skills and abilities occurs when cognitive load is kept at a manageable level. Cognitive load can be related to the mental effort imposed on our working memory each time we attempt to solve a complex task, such as problem solving in mathematics. However, CLT claims that this load (effort) can be managed in order to release working memory resources required to construct schemas for problem solving (see further discussion in Chapter 3 & Chapter 4).

In addition, the present study used real-life context of learners to facilitate the development of their problem solving skills. It was assumed that the inclusion of learners' cognitive load, which is perceived to impede on problem solving performance. To test this assumption learners' cognitive load was measured before and after the achievement test. The researcher adopted the measuring instrument developed by Paas, Van Merriënboer and Adams (1994). The instrument is a self-rating scale of cognitive load (mental effort) that, based on early work by Bratfisch, Borg and Dornic (1972), uses a post-test questionnaire in which test takers are asked to report the amount of mental effort invested in performing problem solving tasks in a test. Mental effort is therefore the cognitive capacity that is actually allocated to solve the problem and can be considered to reflect the cognitive load (Sweller *et al*., 1998).

A self-rating scale of mental effort consists of a nine-point scale: 1 (extremely easy); 2 (very easy); 3 (easy); 4 (quite easy); 5 (neither easy or difficult); 6 (quite difficult); 7 (difficult); 8 (very difficult); and, 9 (extremely difficult) (see also, Appendix G). Each of the self-rating scale choices was presented in the learners' answer booklets immediately following each session of the achievement test (pre-test and post-test). The first measure of learners' cognitive load, carried out after the pre-test, served as a baseline measure. The second measure of learners' cognitive

load, carried out after the post-test, served as an indication of the influence of incorporating real-life context into the problem solving tasks. The analysis of the two measurements of learners' cognitive load is discussed in section 6.7.

5.5.2 Development of instruments

5.5.2.1 Achievement tests

A section of the mathematics syllabus, Financial Mathematics, was selected for the study. Topics in this section cover *simple and compound interest, hire purchase, inflation* and *exchange rates*. This topic was chosen because it offered opportunities for problem solving tasks and possibilities for exploring mathematical connections with real-life issues. The test was developed using guidelines from the new Curriculum and Assessment Policy Statement (CAPS) and the National Curriculum Statement (NCS) (DoE, 2005; DBE, 2011b).

The aim of the test was to differentiate learners according to performance (DoE, 2005). In South Africa, the Department of Education has adopted a seven-point scale to rate learners according to their test or examination scores. This is illustrated in Table 5.3.

Table 5.3: The seven-point scale used in schools for reporting purposes

Rating code	Rating	Marks (%)
7	Outstanding achievement	80 – 100
6	Meritorious achievement	70 – 79
5	Substantial achievement	60 – 69
4	Adequate achievement	50 – 59
3	Moderate achievement	40 – 49
2	Elementary achievement	30 – 39
1	Not achieved	0 – 29

Source: DoE (2005, p.6)

Using the guidelines in Table 5.3 teachers can differentiate between learners on the basis of their performance; tests and examinations should be set in such a way as to allow this differentiation

between learners. For learners in Grade 10, the taxonomical table in Table 5.4 should be considered when constructing a differentiated test or examination paper:

Table 5.4: Taxonomical differentiation of questions on Grade 10 mathematics test[34]

Category	Knowing	Performing routine procedures	Performing complex procedures	Solving problems
Weight (%)	10 – 20%	40 – 50%	20 – 30%	5 – 10%

Source: DoE (2000, p. 12)

Given these assessment guidelines, the achievement test for the current study was constructed. However, it was not possible to adopt the taxonomy in Table 5.4 as the current study focussed on problem solving rather than on the other cognitive levels. For this reason, the following tool was designed for use in construction of the achievement test used in this study:

Test questions were sampled from previous Grade 10 examination question papers. It was also noted that, according to the CAPS mathematics document, "The approximate weighting of teaching time for Financial Mathematics at Grade 10 level is 5%" (DBE, 2011b, p. 14). The 5% teaching time specified in DBE (2011b) means that "exactly two weeks of teaching time should be spent teaching Financial Mathematics at Grade 10 level" (p. 23). During this period, the teacher should "use the simple and compound growth formulae to solve problems, including interest, hire purchase, inflation, population growth and other real-life problems" (DBE, 2011b, p. 23). Furthermore, according to DBE (2011b, p. 5), in Grades 10 to 12, the "instructional time" per week for mathematics is 4.5 hours. Given these guidelines, the researcher constructed a one-hour achievement test. The test was modelled on previous DBE question papers.

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[34] The above taxonomical categories are based on the 1999 TIMSS survey (see also DoE, 2005, p. 12).

Table5.5: Tool used to construct the achievement test [35]

Cognitive level	Description of cognitive level	%	Example of question
Knowing	These are questions that require the recall of information or comprehension of knowledge and basic facts.	17%	Q: 4.3 and 4.4 of achievement test
Performing routine procedures	These questions require learners to apply learned procedures involving a number of steps to solve questions. These questions are similar to those encountered in class.	25%	Q: 1.1 and 1.2 of achievement test
Performing complex procedures	Learners are required to choose correct procedure, analyse question by breaking it down, apply knowledge in problem solving.	8%	Q: 5 of achievement test
Solving problems	These are novel questions requiring learners to integrate their knowledge. Learner must break problem into pieces and identify what is to be solved.	50%	Q: 2.1; 2.2 and 2.3 of achievement test

5.5.2.2 Observation schedule

An observation schedule was constructed to observe how lessons were offered in both groups (see Appendix C). Given the research questions of the study, the researcher identified key issues for attention during lessons. For instance, the researcher wanted to observe how CBPSI could be incorporated into a mathematics lesson (research question 1). Also, possible challenges, if any, posed to teaching and learning mathematics by the incorporation of intervention instruction required observation (research question 2). With this in mind, the observation schedule was developed to address research questions 1 and 2 of the study.

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[35] The descriptions of each cognitive level in Table 5.5 were taken from DoE (2005, p. 26). See also Appendix N.

5.5.2.3 Semi-structured interviews

As in the case of the observation schedule, the interview schedule was developed to address the first two research questions (see Appendix B). As interviews were semi-structured, some of the questions were formulated to address various contexts presented by different participants during lessons. However, each question was posed in a way that generated feedback that addressed common themes.

5.5.3 Validation of instruments

In the context of this study, validity refers to the extent to which a specific instrument was able to provide data that related to the enhancement of learners' mathematical problem solving skills through intervention.

5.5.3.1 Achievement test

Content validity, including forms of *face validity*, was established for the achievement test. Face validity was established because it was necessary to judge whether measurement of learners' problem solving skills through the test was worth pursuing (Cohen *et al*., 2007; Johnson & Christensen, 2012; Rubin & Babbie, 2010). Content validity, which is the degree to which a measure covers the range of meanings included within the concept, was established when mathematics practitioners confirmed that the content of the test adhered to the requirements of the Grade 10 mathematics curriculum. Both forms of validity were established on the basis of personal judgements. The use of expert judgement on validation is common in educational studies (examples include, Demircioglu, Demircioglu & Calik, 2009; Donkor, 2010; Hattingh & Killen, 2003; Kasanda *et al*., 2005).

Rubin and Babbie (2010, p. 198) advise that "it is important to conduct an empirical assessment of the adequacy of those judgements". In order to address the latter and to further strengthen the validity of the test, *criterion-related validity* was established during the pilot phase. In this case, the criterion was whether the test provided feedback on the status of learners' problem solving skills. Subsequently, the validity of the test, on the basis of its scores, was determined by its ability to distinguish between problem solving skills of learners who had received treatment and those who had not. The type of criterion-related validity that was demonstrated in this process

was *predictive validity*. Predictive validity is determined when the ability of an instrument to "predict a criterion that will occur in the future" is tested (Rubin & Babbie, 2010, p. 198).

5.5.3.1.1 The process of content validation for the achievement test

The present study attempted to locate mathematical problem solving within the everyday context of participants. Efforts were therefore made to construct an achievement test that would meet this objective. In order to achieve this, a context-rich mathematical topic, Financial Mathematics*,* was selected from the Grade 10 mathematics syllabus. Initially, the selected themes from this topic included *foreign exchange, percentages, profits and discounts, simple and compound interest* and *inflation*. After construction, the test was given to credible mathematics practitioners, two university professors, two university lecturers with doctoral qualifications in mathematics education, two school mathematics curriculum advisors, two heads of department for mathematics at school level and two mathematics teachers teaching mathematics at Grade 10 - 12 levels. In all, ten experts validated the test. They all worked independently and were employed at different education institutions.

5.5.3.1.2 Comments from mathematics practitioners

The mathematics practitioners commented on various aspects of the achievement test, ranging from language editing, to relevance and compliance of test content and the requirements of the curriculum it was purporting to address. For instance, some judges raised the concern that the topic of "percentages" formed part of the content for Grades 7 - 9 and was thus not appropriate in a Grade 10 test.

Comments on the extent to which high achievers would be challenged by the test were also incorporated in the feedback. In this regard, the test was generally judged to be "not very discriminating". The researcher was further advised to formulate questions at increasing levels of difficulty so that learners could differentiate themselves by ability. There was also the suggestion that open-ended questions requiring learner thinking be incorporated in the test. The problem solving task in Example 5.6 was suggested by one professor.

Example 5.6: A context-based problem solving task suggested by one professor

> *Manala spent R475 on two skirts and a pair of shoes.*
>
> *How much did she pay for the skirts and the shoes?*

Although this question appeared to be unsolvable, it was deemed capable of promoting mathematical reasoning and thinking and was thought likely to induce the exposition of learners' problem solving strategies. In one comment, the researcher was also advised to cross-check the test against taxonomical categories (see Table 3.7 of DoE, 2006a, p. 12 in Appendix N). Table 3.7 was also recommended as a guideline in the allocation of marks.

5.5.3.1.3 Adjustments to test

The researcher considered all suggestions. Some of the questions were discarded because they were not appropriate for Grade 10 mathematics which was tested in this study. More relevant questions were incorporated in the newly constructed test (see test in Appendix A). The researcher revised both NCS and CAPS documents to maximise test alignment and content of the test and curriculum expectations. Finally, the following topics were included in the test: *foreign exchange*; *simple and compound interest*; *hire purchase*; and *inflation*.

5.5.3.2 Validation of interviews and observation schedules

Prior to the commencement of the main study, a pilot study was conducted (section 5.6.1). The purpose of the pilot study was to examine the level of bias in the research process, in the interviews and in the interview questions, and also to trial the implementation of the observation process (Johnson & Christensen, 2012; MacMillan & Schumacher, 2006). During piloting, all questions from the interview schedule were asked to strengthen consistency in data elicitation across respondents. Classroom observations were guided by the observation schedule. Some of the constructs that guided the development of data collection instruments appear in Table 5.6.

Table 5.6: Constructs measured by each research instrument

Research question	Instrument(s)	What the researcher intended to measure
1	Interviews/ observations	• Attitude and views on problem solving instruction and context; • Approach to and strategies of problem solving (methodology); • Infusion of problem solving approach in instruction (classroom); • When and how to incorporate problem solving approach; • Teacher training.
2	Interviews/ observations	• Teacher training and preparedness; • Learner participation and preparedness; • Class sizes and infrastructure; • Curriculum organisation and time factor; • Teaching and learning material; • Knowledge base and scope; • Learner participation.
3	Achievement test	• Enhancement of problem solving skills.

Data from semi-structured interviews and classroom observations were cross-validated through convergent validity. Convergent validity was used to examine the level of relationship and agreement between data from both interviews and observations (Brasil & Bordin, 2010). This comparison was possible because both instruments measured the same constructs (see Table 5.6 above). This method was used in an attempt to decrease the weaknesses and bias of each method and "to increase the potential for counter-balancing the weaknesses and bias of one method with the strengths of the other" (Waltz, Strickland & Lenz, 2010, p. 460). Results from the pilot study demonstrated a strong correlation between the two instruments, hence the strong convergent validity.

5.5.4 Reliability of the instruments

5.5.4.1 Achievement test

The reliability of test items was determined with application of the Spearman Brown formula. This was used to measure the "linear relationship between two sets of ranked data" (Charter,

2001, p. 693), which was learners' scores obtained in the pre and post-tests. The results confirmed the reliability of the test to measure learners' problem solving skills. With a sample of n = 57, a value of r = 0.92 was computed for reliability of the test.

5.5.4.2 Classroom observations

Reliability of the observations was determined through a process of repeated usage of the observation schedule. In addition, comparative checking of consistency in the outcomes was done. Observation results were checked against interview results in every case.

5.5.4.3 Semi-structured interviews

In order to enhance reliability in the semi-structured interviews, the following precautions were taken: 1) the researcher conducted all the interviews in an attempt to reduce subjectivity and minimise variability (Donkor, 2010); 2) all interview questions were asked in the sequence in which they appeared in the interview schedule and using the same words; and, 3) all participants were interviewed under similar conditions; 4) all interviews were conducted after contact time, at school, and for 30 minutes with all participants.

5.6 DATA COLLECTION

5.6.1 Pilot study

A pilot study was conducted in a high school with socio-economic conditions that resembled those of the schools used in the current study but located in a completely different area from where the experimental schools are located, and almost 100km from where the control schools are located. These geographical locations ensured there was no 'contamination', i.e., there was no possible interaction between participants in the experimental and control groups. Two Grade 10 mathematics classes participated in a two-week intervention in which the researcher implemented context-based problem solving instruction. The sample was one of convenience and included 57 learners (33 girls and 24 boys). The mean age of the learners was 18.44 (*SD* = 0.74) (see Table 5.7). The teacher was interviewed.

Table 5.7: Demographic breakdown of participants in the pilot study

PILOT STUDY				
Age	Boys	Girls	*M*	*SD*
17	1	1	18.44	.74
18	14	26		
19	02	01		
20	07	05		
	24	**33**		

5.6.1.1 Implementation of intervention in pilot study

The pilot school followed departmental guidelines in the construction of its timetable for mathematics at this level (DBE, 2011b). The school allocated nine periods to Grade 10 to Grade 12 mathematics, which is equivalent to 4.5 hours of teaching time per week (DBE, 2011c). Each period was 30 minutes in length, which amounted to an hour for each double period. Given this arrangement, it was possible to implement the following two-week intervention (see Table 5.8):

Table 5.8: A two-week data collection programme for the pilot study

PILOT PROGRAMME			
WEEK	**DAY**	**LESSON ACTIVITY**	**RESEARCH ACTIVITY**
	1	1. Researcher introduces himself; 2. Participants write pre-test; 3. Invigilation by researcher.	} **ADMINISTER** **PRE-TEST**
1	2 - 3	1. Introduction of lesson (**simple interest**); → INTERVENTION 2. Learners arranged in groups; 3. Examples worksheet given to learners; 4. Learners go through solution steps; 5. Self-explanation takes place; ——→ OBSERVATIONS 6. Problem solving activities by learners.	
	4 - 5	1. Introduction: (**hire purchase**); 2. Examples worksheet; 3. Self-explanation; ————→ OBSERVATIONS 4. Problem solving; ————→ OBSERVATIONS 5. Revision and remedial.	
2	6-7	1. Introduction: (**compound interest**); 2. Examples worksheet; 3. Self-explanation; ————→ OBSERVATIONS 4. Problem solving. ————→ OBSERVATIONS	
	8-9	1. Introduction: (**inflation/exchange rates**); 2. Examples worksheet; 3. Self-explanation; ———→ OBSERVATIONS 4. Problem solving; ———→ OBSERVATIONS 5. Revision, remedial, conclusion. → INTERVIEWS	
	10	1. Participants write post-test; 2. Invigilation by researcher.	} **ADMINISTER** **POST-TEST**

5.6.1.2 Quantitative results from the pilot study

Using a t-test, data collected from the pre-test and the post-test were analysed (see section 6.3.1). Having observed the improvement in performance from the pre-test to the post-test performance, the researcher needed to verify that this improvement was in fact due to the problem solving intervention. In order to determine the effectiveness of a context-based problem solving

instruction (CBPSI), the mean scores of the pre and post-tests were compared using a t-test at the significance level of 0.05. The results suggested that the performance of learners in a context-based problem solving achievement test had improved significantly ($p < 0.05$). From these results, it was possible to conclude that the CBPSI designed to improve learners' problem solving skills had been effective. One of the research questions had been answered, i.e.: *To what extent can the incorporation of a context-based problem solving strategy influence learners' performance in mathematics?*

5.6.1.3 Implication of the pilot study results

The quantitative results from the pilot study suggested that the context-based problem solving strategy is effective. Based on these results, it was reasonable to expect similar results from the main study, given that the main study was to be conducted under similar conditions. The pilot school was comparable to the schools in the main study in terms of its socioeconomic status. The pilot school was governed by similar rules as those applied at the schools in the main study and it was therefore reasonable to expect similar results from the main study.

5.6.2 Main study

Collection of data followed a similar procedure to that used in the pilot study (see Table 5.8).

5.6.2.1 Achievement test

The study began with the administration of a pre-test - an achievement test - to both groups (experimental and control). In order to ensure anonymity, learners were assigned index numbers for use in the achievement test; they were given codes such as PRE-001, representing learner 1 in the pre-test. So, PRE-234 referred to learner 234 in the pre-test. Learners were requested to use the same numbers for the post-test. For instance, a learner with a pre-test code of PRE-051 used the code POS-051 for the post-test. Each learner was allocated a unique code and numbers continued consecutively without interruption from school to school. For instance, if the last learner at school E1 was coded PRE-070 for the pre-test, the first learner at school E2 was coded PRE-071 for pre-test and POS-071 for the post-test.

The test was one hour in duration and in most schools a double period of mathematics was used for this purpose. The researcher administered the test in the experimental schools, while teachers administered the test in the control schools. In order to ensure that conditions remained similar for both groups, which were situated almost 80km apart (see section 5.4.3), the researcher met with each teacher prior to the test. Teachers were requested to start and end the test on time and to encourage learners to be on time for the test. They were asked to invigilate scrupulously and to remain at their invigilation stations during the test. They were also reminded not to provide any assistance to learners while they were writing the test. These precautions ensured that test conditions were fairly similar in all schools.

5.6.2.2 Instruction

The researcher himself implemented a context-based problem solving instruction (CBPSI) in five experimental schools while teachers retained conventional problem solving instructions (CPSI) in four control schools (see descriptions of CBPSI and CPSI in section 1.9.7 and section 1.9.6 respectively). The avoidance of a teacher component in experimental schools was designed to eliminate variations in the implementation of CBPSI. In addition, teachers would have had to be trained on how to use CBPSI and this might have prolonged the study. In total, the CBPSI was implemented over a period of eight weeks, with each school undergoing a two-week period of intervention. Each control school was paired with an experimental school during each two-week period of experimental intervention (see Figure 6.6). This pairing allowed the researcher to visit the twinned control schools during the period of the implementation of CBPSI at the paired experimental school. In order to achieve this, arrangements were made with teachers to allow the researcher conduct classroom observation in control schools at least once during this period, particularly on days on which the researcher had little teaching time at a corresponding experimental school.

There was a concern that the staggered format of implementing CBPSI would advantage schools that were taught in the latter part of the eight weeks of the study, given that the researcher could already have found solutions to challenges observed in earlier implementation. However, prior to this study, the researcher had worked with various high schools in intervention and remedial programmes. It was during this period that the researcher tried, tested and further modified the

implementation of CBPSI. To a large extent, this ensured that the staggered approach of implementation did not disadvantage schools that were taught first.

All participating schools followed departmental guidelines on the construction of their school timetables, allowing 4.5 hours of teaching time for mathematics per week. It was therefore possible to implement CBPSI uniformly in all schools. In each of the experimental schools, the researcher was given a timetable of instruction (see Figure 5.1 for an example of a mathematics timetable used in school E2).

Figure 5.1: An instructional timetable used by the researcher at school E2 during the intervention

	8:00 8:30	8:30 9:00	9:00 9:30	9:30 10:00	10:00 10:30	10:30 11:00	11:45 12:15	12:15 12:45	12:45 13:15	13:15 13:45	13:45 14:15
	1	2	3	4	5	6	7	8	9	10	11
Monday	MAT	MAT		MAT	MAT						
Tuesday		MAT	MAT		MAT	MAT					
Wednesday	MAT	MAT	MAT	MAT							
Thursday	MAT	MAT	MAT								
Friday	MAT	MAT		MAT							

The Principal and teachers at school E2 believed that it was preferable to teach mathematics in the morning when learners were still mentally and physically fresh; it was observed that this practice was in fact common to almost all schools. At school E2, a normal school day started at 8H00 and ended at 14H15. Teachers were advised to report for duty at 7H30 or earlier. At almost all schools, teachers remained at school until 15H00, during which time they prepared lessons for the following day, marked learners' work, fulfilled extra-curricular duties, held departmental meetings and handled other administrative tasks. School E2 had 74 Grade 10 mathematics learners in two classes (Grade 10A and Grade 10C). The Grade 10A class consisted of 43 learners and the Grade 10C of 31 learners. For the purpose of this study, the first double period

(one hour) on Monday (Day 1) was used for the introduction and the writing of the pre-test (achievement test).

The post-test was written on the last Friday of the two-week intervention period as follows: periods 1 and 2 for Grade 10A learners; and periods 3 and 4 for Grade 10C learners. The challenge was that there was only one period available for Grade 10C to write the post-test on the Friday. However, arrangements were made with the school to make use of periods 3 and 4 for this purpose. The researcher invigilated both classes (Grade 10A and Grade 10C) during the test sessions and this arrangement preserved uniformity across all the experimental schools. Given that the researcher worked with intact groups at each of the experimental schools and that the research involved four teachers at the control schools, it was not possible to extend the intervention period (or the study) beyond two weeks for each school. This complied with the Department of Basic Education's curriculum policy guidelines (DBE, 2011b).

Some of the challenges facing the implementation of the new instruction (CBPSI) included variations in the number of Grade 10 mathematics classes across schools. Some schools had more classes than others. For instance, in school E3, there were 101 learners of Grade 10 mathematics divided into three classes comprising 33, 31 and 37 learners respectively. On some days the researcher taught six periods of mathematics at this school. This became even more strenuous when all three double periods ran consecutively; however, the researcher strove to preserve the same momentum with all classes.

5.6.2.2.1 The lesson (The CBPSI lesson)

The following stages (phases) comprised the CBPSI lesson (see also section 8.4.1 & Figure 8.1).
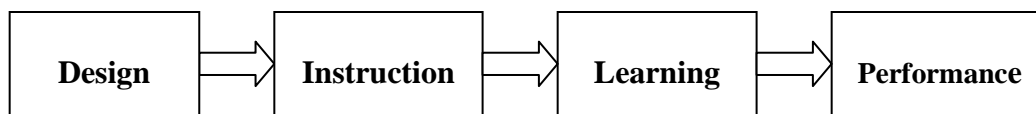
(i) The design phase

This phase of the lesson is called the design phase because an effective and meaningful learning environment is constructed. In this context *learning* is conceived in terms of the operational definition provided in section 1.9.3. In terms of the definition in section 1.9.3, an instructional environment is constructed to enhance the development of learners' problem solving schemas.

Three activities characterised this phase: designing activities that minimise the split-attention effect; redesigning or contextualising the problem solving tasks to the real-life context of the learners; and, redesigning and restructuring the arrangement of learners in the classroom.

Why minimise the split-attention effect

Context-based problem solving activities (worksheets) were planned in such a way that they minimised the effect of split-attention. For instance, all tasks started and ended on the same problem sheet. All components of the problem, that is, the problem and associated questions, were integrated to minimise the negative effects of visual search during problem solving activity. When the visual search is minimised the cognitive load that hinders problem solving performance is also at a minimal. Problem solving performance is maximised and learning takes place.

Why contextualise the problem solving tasks

Placing problem tasks within the real-life context stimulated motivation and robust interactions in groups.

Why arrange learners in groups

Research on cognitive load theory (CLT) recognises group learning as "an alternative way of overcoming individual working memory limitations" (Paas *et al*., 2010, p. 118). According to the CLT perspective, "a group of learners can be considered as an information processing system consisting of multiple, limited working memories that can create a collective working space" (Paas, *et. al*., 2010, p. 119). In a group setting, the cognitive load inherent in a problem solving task can be distributed across the multiple collaborating working memories, thus reducing the risk of overloading each individual working memory. Kirschner, Paas and Kirschner (2009a,

2009b; 2009c) have shown that because of the distribution advantage and expanded processing capacity, meaningful learning from tasks that impose high cognitive load is more likely to occur in a collaborative learning setting than in an individual learning setting.

(ii) Instruction phase

In order to facilitate learning, each group was given an example sheet (worked-out examples with all solution steps) with three to four examples that had been worked out step by step (see Appendix J; Salden *et al*. 2010; Schwonke, Renkl, Salden & Aleven, 2011; Sweller *et al*., 2011). Learners studied the examples (see section 5.6.2.2.2). After going through the solution steps of the worked-out example they embarked on a "*self-explanation*" activity to demonstrate their understanding of the solution steps (Sweller *et al*., 2011, p. 187). In addition, self-explanation was coupled with "self-explanation prompts[36]" (Hilbert, Schworm & Renkl, 2004, p. 185). During a self-explanation prompt the researcher asked questions to learners during each worked-out problem activity, and this occurred in each group. The main purpose of the self-explanation prompts was to facilitate the self-explanation activity and thereby foster learning (Hilbert *et al*., 2004).

(iii) Learning phase

The third phase was allocated to schema construction and problem solving. The aim of the third phase was to test whether learners had been able to learn from the worked-out examples. Evidence of the development of problem solving schema is observed when learners are able to relate new knowledge to old knowledge, and are able to identify novel problems as belonging to a particular group of similar problems.

At this phase, learners actively solved problems in groups as well as individually, while the researcher moved from one group to another. Questions such as the following were posed by the researcher: "W*hat came into your mind when you were first confronted with this problem?";* *"Do you understand this problem?"; "What is your solution strategy for this problem?", "How does this problem relate to your situation at home?"; "How do you normally deal with this*

---

[36] Self-explanation prompts are more like follow-up questions posed by the teacher when learners do not take the initiative to externalise their thoughts or give superficial explanations of their understanding of the solution steps (see Bud´e, Van de Wiel, Tjaart Imbos & Berger, 2011; Hilbert *et al*., 2004; Sweller *et al*., 2011, p. 183).

problem at home?". The purpose of these questions was to ascertain the extent to which example-related activities, administered at the start of the lesson, were able to stimulate and enhance learners' problem solving abilities.

(iv) Performance phase

The performance phase constitutes the final phase of the CBPSI lesson. At this phase learners demonstrate the levels at which they have mastered the skill of solving the problems. They demonstrate that their problem solving skills and performance have been automated.

5.6.2.2.2 Worked-out examples (activities and worksheets)

Cognitive load research has shown that learning from worked-out examples, in comparison to problem solving, is very effective during the initial stages of problem solving skill acquisition (Renkl & Atkinson, 2010; Van Gog & Rummel, 2010; Sweller *et al*., 2011; see also section 2.9 for further discussion).

In the present study, the researcher used a "*worked-out example effect*" (Sweller *et al*., 2011; Renkl & Atkinson, 2010; Schwonke *et al*., 2011; Van Loon-Hillen *et al*., 2012), which is advanced through the cognitive load theory (CLT) (Retnowati, Ayres & Sweller, 2010; Sweller, 2010; Sweller *et al*., 2011) to optimise the acquisition of problem solving skills by Grade 10 learners performing poorly in mathematics. Using this approach, the researcher developed example worksheets for learners, which provided a model for solving a particular type of problem in a step-by-step fashion (see also Appendix J). The purpose of learning from examples was to build into learners' cognitive schemata an idea of how such problems could be solved (see Table 5.9 for a sample).

Table 5.9: A summary of a planned context-based problem solving lesson

CONTEXT BASED PROBLEM SOLVING LESSON	
Lesson stages	**Planned activities**
INTRODUCTION (15 min)	• Researcher introduces topic to class; • Explanation of key terms and concepts; • Questions asked to assess learners' knowledge of topic; • Researcher establishes the level of connections between topic and learners' real-life experience.
BODY (20 min)	• Learners arranged in groups; • Example sheets given to groups; • Learners discuss solution steps; • Researcher monitors group discussions; • Self-explanation activity and probing takes place.
CONCLUSION (25 min)	• Reflection; • Problem solving activity (class work/group discussions); • Evaluation of success rate; • More problems tackled; • Homework given.

5.6.2.3 Classroom observation

The researcher conducted all classroom observations of both teachers and learners. Observation with experimental groups continued throughout the intervention. The researcher visited each of the control schools only once, and this visit covered observation of both teachers and learners. These visits were limited in order to minimize possible disruption during lessons and to avoid over-burdening teachers and learners with the researcher's presence at these control schools. Limited visits by the researcher allowed lessons to run naturally at these schools. The researcher arranged the timing of each visit with the teachers. Teachers helped the researcher to identify a lesson that was likely to offer rich problem solving opportunities which, would allow both the teacher and the learners to reflect on their problem solving behavior. Other factors, such as arrangements of timetables at schools, were also considered when planning these visits. Visits were scheduled for days on which the researcher had fewer teaching periods at the experimental schools.

It was also important for the researcher to observe the dress code at each school. Naturally, trends varied from one school to another, but not to a significant extent, as all schools were governed by the same basic dress code. Most importantly, the researcher avoided wearing anything that suggested affiliation with a political organization or sports team - something which might have influenced participants' reception of and reactions towards him.

5.6.2.3.1 Teacher observation

Teachers in the control schools were observed during their conventional problem solving lessons (section 1.9.6). They were encouraged to continue with their usual style of teaching, and were only given context-based problem solving activity sheets constructed by the researcher (see Appendix C). The purpose of the observation was to: 1) verify and ascertain the type of instruction the teacher implemented during intervention; 2) identify problem solving strategies employed in context-based problem solving activities; 3) observe how the teacher used conventional instruction to solve context-based problems; 4) observe the quality of teacher-learner interaction during context-based problem solving; 5) determine the extent to which real-life knowledge was used to influence the lesson and the problem solving success; 6) determine stages of the lesson where the teacher incorporated problem solving, and how it was incorporated; 7) determine how the teacher developed learners' problem solving skills; and, 8) identify teachers' tendencies to rely on routine procedures of solution.

5.6.2.3.2 Observations of learners in control group

During the problem solving session, the following were observed in the learners in the control group: 1) problem solving strategies and approach; 2) level of involvement and contribution during instruction; 3) level of exposition of previously acquired knowledge; 4) challenges faced by learners exposed to conventional instruction during problem solving; and, 5) ability to connect real-life experience to problem solving activities.

5.6.2.3.3 Observations of learners in experimental group

Observations in this group were on-going throughout the intervention. This group was taught by the researcher, and was the focus group in testing the effectiveness of context-based problem solving instruction. Most of the data was generated from this group. They engaged in the same

problem solving activities as learners in the control schools, but were exposed to the new instruction that was implemented by the researcher. The following were observed in learners: 1) how learners reacted to the context-based problem solving instruction; 2) how learners adapted to a context-based problem solving approach; 3) how the intervention instruction influenced learners' problem solving skills; 4) challenges posed to learners by the learners' exposure to the intervention instruction; and, 5) learners' experiences in learning new strategies for problem solving.

5.6.2.4 Interviews

5.6.2.4.1 Interviews with teachers

Four teachers participated in the study, but only two of them were purposively selected for the interviews. This selection was based on teachers' tendencies to display problem solving actions that related to the research questions in the current study. For instance, a teacher who openly encouraged learners to make meaningful connections between mathematics and real-life issues was deemed likely to provide meaningful responses on how to incorporate context-based problem solving instruction in a mathematics classroom. On the other hand, a teacher who seemed not to advocate discourse that would encourage the infusion of real-life material into mathematics would be regarded as likely to provide meaningful responses regarding possible challenges related to the incorporation of context-based instruction into mathematics instruction.

During the semi-structured interviews, the researcher probed teachers on: 1) their problem-solving beliefs. According to Leikin (2003), teachers' problem solving beliefs strongly influence their mathematical performance and their preferences for using different problem solving tools and strategies; 2) their views on how mathematical problem solving should be taught; 3) their views on the incorporation of real-life context into mathematical instruction; 4) the way they characterized a problem solving approach; 5) what they regarded as challenges in the implementation of context-based problem solving instruction for mathematics; and, 6) how they taught problem solving skills in their mathematics classrooms.

5.6.2.4.2 Interviews with learners in the control group

The control group was subjected to conventional instruction. The researcher was keen to listen to learners' experiences in tackling context-based problem solving tasks using conventional approaches. Only a few learners were purposely selected for the interviews. This selection was based on learners' observed problem solving behavior during instruction and their scores on an achievement test. Interviewees included learners whose performance was excellent, average and weak during problem solving tasks.

During interviews, the interviewer probed learners on: 1) their views and understanding of mathematical problem solving; 2) their views on how mathematics should be taught; 3) their views on the incorporation of context in mathematical learning (the role of real-life context in mathematics learning); 4) what learners regarded as challenges in the incorporation of context-based problem instruction into mathematics instruction; and, 5) their suggestions on how to incorporate context-based problem solving instruction.

5.6.2.4.3 Interviews with learners in the experimental group

This group was subjected to a context-based problem solving treatment administered by the researcher. From this group, the researcher was keen to document learners' experiences during intervention, particularly their gains. Similarly, only a few learners were purposively selected for the interviews. This selection was based on their observed problem solving behavior during context-based problem solving instruction and their results on the achievement test. The interviewees included learners whose performance had been excellent, average and weak during the problem solving tasks. In terms of the observation, feedback interviewees comprised learners who had participated most, moderately and least during the problem solving sessions.

During interviews, the interviewer probed learners on: 1) their experiences and exposure to new instruction; 2) their observed problem solving strategies and behaviours; and, 3) their suggestions on how to incorporate context-based problem solving instruction in mathematics.

5.7 DATA ANALYSIS

Data were analysed in several different ways, starting with statistical analysis of scores from the quantitative data (achievement test). Data from classroom observations and semi-structured interviews were analysed using qualitative methods.

5.7.1 Quantitative analysis

In analysing quantitative data one-way analysis of covariance (ANCOVA) was performed in order to adjust initial group differences in participants' pre-test scores related to performance on the dependant variable (Gay *et al*., 2011). The dependent variable was learners' mathematics achievement post-test scores; the covariate was learners' pre-test scores. Before performing the ANCOVA test, the researcher evaluated the assumptions underlying it, namely, the homogeneity of regression (slope) assumption and the assumption of linearity of data distribution.

Besides the use of ANCOVA various statistical techniques are also employed to analyse certain aspects of quantitative data (see section 6.1). An alpha level of 0.05 was used for all statistical data. The magnitude of relationships reported were interpreted using Jacksons' (2012) descriptors, as listed in Table 5.11:

Table 5.10: Estimates for weak, moderate and strong correlation coefficients

Correlation coefficient	Strength of relationship
$\pm$ 0.70 – 1.00	Strong
$\pm$ 0.30 – 0.60	Moderate
$\pm$ 0.00 – 0.29	None (0.0) to weak

Source: *Jackson (2012, p. 149)*

5.7.1.1. Homogeneity of regression test

The homogeneity of regression test evaluates the interaction between the covariate and the independent variable in the prediction of the dependent variable. The interaction can either be significant ($p < 0.05$) or non-significant ($p > 0.05$). A significant interaction between the

covariate and the independent variable suggests that the differences in the dependent variable among groups vary as a function of the covariate. This output implies that the results from an ANCOVA are not meaningful, and as such ANCOVA cannot be conducted. However, if the output suggests that the interaction is not significant, implying that the results from an ANCOVA are meaningful, the researcher can proceed with ANCOVA analysis. In Chapter 5 it is reported how the researcher conducted this test in this study.

5.7.1.2 Assumption of linearity of data distribution

ANCOVA assumes that the relation between each covariate and the dependent variable and the relations among the covariates are linear. If there is no linear relationship then there is no point in performing an ANCOVA. Using SPSS, the researcher inspects the linear relationship of data distribution graphically, using a scatter plot. If the slope of the regression lines is roughly parallel, then it is assumed that there is a linear relationship between the covariate and the dependent variable and an ANCOVA can be performed.

5.7.1.3 Testing research hypothesis

The study investigated whether or not learners who are taught using context-based problem solving instruction techniques would demonstrate a greater improvement in problem solving skills than learners taught using conventional instruction techniques.

| The null hypothesis is: | H_0: $\mu_{\text{context-based problem solving instruction}} = \mu_{\text{conventional instruction.}}$ |

| The alternative hypothesis is: | H_1: $\mu_{\text{context-based problem solving instruction}} > \mu_{\text{conventional instruction.}}$ |

In order to test the null hypothesis, an ANCOVA test was performed. The post-test scores were entered as the dependent variable and the experimental group was entered as the facto variable on SPSS (see section 6.3). The pre-test scores were entered as covariates to control for

differences among learners before the treatment. The alpha level was established a *priori* at 0.05 (see more detail in section 6.3.2).

5.7.2 Qualitative analysis

Qualitative data were collected through classroom observations and semi-structured interviews with both teachers and learners. Generally, the steps suggested in Table 7.1 of Chapter 7 were considered when analysing data from semi-structured interviews and classroom observations.

5.7.2.1 Classroom observations

The researcher used a notebook to record feedback from classroom observations (see step 1 of Table 7.1). Areas of focus during classroom observation had been established by the researcher in line with the study research questions. Observations of teachers were labelled OT1, OT2, OT3 and OT4. The number following "OT" corresponded with the sequence of visits to teachers. For instance, OT3 meant that this teacher was observed third in the sequence of observation visits, OT2 second, and so forth. Learners' observations were labelled OEL1, OEL2, OEL3, etc., for learners in experimental schools, and OCL1, OCL2, OCL3, etc., for learners in control schools. For instance, OEL1 indicated that this learner was observed first in the experimental school. In the same way, OCL2 referred to a learner who was observed second in control schools, and so on. Using this system of identification, data was not muddled and the researcher was able to link the source of a particular behaviour to a particular participant and to a particular school. Most importantly, the system used for identification ensured anonymity for all participants (see section 4.7).

Data were transcribed and sorted according to commonalities. The transcribed data were then analysed into common themes and represented in terms of the area of focus to which they were linked in the observation schedule. Similarities and differences were identified. In some cases, especially in the experimental group, the researcher was able to follow up on certain observed problem solving behaviours as he spent more time with learners in these schools. In other cases follow-up was made during semi-structured interviews (see also steps in Table 7.1).

5.7.2.2 Semi-structured interviews

Semi-structured interviews with learners and teachers were recorded. The interviews were transcribed verbatim using a computer. Transcribed information was later printed on an A4 sheet. Learners who participated in the interviews were identified as L1, L2, L3, etc., with the letter "L" standing for learner and the number corresponding to the numerical sequencing of interviews. For instance, L10 referred to a learner who was tenth on the interview list (see Table 7.5 on how the codes were assigned to learners in experimental schools and control schools).

Two teachers were interviewed and were identified as T1 and T2. T1 (teacher 1) was interviewed first, and T2 was interviewed second. Established codes for each school were used to label transcribed data according to schools. Interviews at experimental schools were classified as E1, E2, E3, E4 and E5, and those from control schools as C1, C2, C3 and C4 (see also section 5.4.4).

Transcribed interviews were classified according to similar themes; data from each interview session were grouped under sub-headings that related to the main question that was asked during the interview session. Given that interview questions were exactly the same, sub-headings were similar. Items from these categories (sub-headings) were compared for similarities and differences. Prominent themes that emerged from each category were noted (see also steps in Table 7.1 of Chapter 7).

5.8 ETHICAL CONSIDERATIONS

The selection of teachers and learners to participate in this study was based on informed consent. The likely research benefits to the researcher were weighed against the personal costs to the individual taking part. The researcher was aware that the costs/benefits ratio (Horner, 2011**;** Suiter, 2011) can impose a serious ethical dilemma on one's research work when it is not properly aligned. The cost to participants may include an affront to dignity, embarrassment, loss of trust in social relations, lowered self-esteem, etc. Benefits to the researcher may take the form of deriving satisfaction from making a contribution in a particular field of knowledge and acquiring greater expertise and professional status in the research area under scrutiny.

In order to address these concerns, the researcher: 1) provided a clear explanation of all the procedures that would be followed and their purpose; 2) gave participants satisfactory answers to queries concerning their participation; 3) explained that participation was voluntary and that participants were free to withdraw consent and discontinue participation at any time without prejudice; 4) ensured that participants remained anonymous (through confidentiality or aggregation of data); and, 5) promised to seek permission for publication of research findings (Horner & Minifie, 2011a; Ingham *et al*., 2011).

In addition, protocol was observed in obtaining permission for research and participation in the study. Because the study involved teachers and learners at various high schools, official channels were cleared by requesting permission to conduct the research from the Department of Basic Education (see Appendix E). Letters were written to school principals and school governing bodies to obtain permission to use the schools for research purposes. Parents' approval of their children's participation in the study was also obtained. The language used in the consent letters was simple, straightforward and precise. Ethical clearance was also obtained from the University's Ethical Committee (Appendix S).

The researcher was honest in his dealings with all participants and all agreements with them were honoured. The researcher was punctual for all appointments and lessons. In all instances, the researcher's identity was fully revealed to the participants. Lastly, the following precautions were also taken: 1) the researcher did not abuse his position as someone in authority (this was important given that the research involved minors) (Minifie *et al*., 2011); 2) data was not falsified (Horner & Minifie, 2011b); 3) the researcher ensured sensitivity to all people (e.g. age, ethnicity, gender, culture, religion, personality, socio-economic status, etc.); 4) the researcher did not jeopardise future research; 5) the researcher used appropriate and correct procedures and instruments to collect data; 6) the researcher kept research work visible and was open to suggestions (data were made available to participants); and; 7) the researcher wrote letters of appreciation to schools after the research study had been completed.

5.9 SUMMARY AND CONCLUSION OF THE CHAPTER

Chapter 5 has provided a discussion that covers methodological issues of the study. The research design and the sampling techniques were explored in this chapter. Data collection and data analysis techniques were also discussed. The chapter also provided details on intervention procedures for the experiment and groups. The chapter concluded by providing detail on how ethical issues were addressed in the study. In the next two chapters, data from the achievement test, semi-structured interviews and classroom observations are presented and analysed.

CHAPTER SIX

RESULTS AND DATA ANALYSIS: QUANTITATIVE DATA

6.1 INTRODUCTION

Creswell and Clark (2007) mention that data analysis in a mixed-methods research study consists of analysing the quantitative data using quantitative methods and the qualitative data using qualitative methods. According to Gall *et al*. (2007, p. 32), such an approach "provides richer insights and raises more interesting questions for future research than if only one type of analysis is considered". Therefore, this chapter presents and discusses the quantitative data of the study. As discussed in section 5.3, the data was collected using a non-equivalent control group design.

The main threat to internal validity of a non-equivalent control group experiment is "the possibility that group differences on the post-test may be due to pre-existing group differences rather than to the treatment effect" (Gall *et al*., 2007, p. 417). Thus, an analysis of covariance (ANCOVA) is used to deal with this problem because "ANCOVA statistically reduces the effects of initial group differences by making compensating adjustments to the post-test means of the two groups" (Gall *et al*., 2007, p. 417). Given this background, in this chapter quantitative data from the achievement test are analysed using one-way ANCOVA analysis. The Statistical Package for Social Sciences (SPSS) version 19.0 computer program for windows was used to perform ANCOVA and other statistical analysis.

One-way analysis of variance (ANOVA), t-test, Kendall's *tau* and correlation analysis were also performed to analyse certain aspects of quantitative data and are discussed in this chapter.

6.2 VERIFICATION OF PARTICIPANTS' DEMOGRAPHIC DETAILS AND THEIR SUITABILITY FOR PARTICIPATION

The present study consisted of participants from a disadvantaged township background who were low-performing in mathematics (section 1.1; section 5.3.1; section 6.2.7.1, section 7.5.3.7, Table 5.2 & Figure 6.6). To verify participants' socioeconomic status, their demographic details were

collected and analyzed (see Appendix D; section 5.5.1.8). It is through this data that the actual background of the participants and their suitability for participation in the study are established. According to Welman, Kruger and Mitchell (2005) this kind of data provides a comprehensive and holistic picture of the phenomenon under investigation.

It is evident from the discussion in section 2.14 that socioeconomic status is an important factor to consider when studying learners' performance. Data in Table 6.1 were collected from learners at the beginning of the study and during a 2-week intervention at each experimental school. For the schools in the control group, mathematics teachers helped with data collection. Altogether, data was gathered from 783 learners in the participating schools. Participant gender was also considered (see Table 6.1) because it was deemed necessary to know the influence of context-based problem solving instruction on gender groups.

6.2.1 Age distribution of the main sample

Of the 783 (100%) participants: 724 (92.5%) supplied information on their age; 59 (7.5%) withheld this information. The mean age was computed from returned forms. The age of the participants ranged from 15 to 19 years ($M = 16.45$; $SD = 1.25$). The distribution of learners' age across age groups is shown in Figure 6.1.

Figure 6.1: Age distribution of learners
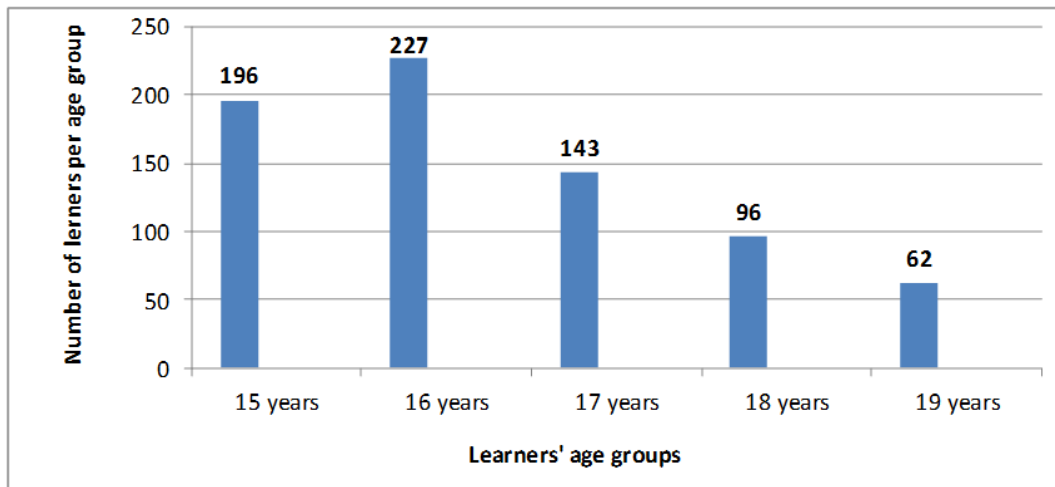
Table 6.1: Background characteristics of learners in the study[37]

	Boys (n=322)	Girls (n=461)	Total (n = 783)
Median age	-	-	16.45(*SD*=1.25)
Learners' parentage status			
Living with both parents	61(8%)	87(11%)	19%
Living with single parent/ living with guardian	113(14%)	206(27%)	41%
No parents	105(13%)	157(20%)	33%
No response on parent information	43(6%)	11(1%)	7%
			100%
Learners' parents' employment status			
Parent employed	92(12%)	107(14%)	26%
Parent self-employed	73(9%)	61(8%)	17%
Parent unemployed	128(16%)	218(28%)	44%
No response on parent(s)' employment status	33(4%)	71(95)	13%
			100%
Learners' parents' education status			
Parent education: Primary	243(31%)	297(38%)	69%
Secondary	28(3.6%)	35(4.4%)	8%
Tertiary	10(1.3%)	13(1.7%)	3%
No response on parents' education status	38(5%)	119(15%)	20%
			100%
Learners' accessibility to computer at home			
Have a computer at home	65(8%)	71(9%)	17%
Do not have a computer at home	248(32%)	369(47%)	79%
No response on computer accessibility	9(1%)	21(3%)	4%
			100%

Figure 6.1 shows that of the 724 learners who supplied information on age, 196 (27.07%) are 15 years of age; 227 (31.34%) are 16 years of age; 143 (19.75%) are 17 years; 96 (13.26%) are aged 18 years; and 62 (8.56%) are aged 19 years. It is clear that the study sample is largely populated by participants aged 16, followed by; 15 years and 17 years.

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[37] All the percentages reflected in Table 6.1 have been averaged to the nearest integer. The actual percentages are used in subsequent discussions.

Dacey (1989) established that children aged 15 to 17 are in the best state to learn problem solving skills through context-based instruction (section 5.3.2). Lianghuo and Yan (2000) acknowledged that this period is the optimal age at which to develop learners' abilities and skills in problem solving (section 5.3.2). It is therefore reasonable to conclude that participants in this study were generally at a suitable age to develop problem solving skills for mathematics.

6.2.2 Parental status of learners

Participants' parental status was considered to ascertain the level of parental support received by participants on educational issues. Parent support or involvement[38] was explored in terms of parent's level of education (see section 6.2.3). Parent involvement has long been associated with indicators of learner educational attainment. Jeynes (2007) conducted a study in which he identified a strong link between parent involvement and learners' scholastic outcomes.

The role of parents in enhancing children's educational outcome has been emphasised (see, for example, Corwyn & Bradley, 2002; Davis-Kean, 2005; Jeynes, 2007). Some teachers have increasingly identified parent involvement as the primary tool to elevate learner achievement (Jeynes, 2007). The following data were collected for the current study (Figure 6.2).

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[38] For purposes of the current study, parent involvement was defined as parent or guardian participation in the scholastic development of the children. This support is normally provided by parents in the form of providing assistance when a learner is doing homework, checking the learner's work books, attending grade meetings at the learner's school, interacting with a subject teacher on a regular basis, etc. Hence this definition is conceptualized within Epstein's (1992) framework of parent involvement. Epstein's (1992) six-level framework of parent involvement includes: parenting; learning at home; communicating with the school; volunteering at school; decision making in the school; and, collaborating with the community.

Figure 6.2: Information regarding parent status of each learner
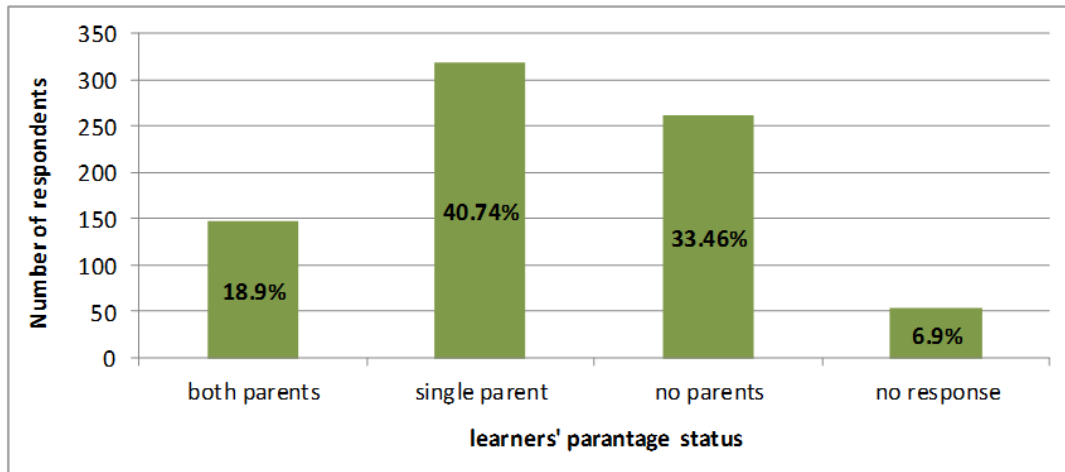
Figure 6.2 shows that of the 783 study participants, 148 (18.90%) live with both parents. Most participants live with single parents (40.74%). In the context of this study, the word "*parent*" refers to a biological parent. A guardian or anyone providing foster care or surrogate[39] support to the learner is not defined as a parent. The majority of participants do not experience parental care from both parents. Some of the participants noted that they had never seen their parents in their lives. Some participants (6.9%) chose not to reveal their parent status. When one boy was probed on his decision not to supply information in this regard he replied:

> **L[40]:** "*Meneer[41], hey… I don't want to talk about my parents because their story makes me cry*".

[39] It also emerged that some of participants lived with non-biological parents. Other participants had been orphaned and adopted by those close to them. Due to time constraints, these issues were not explored and probed further in the current study.

[40] In this study, qualitative data were collected through classroom observations and semi-structured interviews (section 5.5). However, during classroom observations participants were probed on certain behaviours and provided responses that did not fall within the scope of the planned interviews. In such responses, only a letter "*L*" is used as opposed to specific codes, such as "*L1*" and "*L2*", given to the interviewees (see section 5.8.2.2). Hence responses such as the one quoted in section 6.2.2 were drawn from a booster sample.

[41] The word *meneer* is an Afrikaans word for Mister (Mr). In South Africa it is common for township learners to refer to their male teachers as *meneer*, as a sign of respect.

It is clear that this boy was emotional and felt strongly about the parental situation at his home and seemingly there was a problem regarding his parents. It is common to get such reactions from children who feel neglected by their parents.

For statistical analysis, data were entered as: "*1 = both parents*", "*2 = single parent*", "*3 = without parent*" and "*4 = no response*". Results show that participants' parent status largely belonged to categories "*2*" and "*3*". These results suggest that most participants are either living with single parents or without parents ($M = 2.28$; $SD = 0.85$).

From these results it may be concluded that participants in this study were largely learners who come from a single parent or no-parent background. It is unlikely to expect learners from these backgrounds to enjoy meaningful parental support to enhance their mathematics performance, which hinges on problem solving skills.

6.2.3 Employment status of parents

One variable that is most significant when exploring the socioeconomic background of a learner is his or her parent's employment status. Research on the impact of parent employment status on children's outcomes has proliferated in recent years (see, for example, Bulanda, 2004; Foster & Kalil, 2005; Talib, 2009; Heystek, 2003; Lewis & Naidoo, 2004). Ho Sui-Chu and Williams (1996) argue that parents from a low socioeconomic background who have a low employment status tend to place less emphasis on schooling than do those from the social middle class. According to Mmotlane, Winnaar and Wa Kivilu (2008), South African parents from a lower social class have shown less determination regarding participation in their children's schooling than those from a higher class. The following results reflect on the employment status of participants' parents in the present study (Figure 6.3).

Figure 6.3: Employment status of parents
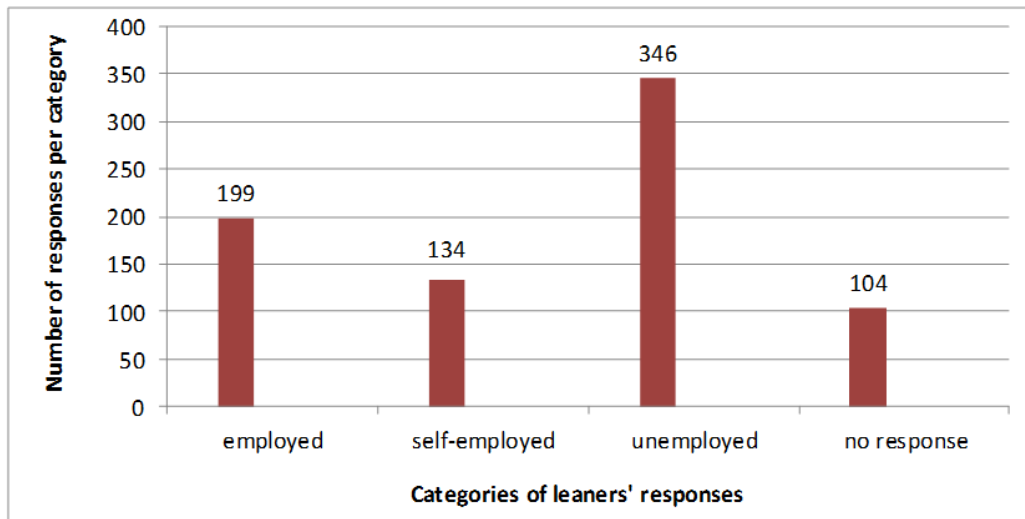
Figure 6.3 shows that most participants are raised by unemployed or self-employed parents. It is noted that 104 (13.28%) participants withheld information on their parents' employment status. Upon probing, it became evident that most parents who are linked to self-employment trade are entrepreneurs such as street-vendors, hawkers and 'backyard' motor mechanics. Given their nature and target market, these forms of business are generally dependent on low-income earners who live in the townships. It therefore means the businesses are neither reliable nor sustainable sources of meaningful household income.

One participant who withheld information on parents' employment status summed up her father's employment situation as follows:

> **L:** *"My father was retrenched in 2001 and is no longer working anymore. It's hard to talk about this…, he can't find another job. I don't know why."*

This reaction gives a general picture of some of the problems experienced by learners who chose not to supply information on their parents' employment status.

For statistical analysis, data in section 6.2.3 were entered as, "*1 = employed*", "*2 = self-employed*", "*3 = unemployed*" and "*4 = no response*". The output confirms that most responses are concentrated between the status "*2*" and "*3*" ($M = 2.45$; $SD = 1.01$). It may be concluded that most participants in this study are disadvantaged socioeconomically.

6.2.4 Learners' parents' education

Literature on achievement points to "parent education as an important predictor of children's achievement" (Davis-Kean, 2005, p. 294). There is general agreement that parents with a good educational background have a positive influence on their children's educational outcome compared to less educationally enriched parents. Education can influence ones' beliefs and behaviour (Davis-Kean, 2005). At home this aspect can be a salient point in determining the nature and quality of scholastic support a parent provides to a child. The following data were collected for the current study (Figure 6.4).

Figure 6.4: Parents' levels of education[42]

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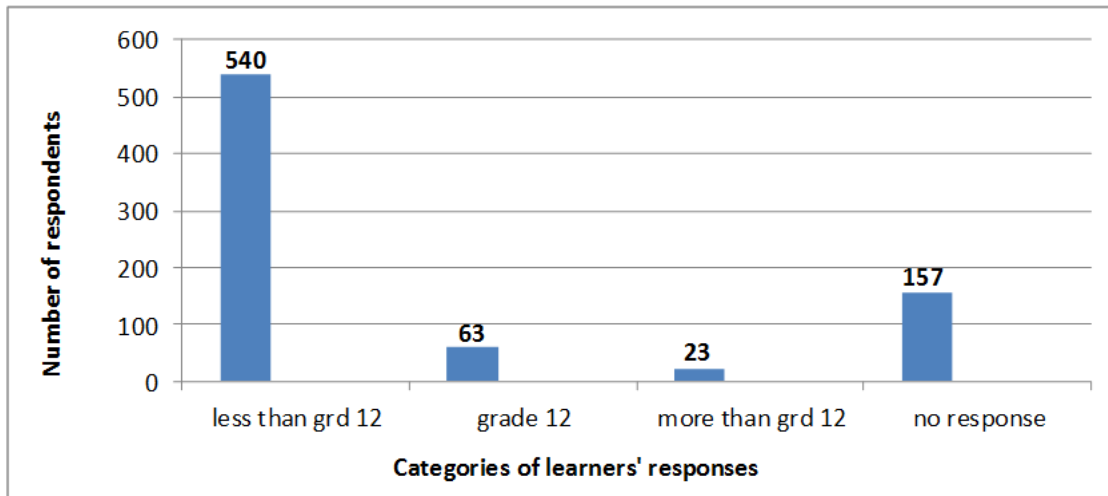
[42] In Figure 6.4 the educational status of a parent is considered poor when it is less than Grade 12 (primary = less than Grade 12). Also, secondary = Grade 12, and tertiary = more than Grade 12.

For statistical analysis, data were entered on SPSS as, "*1 = less than Grade 12*", "*2 = Grade 12*", "*3 = more than Grade 12*" and "*4 = no response*". The output shows that the majority of participants' parents have either a primary or secondary qualification ($M = 1.78$; $SD = 1.29$).

Figure 6.4 shows that 540 (68.97%) parents have primary education. Of all participants' parents, 86 (10.98%) have a secondary qualification and only 23 (2.94%) have a tertiary qualification. It is noted that 157 (20.05%) participants did not reveal the status of their parents' education. According to Table 6.1, of the 157 participants who withheld information on their parents' education, 38 (24.20%) are boys and 119 (75.80%) are girls, suggesting that girls are more likely to conceal information about their parents' education. Research is needed to verify this claim. When one girl was probed about her decision not to supply information she responded:

> **L:** *"No, Sir, no, ... I don't want to expose my parents, why ..."* (Responding in a giggling way, but making her views and stance clear).

One boy in this category reacted:

> **L:** *"Hayi Meneer i-thayima kuyabheda, mara kuzolunga one day"* (Hey, Sir, for my father it is bad, but it will be better one day[43]).

The phrase "*kuzolunga one day*" (things will get better one day) paints a picture of someone experiencing socioeconomic hardship. The term "*kuyabheda*" means "it's bad", implying something is not proper.

6.2.5 Learners' access to a computer at home

Participants' access to a computer as a learning resource support tool in participants' households was explored. Results are shown in Figure 6.5:

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[43] The phrase inside the parenthesis is a translated version of the boy's response.

Figure 6.5: Learners' access to a computer at home
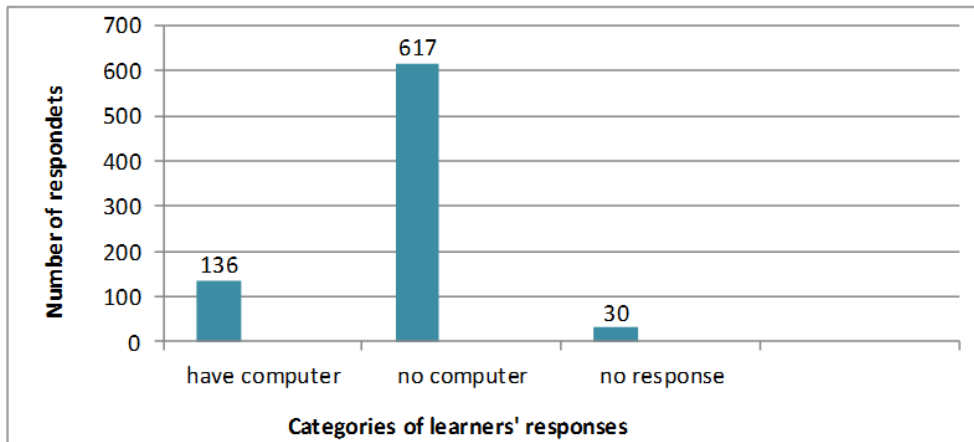
Figure 6.5 shows that only 136 (17.37%) of participants have access to a computer at home. Of all 783 participants, 617 (78.80%) do not have a computer at home. It is also noted that 3.83% (30) did not supply information on whether they have a computer in their home or not. It may be assumed that this behaviour is linked to the observed tendency by some learners not to supply information about their actual home situation (see section 6.2.4 for similar observations).

For further analysis, data were entered statistically where: "*1 = have computer*", "*2 = no computer*" and "*3 = no response*". The output shows that the majority of learners do not have computers in their homes (M = 1.86; SD = 0.44), suggesting that most participants are from disadvantaged homes that do not provide a supportive environment for learning.

6.2.6 Conclusions from analysis of participating learners' demographic data

The analysis in sections 6.2.1 to section 6.2.5 suggests that most participants are demographically comparable, and are largely from disadvantaged socioeconomic communities. Table 6.2 provides a summary of the data analysis discussed in sections 6.2.1 to 6.2.5.

Table 6.2: Summary of learners' demographic data

Variable	Findings	In-text reference
Parent status of learners	More than 74% of learners do not receive care from both parents.	6.2.2
Employment status of parents	Most learners' parents' (61.30%) are either unemployed or low-income earners.	6.2.3
Learners' parents' education	Most learners' parents (68.97%) have a primary school education.	6.2.4
Learners' accessibility to computer at home	78.80% of learners do not have a computer at home.	6.2.5

The review of the literature shows that schools in disadvantaged communities lag far behind when compared to schools in economically affluent communities (see section 2.14). According to Tsanwani (2009, p. 17), "Under-achievement in mathematics and problem solving is particularly recognised as a major problem in schools serving disadvantaged communities in South Africa" (see also, section 1.14). It may be concluded that the sample (n = 783) is suitable for participation in the study (see also sections 1.1 & section 5.4.2).

6.2.7 School and teacher profiles

6.2.7.1 Participating schools

Results from the questionnaire designed to collect data on school profiles (Appendix E) reveal that almost all nine participating schools are disadvantaged in terms of scholastic performance and infrastructure. The performance of each school was determined from Grade 12 end-of-the-year mathematics results in 2010 (see Figure 6.6; Table 5.2).

Figure 6.6: The 2010 Grade 12 mathematics average performances in all participating schools
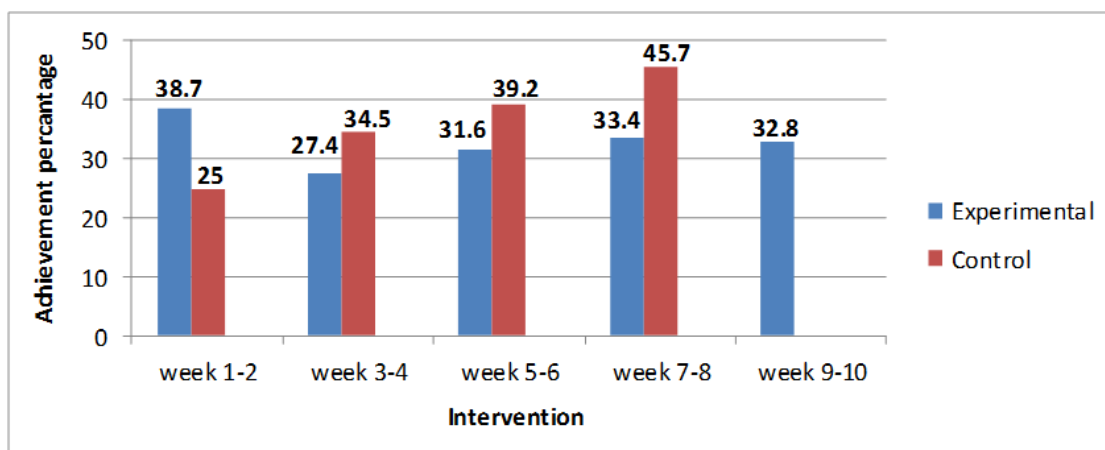
In Figure 6.6, schools are arranged according to the way in which they were paired during the intervention (see sections 5.4.3 and 5.4.4 for an explanation of school pairs). For instance, in week 1 to week 2, the intervention involved school E1 (in blue) and school C1 (in red), week 3 and week 4 involved school E2 (in blue) and school C2 (in red), and so forth (see section 5.4.4 for the meaning of E2 and C2). It is observed that all schools were performing poorly at the time of this study. The end-of-year Grade 12 mathematics performance of all nine participating schools for 2010 ranged between 25.0% (school C1) and 45.7% (school C4) ($M = 34.26$; $SD = 6.30$) (see also, Table 5.2).

Results shown in Figure 6.6 corroborate the literature (see section 2.14). A study conducted in June 2009 by the Consortium for Research on Educational Access, Transitions and Equity (Create) in township schools showed that learners in disadvantaged township localities struggle to master basic competences and fundamental skills in mathematics (Create, 2010).

In as far as school infrastructure is concerned, the following data were collected from participating schools (see also Appendix E):

Table 6.3: Learning facilities in participating schools

LEARNING FACILITIES				
	Schools where available	Schools where not available	Facility functional	Facility not functional
Science laboratory	8	1	3	5
School library	5	4	1	4
Computer laboratory	6	3	-	6

Table 6.3 shows that most of the schools have facilities thought to enrich learners educationally. Of the nine schools, eight (88.9%) have science laboratories. Five schools have libraries and six schools have computer laboratories. However, further inquiry revealed that most learning facilities in the nine schools are not utilized. All six schools with a computer laboratory are not utilising them. Of the five schools that have school libraries only one uses it effectively. Some teachers were probed on the observed non-use of learning facilities in their schools. The following responses emerged: 1) teachers have not been trained to use facilities; 2) science and library facilities are ill-quipped; 3) the time to utilize teaching and learning facilities is not allocated in the school timetable; 4) some of the facilities are not in a working state; 5) teachers do not have time to use facilities; 6) teachers are not interested in using a facility; etc.

Teachers' responses corroborate Jansen's (2001) study in which the following factors were identified as having a negative influence on learners' mathematics performance (see section 2.14): 1) lack of educational resources; 2) poor school infrastructure and upgrading; and, 3) poor teacher training. Regarding training teachers to use teaching and learning facilities, Tsanwani (2009, p. 170) found that "teachers from high-performing schools attend college/ university mathematics courses more than teachers from low-performing schools". According to Baloyi (2011), these conditions are more prevalent in township schools where a majority of black learners receive their education (see section 2.14).

6.2.7.2 Correlation analysis

Teachers supplied data in Table 6.4 (see also Table 5.2). To examine the effect of teachers' subject qualifications on learners' performance in Grade 10 mathematics, a questionnaire was administered in all participating schools to teachers at the beginning of the study (see Appendix E & Table 5.2). This examination was necessary to ascertain the extent to which teacher characteristics impact on learner achievement. Teachers in all nine schools returned completed questionnaires for analysis. Kendall's tau correlation coefficient was computed using SPSS at a 95% confidence interval. The correlation result being significant at $p < 0.05$ means that the probability of obtaining the correlation by chance is less than five out of one hundred (5%). Kendall's *tau* is preferred for bivariate correlations involving "samples of less than ten" (Gall *et al*., 2007, p. 348). Table 5.11, which is adopted from Jackson (2012), is used to interpret observed strength of relationships between variables (see section 5.8.1 for Jackson's (2012) table of descriptors). The correlation coefficient was computed using data in Table 6.4 and the results in Table 6.5 were obtained:

Table 6.4: Teachers' qualifications and learner achievement in Grade 10 (n = 9)

Teacher	Qualification	Grade 10 mathematics results (%) in previous year
1	Diploma	42
2	Diploma	50
3	Diploma	51
4	Diploma	60
5	Advanced diploma	58
6	Advanced diploma	73
7	Advanced diploma	67
8	Degree	59
9	Degree + Honours	77

Table 6.5: Correlation between learners' achievement in Grade 10 mathematics with variable defining teacher qualification (n = 9)

Variable	r
Teacher qualification	0.612

Significant at $p < 0.05$

Table 6.5 shows that teachers' qualifications have a positive significant relationship with learner achievement in Grade 10 mathematics ($p = 0.612$). Using Table 5.11 it is possible to observe that the correlation between teachers' qualifications and learner achievement is "*moderate*" in magnitude. The result provided in Table 6.5 has a practical significance. According to Gall *et al.*, 2007, p. 376), "A correlation coefficient in the region $\pm 0.70 - 1.00$ is virtually impossible to obtain from a single predictor variable, but it can be achieved by the use of multiple predictor variables that are combined through the technique of multiple regression".

In terms of teachers' qualifications and learner distribution in participating schools, the following allocations are observed (see Table 5.2): Diploma = 360 (45.97%) learners; Advanced diploma/ degree = 333 (42.53%) learners; Post graduate degree = 90 (11.49%) learners. In section 5.4.4, a teacher with a diploma is classified as "INADEQUATELY QUALIFIED" (see Table 5.1; DBE, 2011c; DoE, 2006b). Using the results in Table 6.4 and the qualification criterion in Table 5.1, it may well be concluded that most participants (45.97%) are taught by teachers with inadequate qualifications, and that they are likely to perform poorly in mathematics problem solving.

In section 2.13, poor teacher training, teachers who lack content knowledge and confidence in teaching mathematics and science, and the fact that most teachers were trained in specific disciplines, were cited as reasons for teachers' inability to integrate school knowledge with out-of-school knowledge and to improve learners' problem solving skills (Adler *et al.*, 2000; Howie & Plomp, 2002; Onwu & Mogari, 2004; Pretorius, 2008; Reddy, 2007).

6.2.8 Conclusions from school and teacher profiles

Based on the analysis of data on teacher and school profiles (section 6.2.7), it may well be concluded that learner participants are classified as disadvantaged learners and hence they are suitable participants for the study.

6.3 RESULTS FROM THE ACHIEVEMENT TEST

6.3.1 T-test analysis for the pilot study

A pilot study was conducted with a sample from the study population (see section 5.6; Dhlamini, 2011). The purpose of the pilot study was "to try out the achievement test" (Gall *et al.*, 2007, p. 41). The pre-test and post-test mean scores for the pilot study were ($M = 18.54$; $SD = 6.827$; n = 57) and ($M = 21.35$; $SD = 7.328$; n = 57), respectively.

To determine the statistical significance of the mean difference, in order to affirm the effectiveness of the context-based problem solving instruction, the pre and post-tests scores were compared using a t-test at the significance level of 0.05. The t-test was used because two mean scores of one sample were compared (Gall *et al.*, 2007, p. 317). The single sample t-test tests the null hypothesis that the pre-test and post-test mean is equal. If the *p*-value in the t-test result is smaller than the significant value ($\alpha = 0.05$), then there is evidence that the mean is different from the hypothesized value. If the *p*-value associated with the t-test is not small ($p > 0.05$), then the null hypothesis is not rejected and it can be concluded that the mean is not different from the hypothesised value. The t-test results for the pilot study are represented in Table 6.6.

Table 6.6: Statistical results of the t- test analysis for the achievement test (n = 57)

Test	group	n	$\bar{x}$	SD	SEM	t	p
Pre-test	Grade 10 learners	57	18.54	6.827	0.90	2.116	0.0366
Post-test	Grade 10 learners	57	21.35	7.328	0.97		

Significant at 0.05 level

Table 6.6 shows that the probability of error is less than 0.05 ($p = 0.0366 < 0.05$). Therefore the null hypothesis is rejected. It is concluded that the difference between the mean scores of the pre-test and post-test is statistically significant, meaning the participants' performance in a context-based problem solving achievement test improved significantly. These results warranted proceeding with the main study.

6.3.2 ANCOVA analysis for the main study

Of the 783 participants, only 706 (90.1%) participated fully in the study. Full participation in the study refers to attending all context-based problem solving lessons, participating in context-based problem solving tasks and participating in writing both achievement tests at pre and post-stages. The researcher (in the experimental schools) and four teachers (in the control schools) kept records of participants' attendance daily (see Appendix M for a sample of the attendance register). From the attendance records, it was established that 25 participants in the experimental schools were absent in either two or more sessions during lesson presentations and did not participate in either one or both sessions of the achievement test. In control schools, 23 participants behaved similarly. In total, 48 (6.1%) participants were absent in either two or more sessions during lesson presentations and did not participate in either one or both sessions of the achievement test.

Apart from the above initial 25 non-regular attendees in experimental schools, there were 10 participants who attended all context-based problem solving lessons, but evaded either one or both achievement test sessions. In the control schools, 19 participants behaved similarly. A further 29 participants did not participate fully in the achievement test sessions. All in all, 77 (9.8%) participants did not participate fully in the study (see Table 6.7 for learner attendance data per school). Data from participants who either wrote one achievement test or who missed more than two sessions of the context-based problem solving lessons were not analysed (see also footnote 21).

Table 6.7: Information on learner participation in achievement test[44]

School	Number of learners	Number of learners absent and did not write either 1 test or both tests	Number of learners who were present but did not write either 1 or both tests	Number of learners who wrote both tests
E1	90	6	2	82
E2	74	4	1	69
E3	101	7	2	92
E4	67	5	3	59
E5	81	3	2	76
C1	133	7	7	119
C2	71	4	5	62
C3	80	9	2	69
C4	86	3	5	78
Total	**783(100%)**	**48(6%)**	**29(4%)**	**706(90%)**

Data were entered in the SPSS in the following manner: *pre-test scores = covariate*; *post-test scores = dependent variable*; and *groups = fixed factor*. According to Gall *et al.* (2007), "a covariate is an independent variable whose influence on the dependant variable is controlled by the ANCOVA test" (p. 157). The ANCOVA assumptions were tested.

6.3.3 The rationale for performing ANCOVA

ANCOVA was performed to reduce residual variations between two groups at the pre-stage of the experiment (see also section 6.1).

6.3.4 Levene's test for equality of variance

Levene's test is performed to test the null hypothesis of equal error variance[45] amongst the two groups. In the current study, the Levene's test examined whether there was a difference between

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[44] A participant who missed more than two instruction sessions was considered absent. It was believed that non-attendance at least two sessions would constrain his or her participation and performance during context-based problem solving tasks.

[45] Each time data is collected, there is variability. A systematic variance is the source of variability that is under investigation. Error variance refers to whatever sources of variability on which the researcher is not focussing attention (Jackson, 2012).

the error variance of the dependent variable between participants in the control group and those in the experimental group. In the Levene test, if $p < 0.05$, then the variances in the groups would be different (the groups would not be homogeneous), and therefore the assumptions for ANCOVA would not be met (see also section 5.8.1).

Any time estimation is made about a population parameter (e.g., a mean, a measure of variance explained, etc.), a hypothesis is potentially conducted. To perform the Levene's test in the current study, a Null Hypothesis (H_0) was formulated, stating that population variances are equal. The corresponding alternative Hypothesis (H_1) stated that population variances are not equal.

H_0: Error variance of the dependant variable is equal across groups;

H_1: Error variance differs across groups.

The Levene's test produced the following results (see Table 6.8):

Table 6.8: The results of Levene's test

F	df1	df2	Sig.
.000	1	704	.993

Table 6.8 shows that $p = 0.993 > 0.05 = \alpha$, and the results are statistically insignificant. It is not possible to reject the Null Hypothesis (H_0) of the homogeneity of variance. The results seen in Table 6.4 suggest that the error variance of the dependant variable (post-test scores) is indeed equal across groups. Therefore the assumption of homogeneity is satisfied. It is possible to proceed with the analysis with the aid of more inferential statistical tools.

6.3.5 The homogeneity-of-regression assumption

The second part of the analysis involves verifying the homogeneity of regression assumption by drawing inferences about the interactive relationship between the covariate and the independent variable. In the current study, the interactive relationship between learners' pre-test scores and post test score had to be analysed. The analysis was performed to determine the overall performance of learners' problem solving skills.

The interaction is *significant* if the computed *p*-value is less than the significant value ($p = 0.05$). A significant interaction between the covariate and the dependant variable (post-test) suggests the difference between group scores in a post-test vary as a function of the covariate. In this case, ANCOVA should not be conducted. In the context of this study, the interaction will *not be significant* if $p > 0.05$, suggesting ANCOVA could be conducted. Ideally, there should be no significant interaction between the independent variable and the covariate; meaning if the covariate behaves in the same way in both groups, or equivalently, then the dependant variable is adjusted across both groups.

In the present study, it is tested whether or not a relationship exists between the pre-test (covariate) scores and instruction (independent variable) to determine learners' problem solving performance. The following hypothesis test was conducted.

H$_0$: No significant interaction between covariate and independent variable;

H$_1$: Significant interaction exists between covariate and independent variable.

The results in Table 6.9 are obtained.

Table 6.9: The results of tests for Between-Subjects Effects

Source	F	Sig.	df
groups*pre-test	.917	.339	1
Error			702

In Table 6.9, the interaction source is labelled **groups*pre-test.** The results of the homogeneity-of-regression assumption test suggest that the interaction is not significant, F (1,702) = 0.917, p = 0.339 > α (0.05). In other words, using a 5% significance level, it is not possible to reject the Null Hypothesis (**H$_0$**) of no interaction. Therefore the homogeneity-of-regression assumption is not violated; meaning, the effect of the learners' pre-test scores is the same across groups.

The verification of the homogeneity-of-variance and homogeneity-of-regression assumptions makes it possible to proceed to with ANCOVA.

6.3.6 Performing ANCOVA analysis

Post-test results suggested greater improvement in experimental schools (M = 33.3; SD = 4.213; n = 378) when compared to control schools (M = 25.8; SD = 4.095; n = 328). With the above two assumptions verified, it is now possible to report statistically the main effect of context-based problem solving instruction on participants' overall mathematics problem solving performance. If all goes well, it should be possible to identify a significant effect of context-based problem solving instruction on participants' performance and thus affirm the proposition of the entire study that context-based problem solving instruction is superior to conventional teaching methods and it should be given preference in the area of mathematics problem solving to overcome learners' problem solving obstacles in the classroom.

By using the ANCOVAs, it is possible to determine the main effect of the independent variable on the dependant variable after removing the effect of the covariate. In terms of this study, it should be possible to isolate the effect of context-based problem solving instruction after controlling the effect of the pre-test scores (covariate).

Null Hypothesis (H$_0$): The implementation of context-based problem solving instruction does not enhance learners' mathematical problem solving skills, and hence their performance.

H$_0$: $\mu_{\text{context-based problem solving instruction}} = \mu_{\text{conventional instruction}}$.

Alternative Hypothesis (H₁): The implementation of context-based problem solving instruction enhances learners' mathematical problem solving skills, and hence their performance.

H₁: $\mu_{\text{context-based problem solving instruction}} \neq \mu_{\text{conventional instruction.}}$

The output is presented as follows (see Table 6.10):

Table 6.10: The test of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean square	F	Sig.
Pre-test	42.977	1	42.977	2.490	.115
Groups	9643.604	1	9643.604	558.677	.00

Table 6.10 shows two important results. *Firstly*, it is evident that pre-test scores significantly predicted and influenced participants' context-based problem solving performance, as the significance value is more than 0.05 ($p = 0.115$). This result confirms the classification of pre-test scores as a covariate and thus the use of ANCOVA analysis.

The *second* and far grander observation is the main effect of context-based problem solving instruction after controlling for pre-test scores. When the effect of pre-test scores is removed, the effect of context based problem solving instruction becomes significant, as confirmed by $F(1,703) = 558.677$, $p < 0.05$. It is possible to reject the **H₀** of no effect and favour the **H₁,** i.e. that there is indeed a significant effect of the independent variable on the dependant variable; meaning, the context-based problem solving instruction is superior to conventional instruction in substantially accelerating learners' problem solving skills in the area of *Financial Mathematics*.

H₁: $\mu_{\text{context-based problem solving instruction}} > \mu_{\text{conventional instruction}}$.

6.4 CLASSIFICATION OF PARTICIPANTS' PROBLEM SOLVING PERFORMANCE BY SCORE

6.4.1 Simple mathematical analysis of participants' performance

On the basis of the context-based problem solving achievement test scores, a further analysis of learners' performance is performed. The maximum score for the achievement test is 60 (see section 5.5.2.1). Participants are designated as low-performing (LO), average-performing (AV) and high-performing (HI) according to Table 6.11. The number of learners in each category (LO, AV and HI) is given in Table 6.12.

Table 6.11: Classification of learners' achievement test scores

CRITERIA	CODE	DESCRIPTION
Low-performing	LO	Below 24 marks
Average-performing	AV	Between 24 and 42 marks
High-performing	HI	Above 42

Analysis of participants' scores in both groups at pre and post-stages of the experiment are given in Table 6.12.

Table 6.12: Comparison of achievement tests performance between two groups

Groups (n = 706)	Performance category	Pre-test	Post-test
Experiment **(n = 378)**	Low-performing	282 (74.6%)	16 (4.2%)
	Average-performing	75 (19.8%)	311 (82.3%)
	High-performing	21 (5.6%)	51 (13.5%)
Control **(n = 328)**	Low-performing	224 (68.3%)	127 (38.7%)
	Average-performing	91 (27.7%)	181 (55.2%)
	High-performing	13 (4.0%)	20 (6.1%)

A graphic representation of data in Table 6.12 is shown in Figure 6.7. Figure 6.7 shows that both the context-based problem solving instruction and conventional instructions improved participants' problem solving performance. In experimental schools, low-performance (LO) is reduced from 282 LO-learners in a pre-test to 16 LO-learners in a post test (a reduction of 94.3%). In control schools, this reduction is 43.3%.

Figure 6.7: Analysis of participants' achievement test scores at pre- and post-stages
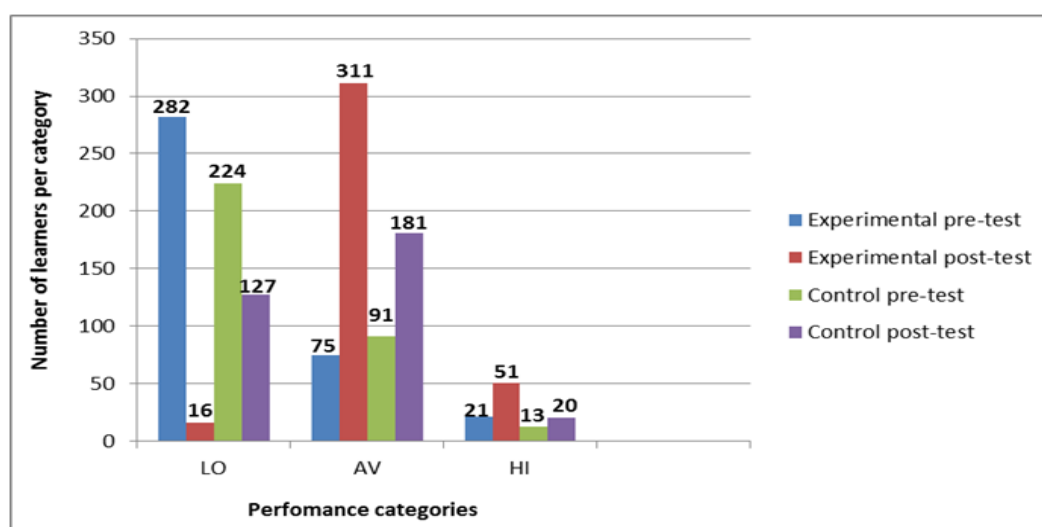
The reduction percentage (%) is determined as follows:

$$\text{Reduction percentage (\%)} = \frac{(pre-test_{LO-learners}) - (post-test_{LO-learners})}{pre-test_{LO-learners}} \times 100\%$$

In both groups there is an improvement in average (AV) performance at pre and post-stages. In the experimental schools, an increase of 75.9% is recorded against a 49.7% increase in the control schools. The increase percentage (%) is determined as follows:

$$\text{Increase percentage (\%)} = \frac{(post-test_{AV-learners}) - (pre-test_{AV-learners})}{post-test_{AV-learners}} \times 100\%$$

Both groups register increases in HI-performances at the post-stage of the experiment. In experimental schools, this increase is 58.8%, while in control schools it is 35.0%. The increase percentage is determined as follows:

$$\text{Increase percentage (\%)} = \frac{(post-test_{HI-learners}) - (pre-test_{HI-learners})}{post-test_{HI-learners}} \times 100\%$$

From the results shown in Figure 6.7 and Table 6.9, it is possible to conclude that context-based problem solving instruction is superior when compared to conventional instruction techniques in addressing learners' problem solving performance in context-based problem solving tasks.

6.4.2 One-way ANOVA for participants' post-test performance by performance categories

One-way analysis of variance (ANOVA) was performed to compare mean post-test performance in the following categories: *LO2 = Low performance for post-test*; *AV2 = Average performance for post-test*; and, *HP = High performance for post-test*, (see Table 6.8 for the explanations of LO, AV and HP). The post-test results are chosen to compare context-based problem solving instruction with conventional problem solving instructions. Unlike a t-test, one-way ANOVA is used to determine whether there are any significant differences between the means of three or more independent groups (Gall et al., 2007, p. 318). Like other statistical tests, ANOVA tests the null hypothesis that: **H$_0$**: $\mu_1 = \mu_2 = \mu_3 = ... = \mu_k$, where μ = group mean and k = number of groups. If, however, the one-way ANOVA returns a significant result, the alternative hypothesis (**H$_1$**) is accepted, indicating that there are at least two group means that are significantly different from each other. Table 6.13 provides the mean scores and standard deviations for both groups for post-test performances in each category.

Table 6.13: Descriptive statistics for post-test mean performance in each category for both groups

	Groups	n	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
LO2	Experiment	16	20.5625	1.54785	0.38696	19.7377	21.3873	17.00	23.00
	Control	127	16.7402	1.33460	0.11843	16.5058	16.9745	15.00	22.00
	Total	143	17.1678	1.81537	0.15181	16.8677	17.4679	15.00	23.00
AV2	Experiment	311	32.9646	4.86350	0.27578	32.4220	33.5073	24.00	42.00
	Control	181	25.1823	1.78728	0.13285	24.9202	25.4445	24.00	33.00
	Total	492	30.1016	5.49707	0.24783	29.6147	30.5886	24.00	42.00
HP2	Experiment	51	46.2353	3.96277	0.55490	45.1207	47.3498	42.00	56.00
	Control	20	42.2000	0.52315	0.11698	41.9552	42.4448	42.00	44.00
	Total	71	45.0986	3.82531	0.45398	44.1932	46.0040	42.00	56.00

Table 6.13 shows that the mean averages of the experimental group are superior in each performance category. The SPSS output for ANOVA analysis for groups in each performance category is provided in Table 6.14.

Table 6.14: ANOVA summary table for comparing performance in each category

Source		Sum of Squares	df	Mean Square	F	Sig.
LO2	Between Groups	207.609	1	207.609	112.431	0.000
	Within Groups	260.363	141	1.847		
	Total	467.972	142			
AV2	Between Groups	6929.324	1	6929.324	429.381	0.000
	Within Groups	7907.594	490	16.138		
	Total	14836.919	491			
HP2	Between Groups	233.933	1	233.933	20.422	0.000
	Within Groups	790.376	69	11.455		
	Total	1024.310	70			

Table 6.14 shows that in each of the performance categories the significance level is less than the critical point ($p < 0.05$). The results seen in Table 6.14 suggest that there is a statistically significant difference in the mean performance of groups.

6.5 PROBLEM SOLVING ERRORS COMMITTED BY PARTICIPANTS DURING AN ACHIEVEMENT TEST

Different types of errors characterized participants' responses in the achievement test. In both groups, most errors occurred in the pre-test. In this section, an examination of the types of errors and the frequency of their occurrence in both groups during pre- and post-stage is made.

6.5.1 Types of participants' problem solving errors

Vignettes of participants' task responses are provided to illuminate each error type. See summary of participants' errors in Table 6.15.

Table 6.15: A summary of participants' errors at pre- and post-stages

Groups (n = 706)	Test	Number of type 1 errors	Number of type 2 errors	Number of type 3 errors	Number of type 4 errors
Experiment group	**Pre-test**	1147	574	741	634
	Post-test	369	153	103	147
Control group	**Pre-test**	838	703	679	415
	Post-test	488	201	291	228

6.5.1.1 <u>TYPE 1 ERROR:</u> *The BODMAS error*

Most participants committed a type 1 error, particularly in the pre-test (see Table 6.10 and Figure 6.15). The BODMAS error is the most prevalent type in Table 6.10: this error occurs 2 842 times (36.86%)[46]. See samples of questions 1.1 and question 1.2 from achievement test (Figure 6.8).

Figure 6.8: Questions in which a type 1 error was seen in achievement test questions

1.1 *Thembi invests R50 000 for 10 years at an interest rate of 15% per annum (p.a.) Simple Interest. Find:*

1.1.1 *The future value of the investment;*

  1.1.2 *The simple interest received at the end of 10th year;*

  1.1.3 *The simple interest received each year.*

1.2 *Mapule's parents are unemployed, and she borrows money from the First National Bank in order to buy her school books. How much did Mapule borrow from the bank at 12% p.a. Simple Interest (SI) if she had to pay R510 interest after 5years?*

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[46] The total number of errors in Table 6.10 accumulates to 7710. The total number of BODMAS errors (type 1) is divided by 7710 and multiplied by 100% to determine the type 1 error percentage of occurrences.

Data in question 1.1 of Figure 6.8 can be arranged as: $P = 50000$; $n = 10$; $i = \dfrac{15}{100} = 0.15$. The simple interest formula is $A = P(1 + in)$. Because working out the solution to question 1.1 entails simplifying brackets, some of the participants committed a BODMAS error. The BODMAS error was committed largely at pre-stages of the experiment. The error occurred 1147 (37.05%)[47] times in the experimental schools and 838 (31.80%) times in the control schools during a pre-test (see Table 6.10). See example of BODMAS error for question 1.1 in Vignette 6.1.

Vignette 6.1: An example of learner's script containing the BODMAS error

Vignette 6.1 shows that the participant struggled to execute operations inside brackets. Inside the bracket, the numbers are arranged as $(1 + 0.15 \times 10)$. According to the BODMAS rule, the product of 0.15 and 10 must be obtained first and then be added to 1. The participant in Vignette 6.1 followed an erratic route by adding 1 to 0.15 first, and then multiplying the sum with 10.

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[47] The percentage is computed by dividing 1147 (sum of type 1 errors at experimental schools during the pre-test) by the total number of errors (*type 1 error + type 2 error + type 3 error + type 4 error* at experimental schools during the pre-test) and multiplying the quotient with 100% (see Table 6.10). A similar computation procedure is followed in subsequent discussions in section 6.5.

6.5.1.2 __TYPE 2 ERROR:__ *The reversal error*

With a type 2 error most participants tended to switch symbols such as "*P*" and "*A*" and "*A*" and "*i*" when applying the formulae $A = P(1 + i)^n$ and $A = P(1 + in)$. For instance, in question 1.2 in Vignette 6.1, some participants committed the error discussed in Examples 6.1 and 6.2.

Example 6.1: An example in which learners switched "A" and "P"

In question 1.2 of Vignette 6.1 some participants switched "*A*" and "*P*". In this question, given data is arranged as $P = ?$, $i = 0,12$, $A = 510$, $n = 5$, the formula $A = P(1 + in)$ should be used. In a switch, some participants presented their data as $P = 510$ and $A = ?$ (see Vignette 6.2).

Vignette 6.2: A sample representing participants who committed a type 2 error
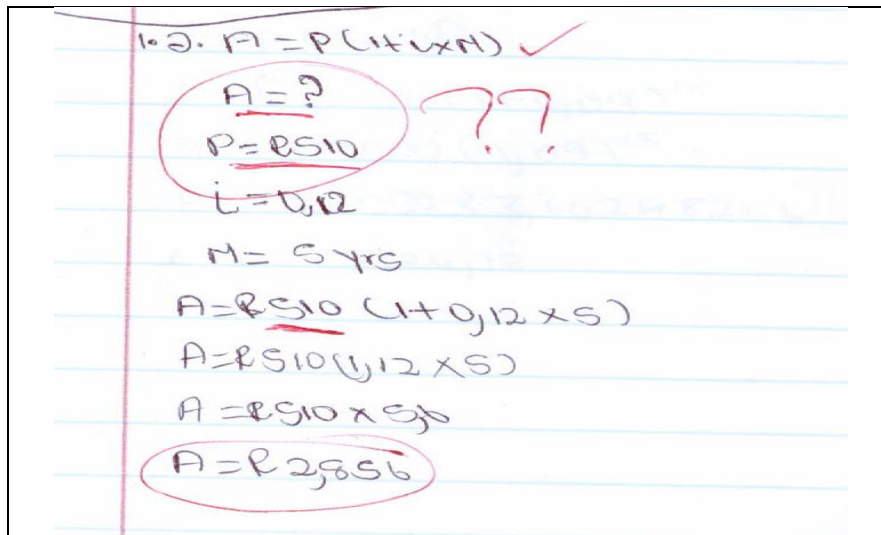
Given the common emergence of type 2 error across questions (21.15% of all error types in both groups and in both stages of intervention)[48], participants were probed on their tendency to commit this error (see Table 6.10). One participant responded.

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[48] The percentage in parenthesis was obtained by computing the sum of all error types in both groups and at both stages of intervention. The total sum of type 2 errors in Table 6.10 is 1631 (both groups and both stages of intervention). The sum of 1631 was divided with the accumulative sum of all errors in both groups during the pre and post-test. The quotient is then multiplied by 100%.

L: *"Our teacher said the "starting amount" is "P". The starting amount is the first amount to be given in a problem. The first amount given in question 1.2 is R510. Therefore, P = 510".*

This misconception was common amongst both groups because most participants supported the previous response.

Example 6.2: An example to illustrate type 4 error

In this example, a type 2 error was committed when participants confused "A" and "i".

Vignette 6.3: An example of a participant who switched "A" and "i"
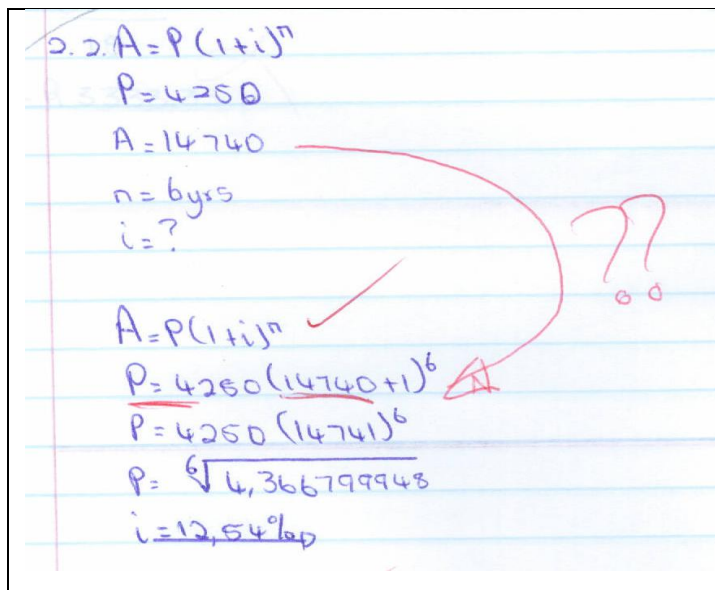
The participant in Vignette 6.3 committed several errors in solving the problem in question 2.2 of the achievement test (see Example 6.1).

Example 6.1: Question 2.2 of achievement test

Question 2.2 of achievement test

R4 250 is invested for 6 years and grows to R14 740. Find the interest rate if interest is compounded annually.

In Example 6.1 data is: $P = 4250$; $A = 14740$; $n = 6$; $i = ?$; and the formula $A = P(1 + i)^n$ should be used.

Solution steps for Example 6.1:

$$A = P(1 + i)^n$$

$$14740 = 4250(1 + i)^6$$

$$\frac{14740}{4250} = (1 + i)^6$$

$$(1 + i)^6 = 3.468235294$$

$$1 + i = \sqrt[6]{3.468235294}$$

$$i = 1.230320024 - 1$$

$$i = 0.230320024$$

$$i = 23.03\%$$

Vignette 6.3 shows that the participant presented data correctly and the choice of formula is correct. A type 2 error is committed during substitution: "*A*" is replaced with "*P*" in step 2, and "*i*" is substituted with 14 741. Most participants fell into this category of type 2 error (switching "*A*" and "*i*"). Of the 1631 (100%) type 2 errors committed in both groups during a pre and post-test, 1190 (72.96%) were identified as switching "*A*" and "*i*".

Upon probing the observed tendency to commit the type 2 error, one participant responded (see also, Dhlamini & Mogari, 2011).

> **L:** *"If you take money to the bank you get interest. The money you get in the end is interest, bigger than your first money".*

Some participants appeared to agree with this response as they nodded in approval. Participants revealed that to them a phrase such as "*accumulated amount*" (incorporated in some simple and compound problem tasks that were treated during lessons) referred to the interest that participants associated with "*i*" (see also, Dhlamini & Mogari, 2011).

6.5.1.3 <u>TYPE 3 ERROR:</u> *Inability to simplify "exponent-root" related problems*
A type 3 error was observed when participants failed to simplify problems with either a root, which in this case was a sixth-root, or an exponential number (see Example 6.3). A participant vignette is provided to illuminate the tendency by some participants to commit a type 3 error (Vignette 6.4).

Vignette 6.4: An example of a participant who incorrectly computed the 6th-root part of the problem

Participants encountered obstacles when solving problems presented in root-exponent format. The type 3 error occurred mostly during the pre-test (see Table 6.10). The type 3 error occurred 844 times in experimental schools and 970 times in control schools during both stages of the intervention. Of the 844 type 3 errors, 103 (12.20%) occurred after intervention in experimental schools. In control schools, 291 (30.0%) type 3 errors occurred after intervention. Participants in the experimental condition largely minimised the occurrence of type 3 errors after intervention.

6.5.1.4 <u>TYPE 4 ERROR:</u> *Confusing "interest" when it is given in different contexts*

With question 4, most participants revealed problem solving deficiencies (see Table 6.10). A type 4 error defines errors committed in problems in which two or more types of interest rates are incorporated (see Example 6.2).

Example 6.2: Question 4 of achievement test

> **Question 4:** *Your brother wins a LOTTO competition and decides to invest R50 000 now. He secures an interest rate of 9% p.a. compounded annually. The inflation rate is currently running at 12% p.a.*

See Vignette 6.5 for solution to the problem posed in Example 6.2 to illustrate how some participants committed a type 4 error.

Vignette 6.5 shows that the participant added the two given interest rates. According to Table 6.10, a type 4 error occurred 634 times in experimental schools and 415 times in control schools during a pre-test. However, after intervention, participants' performance improved (see Vignette 6.6; also compare with Figure 6.15 and Table 6.10; see also Figure 6.9).

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Vignette 6.5: A participant who added two interest rates in question 4 of the test (Example 6.2)

Vignette 6.6: Example of a participant who performed better after intervention

6.5.2 Analysis of participants' problem solving errors

In this section, two types of analysis are performed to compare context-based problem solving instruction to conventional instruction employed by teachers in control schools. The analysis is based on the types of errors participants committed in both groups during both stages of the intervention. The two analyses are based on *simple mathematical computation* and *one-way ANOVA*.

6.5.2.1 Performing simple mathematical error analysis to compare instructions

The four types of errors committed by participants from both groups during pre and post-test have been summarized in Table 6.10. Figure 6.9 provides a graphic representation of this data.

Figure 6.9: A graphical display of learners' errors in both groups at pre- and post-stages
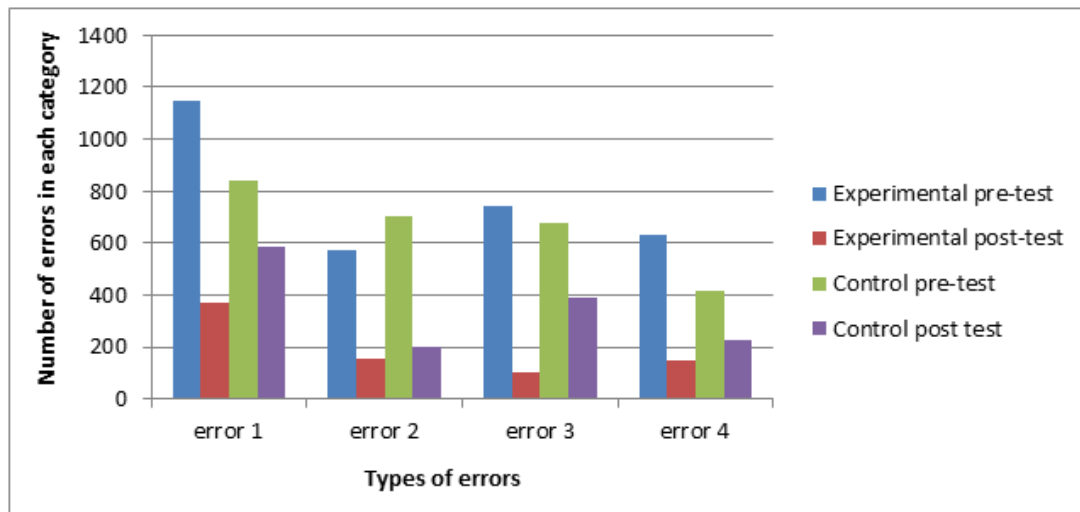
Figure 6.9 shows that the context-based problem solving instruction (CBPSI) is superior to conventional approaches in addressing learners' observed errors during instruction. Results show that CBPSI generally improved participants' errors compared to conventional instructions employed by teachers in control schools. For instance, Figure 6.9 shows that CBPSI reduced type 1 errors from 1147 at the pre-stage to 369 at the post-stage. This is an effective rate of

67.8% compared to a 29.8% effective rate in conventional conditions. The effective rate is obtained as follows:

$$Effective\ rate(\%) = \frac{Error_{pre-test} - Error_{post-test}}{Error_{pre-test}} \times 100\%$$

When applying the same mathematical computation, it is observed that for type 2 errors, CBPSI achieved an effective rate of 73.3% compared to a 71.4% effective rate in control schools. With type 3 errors, the effective rate for CBPSI is 86.1%, while in conventional instructions it is 42.4%. Context-based problem solving instruction dealt with type 4 errors at an effective rate of 76.8%, while conventional instruction registered a 45.1% effective rate. Therefore it may be concluded that CBPSI is superior to conventional instructional approaches when addressing errors relating to context-based problem solving tasks.

6.5.2.2 One-way ANOVA for participants' observed errors

One-way ANOVA was performed to determine the statistical significance of participants' error mean difference in both groups. The analysis was performed to test the assertion that the number of errors committed during both achievement test sessions is linked to the group to which participants were assigned. Two one-way ANOVA tests are conducted to test whether there is a significant difference in the number of errors participants committed at the: 1) pre-stage of the experiment; and, 2) post-stage of the experiment.

6.5.2.2.1 <u>TEST ONE</u>: *One-way ANOVA at the pre-stage*

Data in Table 6.10 were entered on the SPSS, where the *dependent variable* is the number of errors and the *independent variable* (factor) is the group to which each participant belonged. The output is shown in Table 6.16.

Table 6.16: One-way ANOVA table of participants' errors in a pre-test

Source	Sum of Squares	df	Mean square	F	Sig.
Between groups	23762.000	1	23762.000	1.530	0.262
Within groups	93186.000	6	15531.000		
Total	116948.000	7			

Table 6.16 shows that $p = 0.262 > 0.05$. If the p-value is greater than 0.05, then the hypothesis of no difference is *not rejected*, meaning there is no statistically significant difference in the error mean of participants in a pre-test. These results further suggest that at the pre-stage, the group to which each participant belonged did not matter, suggesting that at the pre-stage participants performed equivalently.

6.5.2.2.2 **TEST TWO:** *One-way ANOVA at the post-stage*

Data in Table 6.10 is entered on the SPSS, where the dependent is the number of errors and independent variable (factor) is the group to which each participant belonged. The output is shown in Table 6.17 and Table 6.18.

Table 6.17: Test of homogeneity of variance

Levene Statistic	df1	df2	Sig.
3.683	1	6	0.103

The results in Table 6.17 show that Levene's F Statistic has a significance value of 0.103 and, therefore, the assumption of homogeneity of variance is met. It is possible to continue with the ANOVA test.

Table 6.18: One-way ANOVA table of participants' errors in a pre-test

Source	Sum of Squares	df	Mean Square	F	Sig.
Between groups	161312.000	1	161312.000	8.760	0.025
Within groups	110486.000	6	18414.333		
Total	271798.000	7			

The results in Table 6.18 show that there is a statistically significant difference between groups as determined by one-way ANOVA [$F(1,6) = 8.760$, $p = 0.025$], which is below 0.05. Therefore there is a statistically significant difference in the error mean. The *post hoc* tests are not performed for error because there are fewer than three groups. The results in Table 6.13 suggest that the group to which each participant belonged determined the number of errors participants committed during a post-test. Since the total number of errors committed by learners in experimental schools was minimal, it may be concluded that a context-based problem solving instruction is superior to traditional problem solving instructions.

6.6. MEASUREMENT OF LEARNERS' COGNITIVE LOAD

At the end of both the pre-test and the post-test learners in experimental schools (n = 378) were given a self-rating questionnaire to measure the cognitive load or mental effort they invested in performing context-based problem solving tasks in the achievement test. In section 5.5.1.10 a mental effort is defined as the cognitive capacity that is actually allocated to solve the problem and can be considered to reflect the cognitive load (see also, Sweller *et al*., 1998). In terms of the present study, a cognitive load measuring tool was administered to determine the effect of context-based problem solving instruction (CBPSI) in enhancing the reduction in learners' cognitive load when they engage in problem solving activity. The tool was administered only in experimental schools where the CBPSI was implemented by the researcher.

A self-rating scale of mental effort consisted of a nine-point scale: 1 (extremely easy); 2 (very easy); 3 (easy); 4 (quite easy); 5 (neither easy or difficult); 6 (quite difficult); 7 (difficult); 8 (very difficult); and, 9 (extremely difficult). Each of the self-rating scale choices was presented in the learners' answering scripts immediately following each session of the achievement test

(pre-test and post-test). In the next section the results of the measurements of learners' cognitive load are presented.

6.6.1 The post pre-test measure

The tables that follow reflect on the results of data that were collected to measure learners' cognitive load after they wrote the pre-test.

Table 6.19: The mean of learners' cognitive load during a pre-test

Variable	n	Mean	SD	Min.	Max.
Mental effort	378	6.63	1.56	3.00	9.00

Table 6.19 shows that when learners in experimental schools engaged in context-based problem solving tasks during a pre-test their mean rating of the pre-test was 6.63, suggesting that learners generally rated the test as "difficult". It is also observed that during a pre-test learners' cognitive load ranged between "easy" and "extremely difficult" (see more details in Table 6.20).

Table 6.20: Frequency table of learners' cognitive load during a pre-test

Level of mental effort	n	% of occurrences
Easy	16	4.23
Quite easy	24	6.35
Neither easy or difficult	55	14.55
Quite difficult	61	16.14
Difficult	74	19.58
Very difficult	127	33.60
Extremely difficult	21	5.56
TOTAL	**378**	**100**

According to Table 6.20, of the 378 learners who were engaged in context-based problem solving tasks during a pre-test 127 felt that the test was "very difficult". Almost 283 (74.88%) learners fell within the categories "quite difficult" and "extremely difficult". Only 40 (10.58%) generally felt that the test was "easy".

6.6.2 The post post-test measure

In the tables that follow the results of the measurement of learners' cognitive load during the post-test are provided.

Table 6.21: The mean of learners' cognitive load during a post-test

Variable	n	Mean	SD	Min.	Max.
Mental effort	378	3.25	1.59	1.00	7.00

Table 6.21 shows that most learners in experimental schools generally rated the post-test as being "easy" ($M = 3.25$; SD 1.59). After engaging in context-based problem solving tasks of the post-test learners rated the test between "extremely easy" and "difficult".

Table 6.22: Frequency table of learners' cognitive load during a post-test

Level of mental effort	n	% of occurrences
Extremely easy	29	7.67
Very easy	124	32.80
Easy	87	23.02
Quite easy	64	16.93
Neither easy or difficult	29	7.67
Quite difficult	24	6.35
Difficult	21	5.56
TOTAL	**378**	**100**

The results in Table 6.22 show that most learners felt that the post-test was easy. For instance, 124 (32.80%) learners rated the post-test as "very easy". Of the 378 learners that wrote the post-test 304 (80.42%) ranked the post-test within the continuum "extremely easy" and "quite easy". Of the 378 learners, 45 (11.90%) rated the post-test as either "quite difficult" or "difficult".

6.6.3 Conclusion from the results in section 6.6.1 and section 6.6.2

The results in Table 6.19, Table 6.20, Table 6.21 and Table 6.22 suggest the reduction in learners' cognitive load as a result of intervention in experimental schools. For instance, 124 learners rated the post-test "quite easy" as opposed to 24 learners who rated the pre-test as "quite easy". It is also observed that 21 learners rated the post-test as "difficult" while 74 learners had earlier felt that the pre-test was "difficult". None of the learners felt that the post-test was either "very difficult" or "extremely difficult", however, these rating scales are observable in the pre-test cognitive load measurement (see Table 6.20). On the whole the results in Table 6.19, Table 6.20, Table 6.21 and Table 6.22 suggest that context-based problem solving instruction was effective in reducing learners' cognitive load, thus enhancing learners' problem solving performance. This conclusion is supported by the mean values in Table 6.19 and Table 6.21, suggesting a mean difference of 3.41.

6.7 CHAPTER SUMMARY

In this chapter, quantitative data were presented and analysed using statistical methods (see summary in Table 6.23). In section 6.2, profiles were examined of learner participants, teachers and schools. Descriptive statistics were used to analyse learners' demographic data collected through a questionnaire (Appendix D). The aim was to verify participants' socioeconomic status (see section 5.5.1.8). The analysis of data showed that participants were largely from a disadvantaged socioeconomic background.

In section 6.2.7, the teacher and school profile analysis is discussed. Data from a questionnaire and interviews with teachers showed that almost all nine participating schools are disadvantaged in terms of scholastic performance and infrastructure (section 6.2.7.1). In section 6.2.7.2, the Kendall's *tau* correlation coefficient was computed using SPSS at $p < 0.05$ significant level to determine the effect of teachers' qualifications on learner achievement (see also Table 6.3). The

correlation analysis showed that teachers' qualifications have a positive significant relationship with learners' achievement in Grade 10 mathematics ($p = 0.612$).

Table 6.23: Summary of statistical tests conducted in the study

Statistical technique	When to use the technique	Purpose of test in the study	In-text reference	Results of test
ANCOVA	Preferred when balancing initial group variations during intervention.	To separate the effect of pre-test in order to determine the effect of context-based problem solving instruction using post-test scores of two groups (n=706).	6.3.2 to 6.3.6	After removing the effect of pre-test scores the results, $F(1,703) = 558.677$, $p < 0.05$ were obtained. Meaning, new instruction is effective.
ANOVA	Preferred when determining whether there are any significant differences between the means of three or more independent groups.	To compare the mean post-test group performances in the following categories: "*LO2*"; "*AV2*" and "*HP2*".	6.4.2	The $p < 0.05$ is obtained, suggesting that there is a statistically significant difference in the mean performances of groups.
		To determine statistical significance of participants' *error* mean difference in both groups.	6.6.2	**TEST 1:** $p = 0.262 > 0.05$; suggesting that there is no significant difference in group mean performances and likelihood to commit errors. *Errors* not linked to group assignment. **TEST 2:** $p = 0.025 < 0.05$; suggesting that participants' *errors* are linked to participants' group assignment.
T-test	Preferred when comparing two mean scores of one sample.	To determine the effect of context-based problem solving instruction using pre-test scores in a pilot study (n=57).	6.3.1	The $p = 0.0366 < 0.05$ is obtained, suggesting that there is a statistical difference in mean scores. Meaning, new instruction is effective.
Kendall's *tau*	Preferred for *bivariate* correlations involving samples less than ten.	To examine the link between teachers' subject qualifications and learners' performance in grade 10 mathematics (n=9).	6.2.7.2	The $p = 0.612$ is obtained. The correlation is found to be "*moderate*" using Jackson (2011) correlation framework (section 5.8.1).

The main results of the study were reported and analysed in section 6.3. The t-test was performed to analyse participants' scores obtained from an achievement test administered during a pilot study (section 6.3.1). Results from this test showed that the probability of error is less than 0.05 ($p = 0.0366 < 0.05$), suggesting that context-based problem solving instruction is effective in accelerating participants' problem solving performance, and thus warranting proceeding with the main study. To compare the post-test achievement test scores of the main study for the two groups, one-way ANCOVA was performed and is discussed in sections 6.3.2 to section 6.3.6. The results of the ANCOVA analysis confirmed the pilot study results that context-based problem solving instruction is superior to conventional instruction employed by teachers in control schools ($p < 0.05$).

To further compare two instruction approaches, an analysis of participants' post-test scores was performed using performance categories defined in Table 6.8. A one-way ANOVA test was used to conduct this test (section 6.4.2; Table 6.11). The ANOVA test result, seen in Table 6.11, showed that in each performance category there is a statistically significant difference in mean performances ($p < 0.05$).

Lastly, the number of errors, error types and the frequency of their occurrence in both groups during pre and post-stages were analysed. Four types of errors characterized participant achievement test performance (see sections 6.5.1 to 6.5.4). A summary of the number of errors and the error type committed by both groups in both stages of the experiment were summarised in Table 6.10. One-way ANOVA was used to test the assertion that the number of errors participants committed during both achievement test sessions is linked to the group to which participants were assigned (section 6.6.2). The first ANOVA test for the pre-test errors showed that $p = 0.262 > 0.05$, implying that at the pre-stage of the experiment there was no significant difference in the error means of participants. The results implied that at the pre-stage of the experiment the groups to which participants belonged did not influence their context-based problem solving performance and the resulting errors.

The second ANOVA test showed that there is a statistically significant difference between groups, as determined by a one-way ANOVA [$F(1,6) = 8.760$, $p = 0.025$], which is below 0.05.

The second ANOVA test results suggested that the group to which each participant belonged determined the number of errors participants made during a post-test. Since the total number of errors made by participants in experimental schools was minimal, it was concluded that CBPSI is superior to conventional problem solving instruction (see, section 6.6.2.2; Table 6.10).

In conclusion, quantitative data suggests that context-based problem solving instruction is superior to conventional instruction in enhancing learners' problem solving skills in the area of *Financial Mathematics* in Grade 10. In the following chapter, qualitative data are presented and analysed.

CHAPTER SEVEN

RESULTS AND DATA ANALYSIS: QUALITATIVE DATA

7.1 INTRODUCTION

Qualitative data from semi-structured interviews and classroom observations were collected to account for the outcomes of the quasi-experimental design of the study (see section 5.2 & section 6.1). Burnard (2004, p. 85) noted that "one of the major complaints against the statistical interpretation of data is that details of the actual programme implementation and description of the intervention usually get lost in the process". In this chapter qualitative analysis is mainly guided by the research questions (section 1.8) and research objectives (section 1.2) of the study. In addition, the steps in Table 7.1 were used as a framework to guide the analysis of qualitative data. These steps are adapted from Burnard (1991) and were not necessarily followed as a cookbook set of instructions. The steps suggested in Table 7.1 were considered after all interviews had been transcribed.

7.2 CLASSROOM OBSERVATIONS

Classroom observations were carried out according the schedule (see section 5.6.2.4 & Appendix B). Only one classroom observation session was conducted in each of the control schools, and on the times agreed upon between the researcher and the teacher. Limited visits by the researcher allowed lessons to run naturally in control schools (section 5.6.2.4). Observation with experimental groups continued throughout the intervention.

All four participating teachers were observed by the researcher during their conventional problem solving lessons (see section 1.9.6 & section 5.6.2.3) in which they presented context-based problem solving tasks in control schools (section 5.4.2.3). Learner participants were also observed by the researcher during conventional problem solving lessons in control schools, and during context-based problem solving instructions in experimental schools. During classroom observations in both groups the researcher made notes for post-observation analysis (see step 1 of Table 7.1).

Table 7.1: Steps followed to analyse qualitative data

Step	Method of analysis	Example/ explanation of how each step was carried out in current study
1	During classroom observations and semi-structured interviews, and while listening to the recorded interviews, **notes** were made.	A response relating to either a research question or objective. For instance, a response such as, *"I like this method of teaching because you have taught us with examples"*, was considered to be linked to objective four of the study.
2	Interviews were transcribed. Transcripts were read through and notes were made. General **themes** were identified.	Themes were established using key words from study objectives and research questions statements.
3	Transcripts were read through again and **categorized** according to themes.	This was done during analysis. Themes belonging to specific categories were identified.
4	The number of categories was reduced by surveying their list. Initial categories were then **grouped** together under higher-order headings.	Other categories bore similarities. Eventually the number of categories was reduced when such categories were merged.
5	The new list of categories and sub-headings was worked through and repetitious removed to produce a final list.	See explanation in previous column.
6	Two colleagues were invited to generate their categories without seeing the researcher's list. The three lists (one from researcher and two from colleagues) were discussed and adjustments were made.	This process is explained in section 5.8.2.2 of this report.
7	Transcripts were read alongside the finally agreed list. This was done to establish the degree to which the categories covered all aspects of the interviews.	The researcher read the finalised interview transcripts with colleagues. This process also involved teachers.
8	Each transcript was worked through with the list of categories and sub-headings and was **coded** according to the list of categories and headings.	This process was worked out by the researcher and the results thereof were verified with colleagues.
9	Each coded part of the interviews and observations was cut out of the list and all items of each code were collected together.	This was achieved when it was realised that some of the initially identified themes belonged to the newly established categories.
10	The cut out sections were pasted to the appropriate categories and sub-headings.	This was after the newly established categories were verified and accepted.
11	Selected respondents were asked to check the appropriateness of their responses to categories.	When teachers and learners were approached for the purpose of comparison they were asked the following question: "*Does this quotation from your interview fit this category?*"
12	All the sections were filed together for reference purposes during a write up stage.	This evidence is in the custody of the university.

Adapted from Burnard (1991)

7.3 SEMI-STRUCTURED INTERVIEWS

Prior to the day on which the semi-structured interviews were conducted the researcher communicated with all prospective respondents 24 hours in advance to confirm the times of the interviews, the venue of the interviews, and the scope of the interviews. Two teachers and 20 learners were sampled for the interviews (see section 7.4 & section 7.5). All interviews for teachers and learners took place between 14H00 and 15H00, and each session lasted between 20min to 30min. Some of the learners did not report for the interviews (see Table 7.2). Arrangements were made to proceed with the respondents who were present in each school. All interviews were recorded (section 5.5.1.4).

Table 7.2: Details of interviews attendance in all participating schools[49]

School codes	Number of prospective learner interviewees	Number of prospective teacher interviewees	Learner(s) who was(were) absent for interviews	Teacher(s) who was(were) absent for interviews
E1	2	NA	-	NA
E2	2	NA	-	NA
E3	3	NA	1	NA
E4	2	NA	1	NA
E5	2	NA	-	NA
C1	3	-	-	-
C2	2	1	-	-
C3	2	1	1	-
C4	2	-	-	-
Total	**20**	**2**	**3**	**0**

From Table 7.2 it is observed that both teachers reported for the interviews (see also section 5.3.2). Because three learners did not report for the interviews, 17 (85%) learners were eventually interviewed. Interviews were conducted on different days for each school.

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[49] For the explanation of school codes in Table 7.2 see section 5.3.4.

7.4 SAMPLING TECHNIQUES FOR TEACHER INTERVIEWEES

The sampling techniques used by the researcher to select teachers (T1 and T2) for the interviews are discussed in section 5.3.2. When sampling the teachers the following characteristics were considered (see section 5.3.2 for purposive sampling for teachers): 1) teachers' teaching styles; 2) teachers' qualifications in mathematics; 3) teachers' teaching experience (in years); and, 4) teachers' views on the initiatives to connect mathematics to real-life experience.

7.5 SAMPLING TECHNIQUES FOR LEARNER INTERVIEWEES

Learners form an important part of a teaching and learning process. Naturally learners are the ones on whom novel instructional methods are tested. For that reason, learners may be at a vantage point where they can constantly observe and evaluate their teachers' instructional approaches. Baloyi (2011) noted that "unlike researchers, who in effect spend very little time with teachers through interviews or observations, learners usually spend a minimum period of a year in the company of their teachers" (p. 189). This period is long enough for learners to observe their teachers' natural conduct. Learners are a reliable source of information regarding their teachers' behaviour during instruction.

Kwok-Lun and Lew (1981) noted that "reliable description of the typical behaviour of the teacher has to be based on many hours of classroom observation; and the obvious sources are the students" (p. 50). Learners can provide valuable information about the behaviour within classroom environments. Nevertheless, according to Baloyi (2011, p. 188), "many studies tend to overlook learners' opinions and judgements in this regard". This tendency may omit a crucial information base, which is learners' perspective or inputs based on their daily classroom experience (Baloyi, 2011).

Given this background, learners' views on the role of context-based problem solving instruction (CBPSI) in developing problem solving skills of learners were examined (see Appendix B). A sampling tool in Appendix L was developed to select learners who participated in the interviews. When selecting the learner interviewees the following three characteristics were considered (see also, section 5.3.2):

- Learners' post-test[50] scores (achievement test);
- Learners' participation/ involvement during the treatment of context-based problem solving tasks;
- The initial status of learners' problem solving abilities (almost all participants met this requirement).

7.5.1. Learners' post-test scores as a sampling criterion for interviews

The researcher ensured that participants who were sampled for the interviews represented all levels of performance provided in Table 6.11. The distribution of the selection of learner interviewees in terms of post-test performance is given in Table 7.3 (see Table 6.11 for the interpretation of HIGH, AVERAGE and LOW in Table 7.3):

Table 7.3: Achievement test (post-test) performance distribution for the prospective interviewees[51]

	HIGH	AVERAGE	LOW
LEARNERS	5	8	7
%	25%	40%	35%

Table 7.3 shows that most interviewees were sampled from participants who performed "averagely" 8 (40%). This category is followed by "low performers" 7 (35%). Therefore, prospective interview respondents represented all performance categories (Table 6.11).

The distribution of interviewees in each performance category in terms of groups (experimental group and control group) is shown in Figure 7.1. For instance, out of five interview respondents, four were from experimental schools (one from the control group).

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[50] Learners' post-test scores were considered over their pre-test scores because the post-test scores reflected on their two-week experiences on the intervention program. Because the interviews represented participants' post-intervention experiences the post-test scores were better linked to that experience.
[51] See footnote in Appendix L for the explanation of categories "HIGH", "AVERAGE" and "LOW" as pronouncements of learners' post test scores (see also Table 6.11).

Figure 7.1: Prospective interviewees' post-test scores distributed according to groups
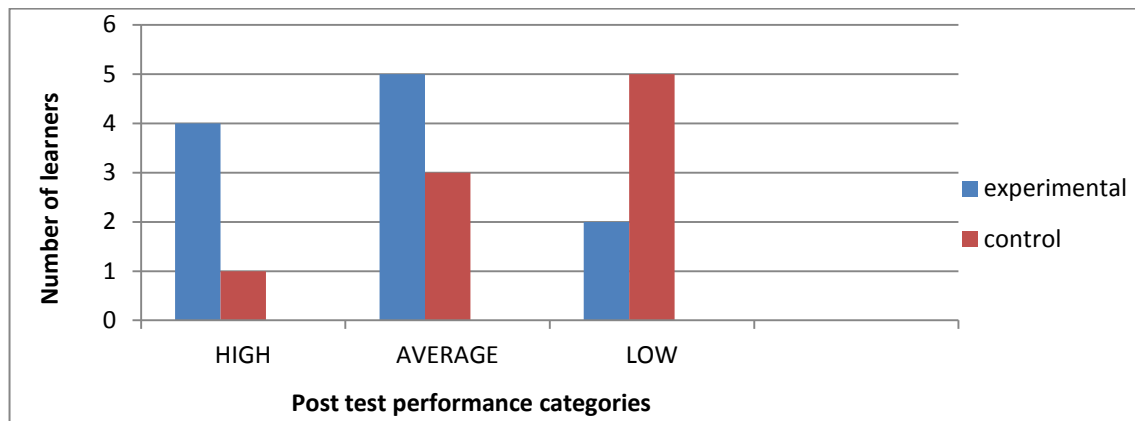
Data in Figure 7.1 and Table 7.3 show that the selection of learner interviewees was not based on a specific performance category. The researcher employed a variety of selection strategies to sample interview respondents (see section 7.5.2).

7.5.2 Learners' participation during context-based problem solving tasks

Based on the level of learners' classroom participation during a two-week intervention study data in Table 7.4 were collected (see also Appendix L). In experimental schools learners worked mainly in groups, and in control schools most learners worked independently (see section 1.9.6 & section 1.9.7).

In Table 7.4 a participation criteria, and the number of learner interviewees, in both groups, who constituted each category are provided. For instance, of the 20 prospective interviewees in Table 7.4 eight (six from experimental schools and two from control schools) were judged to have participated effectively during context-based problem solving tasks (see Footnote 53).

Table 7.4: Number of interviewees sampled in each participation category[52]

CRITERION	EXPERIMENTAL	CONTROL
During problem solving tasks, the learners:		
Participate effectively	6	2
Participation is minimal	1	2
Does not participate	3	4
Works independently	1	1
TOTAL	**11**	**9**

In both experimental schools and control schools some participants were categorised as, "*does not participate*" and "*work independently*" (see Table 7.4). Learners who were categorised as either "*does not participate*" or "*work independently*" claimed they were used to working independently. For instance, one learner in control schools commented:

> **L1:** *I have worked on my own all the time and I get my answers. If I have problems I go to my teacher.*

Another learner who was from an experimental group commented:

> **L2:** *Hi sir … eh… we always work in ones.*

The phrase "*... work in ones*" in this context implies working independently. The fact that in control schools learners usually worked independently during lessons was shared by other class members as they nodded their heads when L2 commented.

In most control schools the mode of instruction that the teachers employed encouraged independent working and non-participation by learners. For instance, the arrangement of desks

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[52] In the context of this study, participation was considered "effective" if it contributed directly to finding context-based solution to the problem. In this regard the learner was expected to be able to explain his or her problem solving approach to other group members, and also be able to clarify all steps leading to the solution. Even in group settings other learners chose to work independently, hence the category "works independently" was incorporated in Table 7.4.

constrained effective interaction between learners. Teachers tended to explain everything to learners (they provided all problem solving information). Given this background, only two learners were identified as "*effective participants*" in control schools. In addition, four learners were classified as "*does not participate*" because they abstained from participation during the course of the lesson (Table 7.4). Learners in the "*does not participate*" category did not give answers to some of the questions their teachers asked.

7.5.3 The initial status of learners' problem solving abilities

At the beginning of the study all participants (n = 783) wrote a pre-test to measure the initial status of their problem solving skills. The pre-test mean (*M*) scores of experimental group and control group ($M_{experimental}$ = 20.9; $M_{control}$ = 22.0) differed by almost 1.1, suggesting baseline equivalence of the two groups before intervention. The pre-test results suggested poor problem solving performance by the two groups at the initial stages of the study (when judged by designated performance levels in Table 6.11).

In addition, the researcher investigated specific areas of problem solving in which learners lacked the skills. To achieve this, an evaluation tool was designed (see Appendix F). The tool in Appendix F evaluated the following areas of problem solving performance:

- Learner's ability to analyse and organise data;
- Learner's ability to choose correct formula for the problem;
- Learner's ability to relate problem to previously solved problems;
- Learner's ability to arrange and identify useful information for problem solving;
- Learner's ability to verify solution after problem solving;
- Learner's ability to sustain problem solving actions.

A special task was designed to evaluate the above-mentioned problem solving abilities. To avoid over-burdening teachers with excessive research-related tasks the researcher administered the tool in Appendix F only in experimental schools. Ten learners in each of the five experimental schools participated in the task (n = 50).

The researcher assumed that feedback from the task would represent the general problem solving abilities of the study sample (n = 783) since both groups in the study were found to be equivalent (see sections 5.4 & section 6.2). The results are discussed in section 7.5.3.1 to section 7.5.3.6.

7.5.3.1 Learners' abilities to organise and analyse problem solving data

When solving context-based problem solving tasks participants were expected to: *structure a problem properly (using given data); to interpret data correctly; to map out possible steps to the solution*; etc. (see Appendix F). The results in Table 7.5 were obtained.

Table 7.5: Participants' abilities to organise and analyse problem solving data (n = 50)

Ability to organise and analyse data	Good	Average	Poor
Number of participants	7(14%)	6(12%)	37(74%)

Table 7.5 shows that 37 (74%) participants were observed to be performing poorly. Only seven (14%) of the participants demonstrated "good" organisation abilities.

7.5.3.2 Learners' abilities to choose correct formula for the problem

When solving problems in *Financial Mathematics* a formula is used. Participants were evaluated on their *abilities to choose the correct formula in each problem*. The results in Table 7.6 were obtained.

Table 7.6: Participants' abilities to choose correct formula for problem solving (n = 50)

Ability to choose correct formula for the problem	Good	Average	Poor
Number of participants	11(22%)	16(32%)	23(46%)

Table 7.6 shows that twenty three participants (46%) performed poorly. In terms of the task in Example 7.1 participants in the "poor category lacked the ability to choose appropriate formula between the *simple* interest formula and *compound* interest formula.

Example 7.1: A context-based task in which learners were expected to demonstrate abilities to select correct formula

2.2 R4 250 is invested for 6 years and grows to R14 740.

Find the interest rate if interest is compounded annually.

Participants in the "*poor*" category of Table 7.6 performed like the learner in Vignette 7.1.

Vignette 7.1: An example of a participant who chose a wrong formula

Instead of choosing a compound interest formula $[A = P(1 + r)^n]$, the participant in Vignette 7.1 chose the simple interest formula $[A = P(1 + i \times n)]$. The participants in Vignette 7.1 lacked knowledge (ability) to distinguish between a simple interest problem task and a compound interest problem task. A closer look into the participant's incorrect solution steps in Vignette 7.1

suggests that several problem solving errors were done (see section 6.5 for the discussion and analysis of participants' errors).

7.5.3.3 Learners' abilities to relate problem to previously solved problems

In this area participants were expected to *demonstrate recognition ability*, that is, demonstrate the ability to relate novel problem(s) to previously encountered problems of the same type. The data in Table 7.7 were collected.

Table 7.7: Participants' ability to link new problem to known problems (n = 50)

Ability to link problem to known problems	Good	Average	Poor
Number of participants	4(8%)	15(30%)	31(62%)

Table 7.7 shows that most participants (almost 92%)[53] struggled to relate novel problems to known problem contexts. In terms of cognitive load theory (Sweller, 1988) they did not possess problem solving schemas (prior knowledge) to facilitate problem solution process.

7.5.3.4 Learners' abilities to arrange and identify useful information for problem solving

In *Financial Mathematics* learners are expected to systematically arrange given data for problem solving. This ability is linked to *being able to make distinctions between principal (P) and final (A) values*. In addition, a learner is expected to *identify useful information* needed to solve the problem. Being able to identify useful information is linked to being able to work with trivial components of the problem such as computing the interest rate (*i*) in different problem contexts (see, for example, section 5.5.1.5). The data in Table 7.8 were collected.

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[53] The 92% in the parenthesis includes participants who performed "average" and "poor" in Table 7.7 (46 participants).

Table 7.8: Participants' abilities to arrange and identify problem solving information (n = 50)

Ability to arrange and identify problem solving information	Good	Average	Poor
Number of participants	3(6%)	6(12%)	41(82%)

Table 7.8 shows that 82% participants were not able to arrange and identify important problem solving information. Only 3 (6%) participants demonstrated this ability.

7.5.3.5 Learners' abilities to verify solution after problem solving

In this category participants were expected *to test and verify their final solutions in respect to the problem*. To evaluate the ability the following data were collected (Table 7.9).

Table 7.9: Participants' abilities to verify problem solving solution (n = 50)

Ability to verify solution after problem solving solution	Good	Average	Poor
Number of participants	2(4%)	-	48(96%)

Table 7.9 shows that most participants did not check their problem solutions. Only 2 (4%) participants demonstrated this ability. Upon probing participants acknowledged that it was not common in their mathematics lessons to check solutions after problem solving (see also section 7.9.1). Participants claimed they verified final answers by either checking solutions from the textbook or consulting other solution sources such as the teacher. One girl noted:

L1: *Our teacher doesn't do it ... so why should I?*

The views of **L1** were shared by **L2** who added (see next comment):

L2: *Yes Sir, our teachers don't stress this step. Remember we are always running to finish and we don't waste time.*

It is clear that teachers' actions and views influenced learners' methods of problem solving. In section 2.6 it was mentioned that the method of instruction that the teacher employs influences learners' performance (see also section 2.7).

7.5.3.6 Learners' abilities to sustain problem solving actions

A good problem solver sustains problem solving actions. Participants were expected *to demonstrate this ability even when the problem appears to be novel to them*. The following data were collected (see Table 7.10).

Table 7.10: Participants' abilities to sustain problem solving actions (n = 50)

Ability to sustain problem solving action	Good	Average	Poor
Number of participants	13(26%)	9(18%)	28(56%)

Table 7.10 shows that most participants (56%) performed poorly when expected to sustain problem solving actions. The 28 (56%) participants who were categorised as poorly performing gave up when they felt the problem was more demanding. In this category the following context-based problem task was given to participants.

Example 7.2: A sample of problem task given to participants (n = 50)

> In 2006 your father replaced his 1992 car with a new one and paid R289 000. The average ratio of inflation is 6,1% p.a. Use this rate to determine how much he paid for the car in 1992.   (5 marks)

The solution steps for Example 7.2 are:

$n = 2006 - 1992 = 14 \text{year}$ √ STEP1: Arrange data

$A = P(1 + \frac{r}{100})^n$ √ STEP2: Choose formula

$P = \dfrac{A}{(1+\frac{r}{100})^n}$ √ STEP3: Subject of formula

$P = \dfrac{289000}{(1+\frac{6,1}{100})^{14}}$ √ STEP4: Substitution/ computation

$P = R126\,148,61$√ [the price of the car in 1992]

Because the task was given to participants prior to the intervention study, it did not look familiar to participants. Only 13 (26%) participants successfully reached the final solution stage. Participants who performed poorly either could not "arrange data" [STEP 1] or could not "choose formula" [STEP 2]. In some cases participants who performed poorly could not execute both STEP 1 and STEP 2. Participants who performed averagely encountered problems in STEP 4 (either substitution or computation), but executed the first three STEPS successfully.

7.5.3.7 Overall judgement of participants' (n = 50) problem solving abilities

To aggregate the status of problem solving ability of participants in section 7.5.3.1 to section 7.5.3.6, and to subsequently make an overall judgement of the initial problem solving status of the study sample (n = 783), a descriptive statistics was performed where, "*1 = weak*", "*2 = average*" and "*3 = good*". The number of all "*weak*" performances in all areas of evaluation was entered into SPSS version 19.0 computer program for analysis. The same procedure was followed when entering the "*good*" and "*average*" performance variables. The mean output in Table 7.11 was obtained.

Table 7.11: Descriptive statistics for mean participants' problem solving performance (n = 50)

Variable	n	Minimum	Maximum	Mean	Std. Deviation
performance	300	1.00	3.00	1.4400	0.71748

Table 7.11 shows that the mean performance of participants is $M = 1.44(SD = 0.717; n = 50)$ in context-based problem solving tasks, suggesting that participants were largely "weak" context-based problem solvers at the initial stage of the intervention. The results in Table 7.11 corroborate the pre-test scores ($M_{experimental} = 20.9$; $M_{control} = 22.0$), by means of which both groups were judged to be weak and low problem solving performers (see Table 6. 11).

7.6 ANALYSIS OF LEARNERS' SEMI-STRUCTURED INTERVIEWS

In section 5.8.2.2 the codes for the interviewees are specified. Because experimental schools were paired with control schools interviews ran in line with the intervention schedule (see

section 5.6.2.2). Learners in school E1 and school C1 were interviewed first (first pair for intervention; see section 6.6), and learners in school E2 and school C2 were interviewed next (second pair for intervention), and so forth. The learners' interview codes were named in terms of the sequence in which learners were interviewed. Because the first two interviews were conducted in experimental school E1, learners who were interviewed in E1 were designated L1 and L2. The next three interviews were conducted in control school C1, which was paired with E1, and the interviewed learners in C1 were given the codes L3, L4 and L4 (see Table 7.12 for the learners' codes in subsequent schools).

Table 7.12: The pairing of schools for the study and details of learners' interviews

Paired schools	Interviewees' codes	Number interviewed
E1	L1 and L2	2
C1	L3, L4 and L5	3
E2	L6 and L7	2
C2	L8 and L9	2
E3	L10 and L11	2
C3	L12	1
E4	L13	1
C4	L14 and L15	2
E5	L16 and L17	2
TOTAL		17

The interview questions (in Appendix B) for the learners addressed the themes in Table 7.13. Questions 1, 4, 7 and 10 ascertained learners' understanding on certain aspects of problem solving. For instance, a question like "*What is a problem solving skill in mathematics?*" in Appendix B was considered to be tapping into learners' understanding of problem solving skills.

Table 7.13: Types of questions that were posed to learners during interviews

I N T E R V I E W S	
Type of question (theme) in interview schedule	**Question in the interview schedule (Appendix B)**
1. Understanding questions	1; 4; 7; and 10
2. Opinion (views)-related questions	2; 6; 8; 11; 12; 15; 16; 17; 18; and 20
3. Strategy-related question	3; 5; 9; and 14

In the subsequent discussion of the analysis of qualitative data, responses that are linked to the study objectives, study aim and research questions have been given preference. At the end of the discussion Tables of summaries are provided.

7.6.1 <u>STUDY OBJECTIVE 4</u>: To compare a context-based problem solving instruction to conventional problem solving instructions[54]

To address the fourth objective of the study the following questions were posed to learners:

- *"Do you think this teaching approach can improve learners' performance in mathematics if it were to be implemented in all schools?"*;
- *"What are your personal strategies for mathematical problem solving?"*;
- *"Do you think there is a need to teach mathematical problem solving through the use of real-life contexts in schools?"*;
- *"If you were a mathematics teacher, how would you use a context-based problem solving method to teach mathematics?"*; etc.

To identify learners' responses that linked to the fourth objective the researcher used Table 7.1 to develop the following themes: *"In favour of new instruction/ like new instruction"* and *"Not in favour of new instruction"*. Responses such as *"I like this method"* (see L2 in the next

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[54] Any mathematics instruction that was implemented prior the intervention in experimental schools and during intervention in control schools was classified as a conventional problem solving instruction (see section 1.9.6 & section 1.9.7). Conventional in this context does not necessarily refer to something "old" but rather to a teaching practice that is customary and popular within a school.

comments), "... *this teaching way is better*" (see L6 in next comments) were categorised as linking to the theme "*In favour of new instruction/ like new instruction*", etc.

Most learners from experimental schools favoured the context-based problem solving instruction. Of the nine learners in the experimental group, 5 (56%) supported the intervention instruction.

> **L2:** *I like this method of teaching because you have taught us with examples.*

> **L6:** *I think this teaching way is better than the one used by our teacher. I have passed my test because of this way.*

> **L9:** *Eh… this method is good because in my class we are not talking, but here we are talking to our friends for answers. It is good because myself I get it better from my learners.*

Comments from other interviewees in experimental schools included the following examples:

> **L6:** *I think I like mathematics when it is taught from our home life. I think it was interesting to talk about our relatives in maths class. I also showed this work to my mother. It was interesting.*

> **L13:** *Mathematics is an important subject. We use it every day, so it must be taught in life.*

Learners' responses from control schools were different to those of respondents from experimental schools. Instead of making a comparison between the intervention instruction and conventional problem solving instructions they chose to reflect on how they felt during lessons in their classes. Respondents in the control group complained that teachers did not give them the opportunity to exhibit their problem solving knowledge and ability. For instance, L9 who was from school C2 complained that the teacher deprived them of the learning opportunities. In

addition, L8 resolved that she would learn better at home, suggesting that meaningful learning was not realised in the classroom.

> **L9:** *The problems were good but our teacher is boring, she does not give us a chance.*

> **L8:** *I don't think I'm comfortable now. I will learn it better at home. But our teacher was OK.*

Responses of L9 and L8 are reminiscent of the format of instructional approach that is described in section 1.9.6 (the conventional problem solving instruction). According to the description in section 1.9.6, in conventional problem solving approaches learners: listen passively to the problem solving information, mainly delivered by the teacher; problem solution examples are not emphasised to facilitate assimilation of new problem solving knowledge, etc.

Learner L9 responded, *"... our teacher is boring ..."*. When learners are observed to be passive during problem solving activity, they may see their teacher as boring if the teacher dominates the lesson (section 1.9.6).

In section 5.3.2, T1 (a teacher from school C2) noted that:

> *"Using contexts is difficult because these learners are different… eh…, I don't think I support it."*

In the comments of T1 the phrase *"Using contexts is difficult ..."* is linked to the idea of connecting mathematics to real-life experiences. Teacher T1 concluded by saying "*I don't think I support it",* suggesting T1 supported conventional instructions as opposed to reformed instructions.

Both L9 and L8 were from school C1, where T1 was teaching (see Table 7.12). The responses from L9 and L8 could provide a window to conceptualise some of learners' views and opinions about conventional problem solving instructions. In section 5.3.2 T1 is described as a traditional

and conventional teacher who is not eager to support reformed instructions such as context-based problem solving instruction.

7.6.2 <u>STUDY OBJECTIVE 5:</u> Learners' views and opinions on the implementation of context-based problem solving instruction

To address the fifth objective of the study Table 7.1 was used to establish the following themes (see questions that were linked to the "views" and "opinions" variables in Table 7.13): *Likes new instruction; Dislikes new instruction; Favours new instructions*; etc. Most views and opinions relating to the implementation of context-based problem solving instruction emerged from experimental schools. Responses from control schools focussed mainly on context-based problem solving tasks that were treated in conventional approaches. Respondents from experimental schools had been exposed to the intervention instruction (see section 5.6.2.2.1 for the description of intervention instruction in experimental schools). Some of the responses from learners included the following examples:

> **L10:** *I have enjoyed this type of teaching because it is related to home issues.*

> **L6:** *Context-based instruction is better than our school method because we also talk as leaners. I like it when we sit and discuss our views in maths. This is the best method to teach maths.*

> **L16:** *This style of teaching I like big time Meneer. Hi … for me, it was the best… It was the best because it takes students' rights serious. Teachers must stop talking too much. This is the time for school children. Power to the children, and long live to the context method.*
> **L1:** *Eh… I liked this method. It is good and train students' mind… It is good because we were given examples that helped us to work alone. We will pass maths now.*

Almost 100% (nine respondents) from experimental schools felt context-based problem solving instruction (CBPSI) is a preferred instructional methodology to teach mathematics and problem

solving. Of the nine respondents from experimental schools, 6 (66.67%) valued CBPSI highly. The L2 referred to the teaching methods that the teachers employed in control schools as *"… old style"*, and suggested that teachers should adopt the CBPSI.

> *L6: Context-based instruction is better than our school method because we also talk as leaners.*

> *L2: Mr Dhlamini you must teach our teachers this new way of teaching maths because they teach in old style.*

> *L13: I think this method is the best than our method that make our brothers to fail matric.*

In terms of learners' views and opinions on the implementation of CBPSI responses from control schools presented mixed reactions.

> *L12: I'm not very sure because we were doing the real-life things and our teacher was doing his own way. I did not see much.*

> *L5: I enjoyed the types of problems we were doing. But I think it was difficult to solve them. But the teacher was solving them easier.*

> *L15: We must do these types of problems in my class. Our teacher must listen to us as students because these are our problems.*

Respondents from the control group chose to focus on context-based problem solving tasks rather than giving views on the implementation of CBPSI. Responses from L12, L5 and L15 (learners from control schools) suggested that there was a feeling of discontentment with the method in which problem solving tasks were presented to them. For instance, L12 blamed her teacher as *"… doing his own way"*, referring to teaching context-based problem solving tasks in the conventional mode. It seems, L12 did not learn from the method in which the teacher

presented context-based problem solving tasks. This view is drawn from L12's final comment that "*I did not see much*", which could be understood as implying, "*I did not learn much*".

One of the respondents in control schools suggested that teachers should resort to learner-centred instruction when teaching mathematics. The learner L15 noted that *"our teacher must listen to us as students ..."*. The respondent L5 seemed to suggest that real-life experiences of learners (views) should guide instruction mathematics classes.

It is observed that most respondents from control schools valued mathematics instruction that incorporated elements of learners' real-life experiences. The fact that respondents from control schools were taught mainly in conventional problem solving approaches (section 1.9.6) effectively constrained their views on the efficaciousness of intervention instruction in promoting problem solving skills of learners. In all, responses from control schools suggested that learners needed an alternative approach to teach mathematics problem solving.

7.6.3 <u>STUDY AIM:</u> The impact of a context-based problem solving instruction on learners' problem solving performance

When analysing the interviews the aim of the study was considered. The aim of the study was considered because it relates to the effect of context-based problem solving instruction (CBPSI) on learners' problem solving performance. Most responses that were linked to the aim of the study came from the experimental schools. For instance, 13 responses from experimental schools were classified as linking to the aim of the study. Only four responses, from control schools, were classified as linking to the aim of the study.

To address study aim the following interview question was asked to learners: *Do you think this form of teaching is effective in mathematics teaching and learning?*

Learners' responses, mainly from experimental schools, included phrases such as, *"We will pass maths now"*, *"... this method is best ..."*, *"I was enjoying ..."*, *"I'm happy I passed ..."*, and, *"I have improved my mathematics test marks"*. The preceding views from learners suggested that

the context-based problem solving instruction impacted positively on learners' problem solving performance. In addition, learners from experimental schools seemed to have been motivated to do mathematics (*"I was enjoying ..."*). Learners from experimental schools were happy to be taught mathematics using outside school activities to hone their problem solving skills.

> **L1:** *Eh... I liked this method. It is good and train students' mind... It is good because we were given examples that helped us to work alone. We will pass maths now.*

> **L13:** *I think this method is the best than our method that make our brothers to fail matric.*

> **L8:** *I was enjoying at certain times. The maths problems were interesting. I'm happy I passed Friday test.*

> **L3:** *I think with this type of problems for maths I can pass with flying colours. I will have passed the second test better but our teacher did not have time to allow more practice.*

> **L11:** *I have improved my mathematics test marks. I think it was because of your method Mr Dhlamini.*

> **L12:** *Last week Monday I failed the first test. But because of practicing that worksheet, and the examples, I passed the last test.*

> **L7:** *I always fail maths but this time I did better.......I think I did better because we did many examples and we were working together and explaining our methods.*

The preceding responses describe learners' views from experimental schools and control schools. It is clear that learners valued CBPSI as impacting positively on their problem solving performance in mathematics. Using the codes in Table 7.12 it is possible to see that a majority of positive views emerged from experimental schools. Respondents from experimental schools felt that CBPSI improved their problem solving performance in mathematics.

However, some of the respondents felt their problem solving performance did not improve.

> **L15:** *I think my Friday marks did not change so much to those of Monday test.*

> **L16:** *Well I must be honest, I did not work hard. But next time I will perform better.*

The learner L16 suggested that learners should also be motivated to work harder to observe the beneficial effects of CBPSI. On the whole, respondents felt that CBPSI improved their problem solving performance.

7.6.4 Learners' views on the implementation of context-based problem solving instruction

In this category participants' views on the implementation of intervention instruction (CBPSI) were examined. The following questions were posed, "*Do you think there are challenges in implementing a context-based problem solving instruction in a mathematics class?*"; "*What are the views of other learners on the implementation of context-based problem solving instruction in mathematics?*"; "*How can you advise someone, maybe your teacher, to implement a context-based problem solving instruction effectively?*".

Phrases such as "*... excellent method ...*", "*I think I like it*", "*... motivated ...*", etc. characterised learners' responses. The preceding responses suggested that learners valued CBPSI highly.

> **L6:** *I think it is an excellent method. I really favour it. I think challenges are going to be there because it is new. It's always difficult to start something new.*

> **L4:** *If it can be taught correctly I think I like it.*

> **L13:** *This method has motivated me to love maths. I'm going to ask my teacher to teach us with examples. I think all students will like maths.*

L9: All teachers must go back to school to learn how to teach maths. Maths must speak to us.

L16: It was a great two weeks. I was always present at school because it was interesting.

L15: These problems that were given to us I like them. I also like many examples that our teacher did.

Almost all responses favoured the implementation of CBPSI. Some respondents suggested that teachers should adopt CBPSI. When asked about the views of their fellow learners on the implementation of CBPSI and the inclusion of context-based tasks in mathematics instruction, respondents commented:

L13: My friend said he liked the way Mr Dhlamini teaches maths.

L11: My friend and my mother have supported this way of teaching mathematics. They say it will make us to pass mathematics.

L16: I think all of the students have liked this context teaching. That is why they were always present at school.

Learners' responses suggested that some learners valued CBPSI highly. On the whole, learners viewed CBPSI positively. Most learners were eager to do mathematics due to the observed beneficial influence CBPSI.

7.7 SUMMARY OF THE THEMES OF LEARNERS' INTERVIEW QUESTIONS IN TABLE 7.6

Table 7.14 reflects on the summary of learners' interview responses to the "understanding" questions in Table 7.13.

Table 7.14: Summary of learners' responses to "understanding" questions

QUESTION	TYPE OF RESPONSE		
	Understands	Average understanding	Do not understand
1. Understanding of problem solving	8	6	3
4. Understanding of problem solving skills	7	2	8
7. Understanding of the notion of real-life context	8	3	6
10. Understanding of context-based problem solving instruction	6	4	7
Total responses	**29 (42.63%)**	**15 (22.06%)**	**24 (35.29%)**

Four of the interview questions probed learners' "understanding" on certain aspects of intervention instruction. The four questions that probed learners' understandings are questions 1, 4, 7 and 10 (see also Table 7.13). Given that 17 learners participated in the interviews, the four types of understanding questions in Table 7.14 could provide a minimum of 68 responses (i.e., 17 learners × 4 questions = 68 responses). To ascertain an overall level of learners' understanding, the number of responses represented in each response column of Table 7.14 (*'understands'*; *'average understanding'*; and, *'do not understand')* is added.

The items in the *'understanding*' category appear 29 (42.65%) times out of 68 total times in Table 7.14. In most of the responses in the 'understanding' questions learners from experimental schools outperformed those from control schools. For instance, Table 7.14 shows that of the 17 interview participants 6 (35.29%) learners gave responses that classified them as '*understanding'* the notion of context-based problem solving instruction (question 10), and 4 (23.53%) showed '*average understanding'*, and 7 (41.18%) were classified as '*not understanding'*. However, further examination of learners' responses in question 10 revealed that of the seven learners in the '*not understanding'* category, five were from control schools. In addition, of the six learners that were classified as '*understanding'* in Table 7.14, five were from experimental schools.

Given the observations in Table 7.14 it is reasonable to conclude that learners in experimental group felt more comfortable to embrace interview questions that dealt with aspects of context-based instruction because they had earlier been taught through CBPSI.

Table 7.8 shows that most learners supported problem solving instruction (CBPSI) in mathematics (most learners held positive views about CBPSI). For instance, 76.5% of participants thought problem solving is important. Of all participants, 82.35% supported the idea that teachers should engage learners in problem solving activities. Respondents thought real-life context should be incorporated in mathematics instruction.

In addition, it is clear that respondents felt strongly that examples can facilitate learning in mathematics problem solving. Also, learners thought certain teacher characteristics influence learner achievement. The view that teachers influence learners' achievement is in agreement with the findings in section 6.2.7.2 that teachers' qualifications correlate positively with learner achievement in mathematics.

The summary of the interview questions that dealt with views- and opinion-related items is provided in Table 7.15.

Table 7.15: Summary of learners' responses to "views an opinion-related" questions

QUESTION	TYPE OF RESPONSE		
	Positive	Not sure	Negative
2. Thinks problem solving is important	13 (76.5%)	2 (11.8)	2 (11.8%)
6. Thinks problem solving can improve performance	9 (52.9%)	5 (29.4%)	3 (17.6%)
8. Thinks real-life context should be included in mathematics	10 (58.82%)	4 (23.53)	3 (17.6%)
11. Thinks context-based problem solving instruction is implemented in South Africa	4 (23.53%)	9 (52.9%)	4 (23.53%)
12. Thinks examples can enhance learners' problem solving skills	12 (70.59%)	2 (11.76%)	3 (17.6%)
15. Thinks group approach is important in mathematics problem solving	9 (52.9%)	3 (17.6%)	5 (29.41%)
16. Thinks learners must be given a chance to explain their problem solving steps	14 (82.35%)	2 (11.76%)	1 (5.88%)
17. Thinks he/ she has benefitted in problem solving approach employed during intervention	7 (41.18%)	4 (23.53%)	6 (35.29%)
18. Thinks teacher's approach can influence learners' problem solving performance	13 (76.47%)	3 (17.65%)	1 (5.88%)
20. Thinks context-based problem solving instruction is better than other problem solving teaching methods	8 (47.06%)	6 (35.29%)	2 (11.76%)

From these observations it is possible to conclude that the success of context-based problem solving instruction hinges on the quality of teachers who are supposed to implement it. In section 2.14 the issue of teacher training is illuminated as a significant variable to influence leaners' performance in mathematics.

Table 7.16: Summary of learners' responses to "strategy-related" questions

QUESTION	TYPE OF RESPONSE		
	Has a strategy	Not sure about strategy	Does not have strategy
3. Strategy for mathematics problem solving	5 (29.41%)	5 (29.41%)	7 (41.18%)
5. Strategy to learn mathematics problem solving	3 (17.65%)	9 (52.94%)	5 (29.41%)
9. Strategy to integrate real-life context with mathematics problem solving	2 (11.76%)	6 (35.29%)	9 (52.94%)
14. Strategy used to solve context-based problem solving tasks	11 (64.71%)	2 (11.76%)	4 (23.53%)

Data in Table 7.16 shows that most learners (52.94%) did not have problem solving strategies to integrate real-life context with mathematics problem solving. Also, 41.18% learners did not have a strategy to handle mathematics problem solving.

The results that are linked to question 9 of Table 7.16 should be interpreted as an indication that teachers seldom present lessons that create opportunities to connect mathematics with real-life experiences of learners. In the analysis of interviews in section 7.6.2 learner L13 responded:

> **L13:** *I think this method is the best than our method that make our brothers to fail matric.*

The comment by L13 could be interpreted as an acknowledgement that CBPSI is better than other teaching methods or strategies for problem solving.

In addition, Table 7.15 shows that the intervention instruction (CBPSI) helped learners to hone their problem solving skills (see response percentages of question 14 in Table 7.15). However, most of the learners who provided responses that were classified as belonging to the category "*has a strategy*" of question 14 (in Table 7.15) emerged from experimental school. The results in Table 7.15 suggest that the question posed in the aim of the study in section 1.2 was addressed. In some of the responses in Table 7.15 learners thought CBPSI could influence their problem solving performance positively. The study aimed to investigate the effect of context-based

problem solving instruction on the problem solving performance of Grade 10 learners who performed poorly in mathematics problem solving.

7.8 ANALYSIS OF TEACHERS' SEMI-STRUCTURED INTERVIEWS

Techniques employed by the researcher in the analysis of learners' interviews were also used to analyse teachers' interviews. Teachers' interviews were analysed in terms of the study objectives, study aims and the three research questions that were posed for the study (section 7.3). Of the four teachers that participated in the study, two teachers (T1 and T2) participated in the interviews. Teachers' interview questions covered the following themes (see Appendix B; see also Table 7.17 & Table 7.18 for the summary of the analysis involving these aspects):

- **Implementation** : Questions 4; 10; 13; 18; 19; and 20;
- **Effectiveness** : Questions 6; 7; and 12;
- **Concerns/ challenges** : Questions 14; and 15;
- **Comparison** : Question 9;
- **Views and opinions** : Questions 16 and 17;
- **Understanding** : Questions 1; 2; 3; 5; 8; 10; and 11.

The above-mentioned themes are considered when analysing teachers' interviews.

7.8.1 <u>STUDY OBJECTIVE 4:</u> To compare a context-based problem solving instruction with conventional problem solving instructions

To address the fourth objective of the study the following questions were posed by the researcher to teachers: *Do you think it is good to implement context-based problem solving instruction in mathematics classrooms*? *Do you think context-based problem solving instruction is better than the other teaching methods that teachers are using for problem solving*? To identify teachers' responses that would link to the fourth objective Table 7.1 was used to establish the following themes: "*In favour of new approach", "Like new approach*" and "*Not in favour of new approach*".

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In the preceding themes the word '*approach*' refers to context-based problem solving tasks that the researcher recommended to the teachers when teaching *Financial Mathematics* topics in Grade 10. The following characterised teachers' responses:

> **T1:** *I think it is good, but we need more training in those worksheets you gave to us.*

> **T2:** *Yes it is good because mathematics must be connected to life.*

Both teachers supported the use of context-based problem solving approach. Teacher T2 emphasised the importance of connecting mathematics to real-life context. Teacher T1 noted that teachers need to be trained to implement context-based problem solving activities in mathematics (see also section 6.2.7.1).

7.8.2 <u>STUDY OBJECTIVE 5 and STUDY AIM:</u> Teachers' views and opinions on the implementation of context-based problem solving instruction

To explore the fifth objective and the aim of the study the following questions were asked to teachers: *"Do you think it is important to include real-life contexts in a mathematics lesson?"*; *"Do you think this form of teaching is effective in mathematics teaching and learning?"*; *"Do you think there are challenges in implementing a context-based problem solving instruction in a mathematics class?"*; etc.

To identify teachers' responses that would be linked to the fifth objective and the aim of the study Table 7.1 was used to develop the following themes: "*Context important"; "Context not important"; "New instruction effective", "New instruction not effective*"; "*See implementation challenges*"; "*Does not see implementation challenges*"; etc.

7.8.2.1 Responses linking to STUDY OBJECTIVE 5

The fifth objective of the study explored teachers' views and opinions on the implementation of a context-based problem solving instruction (section 1.2). In responding to the question linked to the fifth objective of the study both teachers agreed that context-based problem solving instruction (CBPSI) should be incorporated into mathematics curriculum (see also section 7.8).

Teacher T2 noted that CBPSI can help township learners to understand mathematics. The response of T2 went as follows:

> **T2:** *In my understanding context-related style means teaching maths concept within the context of learners' knowledge. I think that's what we need for our students to understand maths better.*

The response from T1 raised important issues relating to teachers' concerns about the inclusion of real-life tasks in mathematics. Teacher T1 was concerned that context would water down mathematics, and felt that it should not be mixed with mathematics which is about numbers. In addition, T1 acknowledged that CBPSI can make mathematics to be interesting, but insisted that she was not very certain.

> **T1:** *For me real-life context in mathematics means including things of life in maths lessons. For me this is a little bit disturbing because it dilutes maths. Maths is about numbers not about discussing real things. But I also think this can make maths interesting, but I don't know how.*

7.8.2.2 Responses linking to STUDY AIM

On the question that probed teachers on the effectiveness of CBPSI in developing learners' problem solving skills, both teachers supported the intervention instruction. Teacher T1 used the phrase *"... the style ..."* to refer to the context-based problem solving instruction.

> **T1:** *If properly implemented the style can work wonders. I still insist, teachers need training. So many things are changing.*

> **T2:** *With good implementation it can really work. Our kids need new ways of learning maths.*

Both teachers agreed that CBPSI can help learners to learn mathematics effectively. When asked to suggest possible ways to implement CBPSI teachers presented different views.

T2: It will be difficult because these learners come from different home background. How do I cater for all these different contexts?

T1: I do not think there would be much challenges. Teachers need training, and the other thing will be to reduce class numbers.

Teacher T2 thought it would be difficult to implement CBPSI in mathematics classes. Teacher T2 was concerned about different contexts possibly brought to class by learners. However, T1 was positive about the success of implementing CBPSI. In addition T1 raised issues of class sizes as a potential threat to the success of implementing CBPSI. Responses from T1 and T2 are indicative of teachers' reactions to recent initiatives to connect mathematics with real-life context.

7.8.3 Teachers' reactions towards context-based problem solving instruction

Both teachers reacted positively towards context-based problem solving tasks. However, teachers' responses revealed tensions amongst them.

T2: These are indeed excellent tasks for problem solving, but it might need a lot of time to prepare such tasks.

T1: I think the idea of adjusting the context to that of the learners was the most impressive aspect of this approach. I liked it and I will try it in my lessons.

Teacher T2 used the phrase "*These are indeed excellent tasks ...*". In addition, T1 commented that the idea of adjusting problem tasks to the real-life experiences was "*... the most impressive aspect of this approach*." On the whole, teachers reacted positively to the CBPSI even though their responses revealed certain concerns on their sides.

7.9 AGGREGRATING TEACHERS' INTERVIEW RESPONSES

Table 7.17 summarises teachers' responses to the interviews.

Table 7.17: Aggregating teachers' interview responses (n = 2)

Objective(O)/ Aim(A)/ Research question(RQ)	Interview category and question(s)	Construct	Construct frequency/ type of response
O: 4	**Compare:** 9	In favour of new approach (F); Not in favour of new approach (NF)	F = 2; NF = 0
RQ: 1	**Implementation:** 4; 10; 13; 18; 19 and 20	Supports reformed approach (RA); supports conventional approach (CA)	RA = 6; CA = 8
RQ: 3/ A	**Effectiveness:** 6; 7 and 12	Positive (P)/ Not certain (NC)/ Not positive (NP) about effectiveness	P = 3; NP = 1; NC=2
RQ: 2	**Concerns:** 14 and 15	List challenges/ Does not list challenges	Teacher training; class size; time; pedagogy type; etc.
O: 5	**Opinion:** 1; 2; 3; 5; 8; 10 and 11	*Q10: Reformed approach(RA);* Conventional approach (CA) *Q8: Understands real-life concept (URL); Does not understand real-life concept (NRLC)* *Q11: Understands context-based problem solving instruction (UCBPSI); Does not understand context-based problem solving instruction (DUCBPSI)*	RA = 1; CA = 1 URL = 2; NRLC = 0 UCBPSI = 1; DUCBPSI = 1

Regarding the implementation of CBPSI the following question was asked to the teachers.

Q: *Can the context-based problem solving instruction enhance learners' performance in mathematics?*

Teacher T1 responded that, "*I am not sure. In my 23 years of experience I still need to see a workable method to teach mathematics*". Teacher T1 was positive that context-based problem solving instruction could improve learners' problem solving skills.

Some of the teachers' concerns on the implementation of CBPSI are listed in Table 7.17. In questions that sought to explore teacher's opinions on certain aspects of CBPSI teachers' responses differed.

In a question that probed teachers' opinions on the best way to incorporate CBPSI in mathematics, teachers responded:

T1: *I will think about designing a common context for all my learners.*

T2: *I think I can allow my students to discuss how they contextualise a mathematical problem in their group.*

Another summary to aggregate teachers' interview responses is provided in Table 7.18.

Table 7:18: Summary of teachers' responses to interviews

INTEVIEW		TYPE OF RESPONSE		
Number of questions asked	Question type	Positive	Neutral	Negative
6	Implementation	6	2	4
3	Effectiveness	3	1	2
2	Concerns and challenges	4	-	-
1	Comparison	1	1	-
1	Reaction	1	-	1
7	Opinion and understanding	8	2	4

Table 7.18 shows that teachers supported context-based problem solving instruction (CBPSI). The responses emphasised that CBPSI should be implemented in schools; and, that CBPSI is an effective instructional technique to hone learners' problem solving skills.

7.10 RESULTS FROM CLASSROOM OBSERVATIONS

Certain aspects of classroom observations that describe participants' context-based problem solving behaviour form part of the discussion in the interview analysis in section 7.6 to section 7.8. The following discussion covers both the teacher and learner components.

7.10.1 Teacher observations

In terms of the aims of teacher classroom observations that are outlined in section 5.6.2.3.1, and the items in the observation schedule in Appendix C, the following teacher observations were made:

- Despite being provided with context-based problem solving tasks, teachers implemented conventional problem solving instructions that, in instances, overlooked initiatives to include real-life context in a mathematics lesson;

- In most cases context-based problem solving tasks were presented to learners in conventional approaches that are described in section 1.9.6;
- The following strategies characterized teachers' problem solving teaching: teachers opted to solely explain problem steps to learners; teachers gave a single example to explain problem solving process; the context-based tasks were solved as presented, without adjusting the problem context to that of the learners;
- The quality of teacher-learner interaction was relatively poor. In most cases, teachers dominated the lesson. Learner involvement was kept at a minimal level;
- The method of teaching problem solving employed by the teachers was mainly to provide one example and give learners many exercises to do on their own. In most cases, learners worked independently;
- The teacher seldom verified the solutions to the problem.

In some cases, teachers' reluctance to incorporate context-based problem solving instruction was explicit. Some teachers felt that the context-based problem solving approach needed more time to be effectively implemented in mathematics classes.

7.10.2 Learner observations

Learner observations were conducted by the researcher in both control schools and experimental schools (see section 7.2). The following observations were made:

7.10.2.1 Learner observations in control schools

- Learners emulated teachers' strategies of problem solving. They preferred not to seek assistance from other learners;
- Because of the mode of instruction employed by teachers in control schools, learners tended to participate minimally during instruction. Learners worked independently during problem solving activities;
- Learners in control schools were observed to experience the following challenges during the lesson: Learners were not adequately prepared to solve similar and novel problems in the future;

- Given that the connections between mathematics and real-life context were not emphasised in control schools, learners did not see the importance of these connections.

7.10.2.2 Learner observations in experimental schools

- Learners in experimental schools supported and enjoyed the context-based problem solving instruction;

- Learners in experimental schools were arranged in groups during the context-based problem solving lessons. Learners found it hard to adapt to the group arrangement which was the new and unfamiliar approach to them. Some of the challenges involved getting learners involved in group discussions, and the researched used the probing technique to guide and stimulate learners interactions during problem solving; and,

- Learners in experimental schools were observed to be supportive of the intervention instruction. Most learners supported the context-based problem solving instruction (see also interview responses in section 7.8).

7.11 CHAPTER SUMMARY

In this chapter data from classroom observations and semi-structured interviews were presented and analysed. The analysis of interviews and classroom observations was guided by the aim of the study, the research objectives and the research questions. Seventeen learners and two teachers were sampled for the interviews (section 7.3 & Table 7.2). In section 7.4 and section 7.5 sampling techniques to select interview respondents were discussed. In section 7.6 the analysis of learners' interviews was conducted.

The analysis in section 7.6 and section 7.7 shows that learners in the experimental group supported context-based problem solving instruction (CBPSI) over conventional problem solving instructions (see section 7.6.1). Learners in control schools complained that their teachers did not provide them with opportunities to demonstrate their problem solving skills. In section 7.6.3 learners acknowledged that CBPSI is effective in developing problem solving skills.

In section 7.8 data from teacher interviews were analysed. The following themes were also developed to analyse teachers' interviews: implementation; effectiveness; concerns and challenges; comparison; views; opinion and understanding (see section 7.8). Teachers

emphasised that issues of teacher development and class sizes should be addressed to facilitate the implementation of CBPSI (section 7.8.1). Teachers' views on the implementation of CBPSI varied. Teacher T1 was more pessimistic about teaching mathematics using real-life contexts while T1 felt the idea is workable (section 7.8.3).

The chapter closes with the analysis of classroom observations (see section 7.9). The analysis shows that learners in experimental schools demonstrated problem solving behaviour that supported the implementation of context-based problem solving instruction. Teachers claimed to support CBPSI but their teaching styles classified them as using conventional problem solving instructions.

The analysis of qualitative has revealed that in some instances both teachers and learners agreed that context-based problem solving instruction is more effective than conventional problem solving instructions, in promoting the problem solving skills of Grade 10 mathematics learners. However, it must be noted that not all responses followed this line of thinking, in some cases it was clear that respondents were not certain on whether or not CBPSI enhances problem solving performance.

CHAPTER EIGHT

DISCUSSION OF RESULTS

8.1 INTRODUCTION

This chapter provides a summary of the study and a discussion of the findings in terms of the research objectives, research questions and the theory that this study adopted. The aim of this study was to investigate the effect of context-based problem solving (CBPSI) on the problem performance of Grade 10 learners who were low-performing in mathematics problem solving, and were from a disadvantaged socioeconomic background.

8.2 SUMMARY OF RESULTS

Here the researcher implemented the CBPSI in five experimental schools while incumbent teachers implemented conventional problem solving instructions (CPSI) in four control schools (see section 1.9.6 & section 5.6.2.2).

A sample of 783 Grade 10 learners who were low-performing in mathematics was studied (see section 7.5.3.7 & Table 7.11). Participants came from nine schools located in a disadvantaged socioeconomic (DSE) township background (section 6.2). On the evidence of literature, children from DSE township background perform poorly in mathematics problem solving when compared to children from historically white schools (Tsanwani, 2009; see also section 2.14). Based on the year-end Grade 12 mathematics performance of the year that preceded this study, all participating schools were classified as low-performing ($M = 34.26$; $SD = 6.30$). This assertion was further confirmed by the mean scores of the pre-test of the two groups ($M_{experimental} = 20.9$; $M_{control} = 22.0$). Since the achievement test was out of 60 marks, participants were designated as low-performing if they scored below 24, average-performing if they scored between 24 and 42, and high-performing if they scored above 42.

The cognitive load theory (CLT) was used in this study as a framework to: 1) facilitate the interpretation and explanation of participants' context-based problem solving performance (see,

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for example, section 8.3.2.1); and, 2) guide the design of CBPSI to hone participants' problem solving skills in experimental schools.

The present study is located within an eclectic paradigm in which data were collected by both quantitative and qualitative methods. The study consisted mainly of a *quasi-experimental design.* However, aspects of a *descriptive survey design* were included to account for the outcomes of the quasi-experimental study. The principal instrument for data collection was a standardised Functional Mathematics Achievement Test (FMAT). The FMAT was aligned to the National Curriculum Statement (NCS) for mathematics at Grade 10 level. The same test was written by all participants at pre- and post-stages of the experiment. The pre-test determined participants' initial problem solving status before intervention. Both groups were found to be homogeneous in terms of problem solving performance when judged from their pre-test scores. A post-test was given at the end of intervention to benchmark change in the functionality of CBPSI over a two-week period.

In addition, to gain access to participants' conceptions of the role of CBPSI in promoting their problem solving performance, and to document the effect of the group approach, the researcher conducted post-intervention semi-structured interviews. Classroom observations were also conducted in both groups during certain context-based problem solving lessons.

In experimental schools the potential of more robust learning was exploited with worked-out context-based problem solving examples that were in a form of worksheets given to participants. In addition, the main aspects of CBPSI embraced elements of the effects of self-explanation and split-attention, as advocated by the cognitive load theory. Due to the design of CBPSI participants in experimental schools became familiar with the basic context-based problem solving tasks that were presented to them through the worked-out example samples. In turn, the associated cognitive load of problem solving tasks was gradually reduced. The reduction in cognitive load was due to participants' ability to relate the problem solving process to their prior knowledge and real-life experience, which included the development of problem solving skills.

The study found that participants in the CBPSI group performed significantly better than participants in the CPSI group on the following problem solving measures of performance: comparison of problem solving performance; comparison of problem solving performance in terms of participants' error rate; and, comparison of problem solving performance in terms of performance categories (see section 6.4.1). In addition, semi-structured interviews and classroom observations revealed that participants rated CBPSI highly (see section 7.6 & section 7.7). Participants viewed CBPSI as an effective instructional tool to bolster the problem solving skills of learners who are low-performing in Grade 10 mathematics. On the whole, the results of this study showed a statistically significant difference of $p < 0.05$ between CBPSI and CPSI groups in all areas of problem solving comparison.

The results of the study are discussed in section 8.3 in terms of the aim, objectives, research questions of the study and the assumptions of the cognitive load theory.

8.3 DISCUSSION OF THE FINDINGS IN TERMS OF STUDY OBJECTIVES

8.3.1 Study objective 1: *Finding evidence of disparities in mathematics problem solving performance between learners of disadvantaged socioeconomic status and those from affluent socioeconomic backgrounds*

All nine schools that participated in this study normally performed poorly in mathematics (section 6.2.7.1, section 7.5.3.7 & Table 7.11). In section 2.14 the literature review showed that learners in historically white schools perform better than township schools learners in mathematics (Van der Berg, 2007; Tsanwani, 2009). Using a theoretical framework which suggests that teacher qualifications impact on learners' achievement in mathematics (Richardson, 2008), this study examined the strength of this correlation in participating schools. The study found a statistically significant relationship, i.e., r = 0.612, between teacher qualification and learner achievement, suggesting that teachers' qualifications in participating schools might have an effect on learners' poor achievement in mathematics.

The results of this study are not unique. Ogbonnaya and Osiki (2007) investigated the relation between learners' achievement in mathematics and teacher qualification and subject major. The

study found the correlations between learners' achievement in mathematics and teachers' qualification to be r = 0.547; learners' achievement in mathematics and teachers' mathematics or mathematics education major to be r = 0.467. Some studies have demonstrated positive effects of advanced teacher qualifications on learners' achievement in mathematics (Betts, Zau & Rice, 2003; Wayne & Young, 2003).

The results of the present study corroborate the results from other studies (see, for example, Din, Khan & Mahmood, 2010; Khurshid, 2008; Richardson, 2008). In section 2.14 it was noted that most teachers in township schools are poorly qualified and those in affluent historically white schools are better qualified. The results of this study, therefore, provide a scientific framework to reflect on issues of poor performance in township schools, and also highlight a need to address educational disparities in the South African schooling system. To this end, the results of this study provide further evidence of the improvement of problem solving performance of township learners taught through context-based problem solving instruction. Thus, objective 1 of the study is fulfilled.

8.3.2 Study objective 2 & 3: *To use cognitive load theory (CLT) as a tool to:*

1) *facilitate the understanding and explanation of participants' context-based problem solving performance; and,*

2) *design context-based problem solving instruction (CBPSI) to enhance participants' problem solving performance*

Post-test results showed a statistically significant improvement in experimental schools ($M = 33.3$; $SD = 4.213$; n = 378) as compared to control schools ($M = 25.8$; $SD = 4.095$; n = 328).

In particular, the study results in section 6.6.2 showed that there was a lower rate of problem solving errors in experimental schools than control schools after the former group was exposed to CBPSI. This suggests that CBPSI facilitates learners' problem solving performance better than the traditional instruction (CPSI) given that learners in the experimental group committed fewer errors after being taught through CBPSI.

8.3.2.1 Accounting for the beneficial influence of context-based problem solving instruction

The beneficial influence of context-based problem solving instruction (CBPSI) in experimental schools is explained in terms of the effects of cognitive load theory.

8.3.2.1.1 The worked-out examples effect

In experimental schools participants studied several worked-out examples by providing them as analogies for problem solving in an existing Grade 10 Financial Mathematics topic (section 4.3). From a cognitive load theory perspective, human working memory has a limited capacity which is taxed during cognitive activities such as problem solving. Such mental work can consume cognitive resources needed for learning and the development of problem solving schemas (McLaren & Isotani, 2011). However, worked-out examples are believed to lessen *extraneous* load associated with cognitive load (McLaren & Isotani, 2011; Salden *et al.*, 2010). The results of this study, therefore, suggest that the extensive use of the worked-out examples approach yielded beneficial results in experimental schools, which can be attributed to the enhancement of participants' problem solving performance in the post-test results.

During interviews in section 7.6.1 learners acknowledged the beneficial effects of worked-out examples approach. For instance, L2 commented:

> **L2:** *I like this method of teaching because you have taught us with examples.*

In section 7.6.2, L1 emphasised the utility of worked-out examples approach, and acknowledged that this approach *"… trains students' mind …"*.

> **L1:** *Eh… I liked this method. It is good and trains students' mind… It is good because we were given examples that helped us to work alone. We will pass maths now.*

The analysis of quantitative and qualitative data in this study provides sufficient evidence to suggest the beneficial influence of worked-out examples in developing learners' problem solving skills. In terms of the cognitive load theory, when participants in experimental schools were immersed into worked-out examples process, the need for extensive search for correct solution

steps was avoided when they had to solve similar context-based problem solving tasks later. While studying worked-out examples, participants concentrated on building problem solving schemas (as confirmed by L1 in preceding comment) that more readily helped them to solve similar problems in the post-test. Instead of grappling with many new and unfamiliar details in a post-test, as well as searching through the memory, participants in experimental schools could easily recall a similar example while engaging in active cognitive processing to strengthen their understanding of the new problem (McLaren & Isotani, 2011).

The results of this study are consistent with previous research on worked-out examples effect that have repeatedly reported learning benefits due to the use of worked-out examples (see, for example, Renkl & Atkinson, 2010; Renkl *et al*., 2009; Schwonke *et al*., 2009; Schwonke *et al*., 2010; Schwonke, Renkl *et al*., 2011; Van Gog & Rummel, 2010; Van Loon-Hillen *et al*., 2012). In all studies, a key theoretical reason cited for the learning benefits of worked-out examples is cognitive load theory (McLaren & Isotani, 2011). According to McLaren and Isotani (2011) and cognitive load theory, the worked-out examples approach facilitates problem solving learning thus enhancing related skills.

However, most of the studies cited here have been conducted in higher education classes and also in artificial experimental settings, meaning they lack a practical value in terms of their influence and application in high school environments. The uniqueness of the present study was its relative focus on actual Grade 10 learners who were low-performing in mathematics, and also its unique emphasis on the integration of problem solving examples with real-life experiences of learners. The infusion of real-life experiences in problem solving tasks, and in associated worked-out examples, reduced the cognitive load to facilitate envisaged development of learners' problem solving skills.
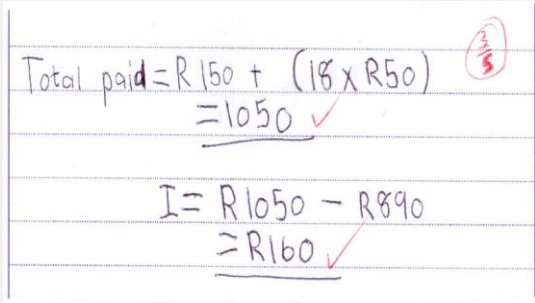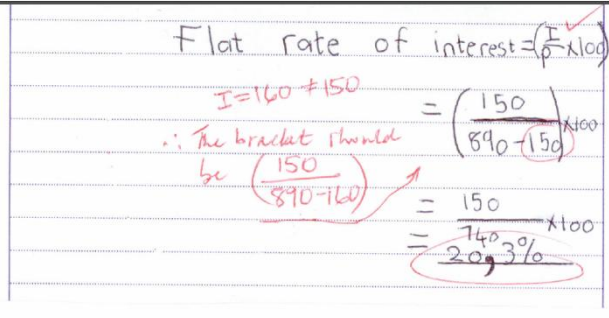
8.3.2.1.2 The split-attention effect

Split-attention is the phenomenon that occurs as a result of physically separating problem solving information (Cierniak *et al*., 2009; see also section 4.4 & section 5.5.1.6). It is the process of simultaneously attending to two distinct sources of information (Dhlamini & Mogari, 2011; Paas *et al*., 2010). Because split-attention creates unnecessary visual search, it may heighten learners'

cognitive load (Paas *et al.*, 2010). Research has shown that reduction in split-attention effect improves learning and problem solving performance (Huk & Ludwigs, 2009).

Example 8.1 provides a snippet of learner's work to illustrate how the researcher dealt with elements of split-attention effect to maximize learners' problem solving performance in experimental schools. From a cognitive load theory perspective, when the problem solver in Example 8.1 disintegrated the problem solution into two pages, two mutually referring sources of problem information were created. To attend to the two information supplying sources (sheet ONE and sheet TWO) the problem solver needed to split her attention. The splitting effect might have created problems for the working memory, as evidenced by the resulting problem solving error. Most likely, the working memory had to temporarily hold pieces of information in sheet ONE while the visual search for the associated information in sheet TWO was made. This practice could have made it difficult for the working memory to process information, and to further understand problem task information. Apparently, when the demand in working memory became too great the problem solver in Example 8.1 easily gave up and was prone to making a problem solving error. Upon probing, the problem solver acknowledged: *When I went to page two I made a substitution mistake. I was going to get total marks* (see Example 8.1).

Example 8.1: Researcher's reaction to the split-attention effect during a context-based problem solving task

Solution sheet ONE (page 1of 2)	*Solution sheet TWO(page 2 of 2)*
When the problem solver was probed on the error in the above vignette, she replied:	
"*When I went to page two I made a substitution mistake. I was going to get total marks*".	

To minimise the split-attention effect, and also maximise problem solving performance in experimental schools, participants were encouraged to: 1) start and finish problem solutions in one solution sheet. This instruction was also incorporated in the achievement test: "*If possible, start every question on a new page*" (see Appendix A); 2) draw a perpendicular line to divide a solution sheet into two parts thereby maximizing possibility to incorporate all components of the problem solution into a single solution space.

The beneficial effect of reducing the split-attention of learners is evidenced by the accelerated problem solving performance in experimental schools (section 6.3 & section 6.6). The results of this study provide support for the instructional designs that are aimed at reducing the effect of learners' split-attention to maximize problem solving performance. Therefore, the results of this study are not unique. The results of this study provides empirical evidence to support the hypothesis that learners who are presented with problem solving tasks that are in a format that separated the two sources of information learn less than learners given material that integrates information (Cierniak *et al*., 2009; Huk & Ludwigs, 2009; Paas *et al*., 2004; Sorden, 2005; Van Gog *et al*., 2009; Van Merriënboer & Sweller, 2005, 2010).

The results of the present study seem to concur with the results of these studies even though some of these studies were conducted in multimedia learning environments. Multimedia learning is defined as "learning from words and pictures" (Mayer & Moreno, 2003, p. 43). Words can be printed (e.g., on-screen text) and the picture can be a chart, photo, or map (Mayer & Moreno, 2003). In addition, multimedia instruction involves a computer-based instruction in which words and pictures should be integrated to minimise the negative effect of split-attention. The present study focussed on a particular mathematics topic, namely, Financial Mathematics, and used a sample of low-performing Grade 10 mathematics learners. Furthermore, Financial Mathematics tasks were presented in experimental schools in a manner that reduced the negative influence of the split-attention effect. Thus the results supported the notion that when designing a mathematics instructional material to enhance learners' problem solving performance, the negative effect of split-attention should not be neglected.

8.3.2.1.3 The group approach effect

In section 5.6.2.2.1 a context-based problem solving lesson is discussed. One of the key components of this lesson is the arrangement of participants into groups of learning (section 5.6.2.2.1). In groups participants discussed, argued and reflected upon the context-based problem solving tasks at hand. Group learning was considered in experimental schools because "cognitive load research recognizes collaborative learning as an alternative way to overcome individual working memory limitations" (Paas *et al*., 2010, p. 118). Regarding group arrangement in experimental schools one participant commented (see section 7.6.1):

> **L9:** *Eh… this method is good because in my class we are not talking, but here we are talking to our friends for answers. It is good because myself I get it better from my learners.*

In section 7.6.2 one respondent elaborated:

> **L6:** *Context-based instruction is better than our school method because we also talk as leaners. I like it when we sit and discuss our views in maths. This is the best method to teach maths.*

From a cognitive load perspective, "groups of collaborating learners are considered to be information-processing systems consisting of multiple limited working memories which can create a collective working space" (Kirschner, Paas, Kirschner & Janssen, 2011, p. 588). Because the group represents a huge working memory the limitations of individual working memories are not exposed and each working memory does not have to be subjected to processing each problem solving information that is processed in a group. As long as the information is communicated between the group members all of them benefit from group problem solving actions (Kirschner *et al*., 2011).

Given that the beneficial effects of group approach are well documented, it was exclusively considered in this study. It is therefore reasonable to conclude that this approach contributed

largely to the development of participants' problem solving performance in experimental schools.

8.3.2.2 Conclusion based on study objective 2 and study objective 3

On the whole, the findings of this study support and extend the previous research regarding the effectiveness of instruction that is aimed at developing problem solving schemas to hone the problem solving skills of learners (see, for example, Jitendra, Dipipi & Perron-Jones, 2002; Jitendra, Griffin, Haria, Leh, Adams & Kaduvettoor, 2007; Rockwell *et al*., 2011). Although these studies relied on schematic diagrams to improve problem solving performance of learners in the area of mathematics word problems, the present study used worked-out examples, split-attention effect, collaborative learning groups and the real-life tasks to bolster the problem solving performance of learners. Nevertheless, the present study does show that there are ways and means to improve learners' problem solving skills.

8.3.3 Study objective 4: *To compare context-based problem solving instruction (CBPSI) with conventional instruction when common context-based problem solving tasks are tackled in class*

The methodological design of the study permitted the comparison of the differentiated instructions employed in different groups. The sample of the study comprised of the experimental group, in which the researcher implemented CBPSI, and the control group in which teachers implemented CPSI. The experimental design used enabled the researcher to statistically compare problem solving performance of the two groups (see also objective 5). The outcome of the study favoured the implementation of CBPSI ($p < 0.05$).

Also, in section 7.6.1 participants' responses to questions that were linked to the forth objective suggested that participants supported CBPSI. In particular, one of the interview questions addressed aspects of "comparison" between two instructions (see section 7.1). Teachers' responses to these types of questions showed that CBPSI is advocated (section 7.7.1). Given these observations, the forth objective for the study was met.

8.3.4 Study objective 5: *To investigate participants' views and opinions on the implementation of a context-based problem solving tasks*

In Table 7.15 and Table 7.18 summaries of learners' responses and teachers' responses to interview questions that tapped into their opinions on certain aspects of the implementation of context-based problem solving instruction are provided. Results in Table 7.15 and Table 7.18 suggested that both teachers and learners supported mathematics instruction that incorporated aspects of learners' real-life experience. For instance, learners' responses to questions 2, 6, 8, 12, 15, 16 and 18 strongly demonstrated *"positive views"* by learners (see Table 7.15). The percentages for *"positive"* responses in these questions are 76.5%; 52.9%; 58.82%; 70.59%; 52.90%; 82.35% and 76.47%, respectively.

Teachers' views followed an almost similar trend. Of the 14 responses that reflected on teachers' *"opinions, views and understanding"*, eight (57.14%) responses were classified as *"positive"* views by teachers (see Table 7.18). Furthermore, six of the questions that were asked to the teachers (n = 2) focussed on the *"implementation"* of CBPSI. The six questions generated 12 responses, and of these, six (50%) were classified as favouring the incorporation of CBPSI in mathematics instruction.

In terms of responding to the fifth objective of the study, it is reasonable to conclude that participants' views (teachers' and learners') favoured the implementation of CBPSI.

8.3.5 Study objective 6: *To evaluate, quantitatively, the effect of a context-based problem solving instruction on learners' problem solving performance*

The analysis of post-test results of the experimental group suggested that CBPSI was more effective in developing participants' problem solving skills than conventional problem solving instructions (CPSI) (see section 6.3). The ANCOVA yielded $F(1,703) = 558.677$, $p < 0.05$, suggesting that CBPSI is more effective.

The ANCOVA results were further corroborated by two one-way ANOVA tests that confirmed the superiority of CBPSI over CPSI. The ANOVA tests confirmed the following two

comparative results: 1) learners taught in CBPSI outperformed learners who were taught in CPSI in three levels of problem solving performance ($p < 0.05$) (see Table 6.12 & section 6.4.2); and, 2) learners taught in CBPSI outperformed learners taught in CPSI when measured on the rate at which both groups tended to make problem solving errors ($p < 0.05$). Learners taught in CBPSI were less likely to make problem solving errors than those taught in CPSI group (see section 6.6).

8.4 EVALUATING STUDY RESULTS AGAINST THE RESEARCH QUESTIONS FOR THE STUDY

The results of the study are evaluated in terms of the research questions set out for the study.

8.4.1 Research question 1: *How can context-based problem solving instruction be incorporated in the teaching and learning of mathematics?*

The present study has emphasised the significance of understanding human cognitive architecture when implementing instruction that is aimed at enhancing learners' problem solving performance. In this study, the success of CBPSI was largely due to its heavy reliance on the assumptions of the cognitive load theory (CLT). In terms of the present study the CLT assumptions included the worked-out examples effects, the split-attention effect, and the fact that participants were arranged in groups to minimise the negative influence of cognitive load. Figure 8.1 demonstrates how the CLT influenced the design of a problem solving instruction. In addition, Figure 8.1 shows how CBPSI can be incorporated in a mathematics lesson.

8.4.1.1 The design phase

The first phase aims to design instruction that minimizes the negative influence of the intrinsic load (section 4.2.1). This load is neutralized by designing context-based problem solving tasks that minimize the effect of split-attention (see section 8.3). In the present study, this is achieved by adjusting problem solving tasks to the real-life experiences of the learners. In that way the cognitive load is reduced. In addition, at this stage participants are arranged in groups to promote collaborative learning (section 8.3).

8.4.1.2 Actualization of instruction

In the second phase, participants engage in context-based problem solving activities. For instance, participants in experimental schools studied several worked-out examples by providing them as analogies for problem solving in an existing Financial Mathematics topic (see section 8.3). A process worksheet with examples was given to learners at the beginning of instruction. Participants worked with peers in groups to study examples and solve problems. The researcher provided assistance as and when it was needed.

Figure 8.1: A summary of the implementation process of context-based problem solving instruction (CBPSI)
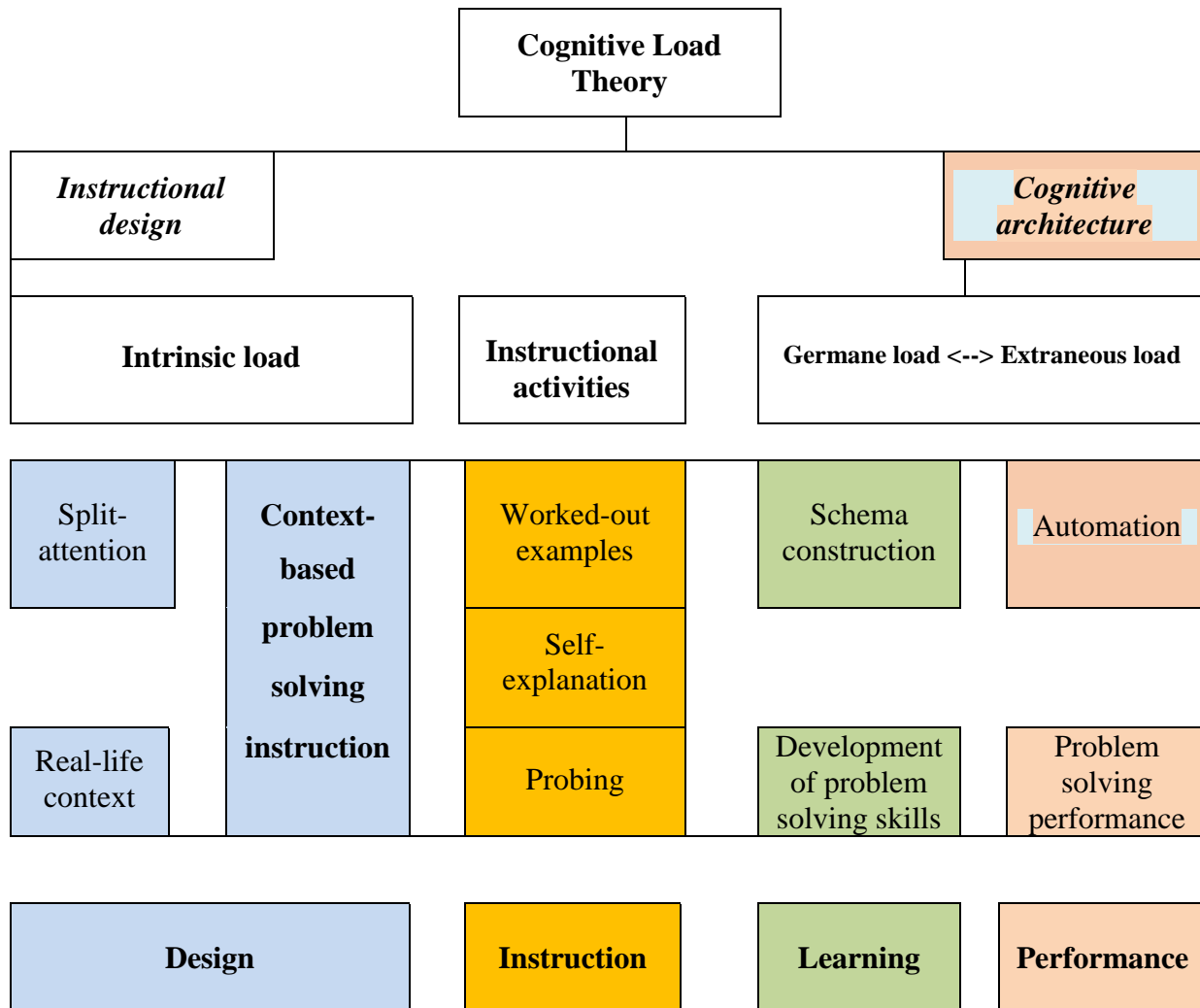
8.4.1.3 Realisation of learning

The third phase of the CBPSI lesson aims to transform extraneous cognitive load to germane load. Unlike extraneous load, germane load contributes directly to learning and schema formation (section 4.2.2 & section 4.2.3). At this phase learners demonstrate their level of problem solving knowledge acquisition, and associated expertise in problem solving process. Learners engage actively and effectively in problem solving tasks and demonstrate their problem solving abilities without being aided. They demonstrate how the worked-out example approach benefited them (that the problem solving schemas have been successfully constructed).

The researcher probed learners as they attempted to solve context-based problem solving tasks without being aided. Their replies suggested substantial gains in problem solving schemas:

> **L1:** *"This problem reminds me of an earlier problem that we solved"*

> **L2:** *"I'm using the same step as in that problem"*

> **L3:** *"I'm solving this one like that one"*

8.4.1.4 Problem solving performance

The final stage in Figure 1 is when learners demonstrate the development of problem solving skills, and the fact that these skills have been automated. At this stage learners are able to solve novel problems using skills gained in previous stages of CBPSI phases.

8.4.2 Research question 2: *What challenges, if any, does the incorporation of context-based problem solving instruction in the teaching and learning of mathematics pose?*

Interaction with the learners revealed some of the inherent challenges that are likely to threaten the effective implementation of CBPSI. The following challenges were documented:

- Teachers are seemingly glued and more comfortable with conventional styles of teaching mathematics and problem solving (see section 1.9.6; section 5.3.2);

- Teacher T1 frequently challenged views for the inclusion of real-life context in mathematics classrooms (section 5.3.2);
- Teachers are more concerned about completing the syllabus (time), and tend to minimize learner interaction during instruction (see some comments in section 7.6.1; see also section 7.8.3);
- Large class sizes;
- Inadequate teaching and learning infrastructure; and,
- Poor training of township teachers (section 7.8.1; see also section 7.8.2.2).

On one hand, teachers complained of the lack of seriousness by learners to promote meaningful learning in mathematics classrooms. On the other hand, learners accused teachers of not giving them a chance to verbalize their problem solving ideas (section 7.6.1).

In terms of the researcher, the following challenges were observed during the intervention study

- Because the teaching style that the researcher employed in experimental schools was considered to be new, learners took longer time to gain familiarity with this approach;
- Some of the learners lacked social skills needed to facilitate meaningful interactions in group settings;
- Other group members dominated discussions at the expense of group members who were relatively withdrawn.

8.4.3 Research question 3: *Will the incorporation of context-based problem solving instruction have any influence on learners' performance in mathematics?*

Incorporating CBPSI in experimental schools had a substantial beneficial influence on the learners' problem solving performance. The post-test results of the achievement test affirm this assertion ($p < 0.05$). The quantitative analysis of post-test participants' scores in section 6.3.6 demonstrated the significant difference in the performance of the experimental and control groups.

Furthermore, interviews with learners in experimental schools revealed that they believe CBPSI is capable of improving their problem solving performance (see section 7.6.1, section 7.6.2 & section 7.6.3).

8.5 IMPLICATIONS OF THE STUDY RESULTS TO THE PRACTICE

The following implications of the study results are discussed.

8.5.1 Epistemological implication

Cognitive load theory has emphasised the use of worked-out examples to reduce the cognitive load of learners that is known to inhibit productive learning and envisaged problem solving performance. As such, cognitive science is replete with studies that have emphasised the learning benefits of worked-out examples (Gerjets *et al*., 2004; Renkl *et al*., 2009; Rourke & Sweller, 2009; Salden *et al*., 2010; Schwonke *et al*., 2009; Sweller & Cooper, 1985; Van Gog & Rummel, 2010). Given this background, the present study incorporated the use of worked-out examples in the design of the context-based problem solving instruction which was implemented in experimental school. However, the present study adds insights in the significance of utilising learners' every day experience in mathematics instruction to facilitate reductions in cognitive load (section 6.7). Over and above, knowledge gained from this study adds another dimension to an on-going dialogue regarding efforts to connect mathematics with every day experiences of learners.

8.5.2 Methodological implication

The uniqueness of this study was the exclusion of teachers in the implementation of context-based problem solving instruction (CBPSI) in experimental schools. The researcher solely implemented the CBPSI in experimental schools. The avoidance of a teacher component was designed to eliminate variations in the implementation of intervention instruction in the experimental group. Furthermore, teachers would have to have been trained on how to use the CBPSI, and this might have prolonged the study (see section 5.6.2.2). The design of the present study is an improvement to Gaigher (2006) and Alexander (2007) studies in which teachers implemented the intervention instruction in experimental school. However, the use of teachers for the implementation of new instruction in these studies required prior training of teachers.

Despite training initiatives, inherent variations, possibly embedded in the use of multiple teachers for the implementation of new instruction, could not be eliminated.

In this study the researcher implemented CBPSI in all five experimental schools. Even though it may be argued that a stranger, in a form of a researcher, was introduced in experimental classes thus creating an artificial and unusual learning atmosphere, the assertion is that this arrangement ensured that the treatment was uniformly and appropriately administered. One of the requirements of conducting experimental research is that the "groups that are to receive the different treatments should be equated on all variables that may influence performance on the dependent variable" (Gay *et al*., 2011, p. 252). The present study strived to achieve this by eliminating the teacher component in the implementation of intervention instruction in experimental schools, thus ensuring that all learners in experimental schools receive similar treatment.

8.5.3 Pedagogical implication

This study provides some evidence of the effects of using context-based problem solving instruction (CBPSI) on learners' problem solving performance. In comparison to conventional problem solving instructions, CBPSI was more effective in the development of learners' problem solving skills. The CBPSI fostered learners' problem solving skills by engaging learners actively in worked-out examples and allowing learners to become aware of every phase in the problem solving process. On the basis of the findings of this study, it is strongly recommended that mathematics instructors should use CBPSI in their lessons to bolster learners' problem solving performance and the related outcomes such as the reduction in the occurrence of learners' problem solving errors.

In addition, the CBPSI embraced elements of group learning in which learners were immersed into dialogues and evolution of problem solving thoughts in a shared space. Using their local real-life experience learners were provided with effective tools to reinforce their problem solving system of thought that enabled them to develop envisaged problem solving skills. Given these observations, this study adds to the existing empirical evidence on the use of group learning and reliance on the connections of mathematics with every day context to improve the effectiveness

of mathematics instruction. Therefore, this study recommends that the use of group learning to teach mathematics, and efforts to connect mathematics with the out-of-school reality should be reinstated as teaching approaches to improve performance in mathematics classrooms.

8.6 SUMMARY OF THE CHAPTER

The results of this study can be interpreted to suggest that CBPSI may be an effective way to teach low-performing learners problem solving skills in Grade 10 Financial Mathematics. This study shows that instruction with contextualized mathematics problem solving items generate constructive problem solving dialogues that help to improve the problem solving performance. In addition, the results of this study show that the inclusion of contextualized items accounts for the reduction in learners' cognitive load.

The uniqueness of this study in the implementation of CBPSI was its emphasis of the connection between using real-life experiences of learners in mathematics instruction and associated reduction in the cognitive load of learners (see section 6.7). The implementation approach used in this study is a demarcation from what is typically found in conventional mathematics classrooms. In conventional classrooms the structure, make and appraise cycles are all based on a closed design methods that are teacher assigned and unrelated to learners' real-life experience. In this study, an alternative and innovative approach to teach mathematics in Grade 10 has emerged.

CHAPTER NINE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

9.1 INTRODUCTION

This study was motivated by the current trend in South African education that learners from a disadvantaged township background do not perform satisfactorily in mathematics problem solving (see section 1.6). The study aimed to investigate the effect of context-based problem solving instruction (CBPSI) on the problem solving performance of Grade 10 learners, who performed poorly in mathematics problem solving. The research objectives for the study were (section 1.2):

1. To explore literature to find evidence of disparities in mathematics problem solving performance between learners of disadvantaged socioeconomic status and those from affluent socioeconomic backgrounds;

2. To use cognitive load theory (CLT) as a tool to understand and explain learners' problem solving performance in mathematics;

3. To use CLT to design a context-based problem solving instruction to enhance the problem solving performance of learners from disadvantaged schools;

4. To compare context-based problem solving instruction with conventional instruction[55] when common context-based problem solving tasks are tackled in class;

5. To investigate participants' views and opinions on the implementation of a context-based problem solving instruction; and,

6. To evaluate, quantitatively, the effect of context-based problem solving instruction on learners' problem solving performance.

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[55] See section 1.9.4 for an explanation of conventional instruction as it applies to this study.

The study explored the following research questions:

1. How can context-based problem solving instruction be incorporated in the teaching and learning of mathematics?
2. What challenges, if any, does the incorporation of context-based problem solving instruction in the teaching and learning of mathematics pose?
3. Will the incorporation of context-based problem solving instruction have any influence on learners' performance in mathematics? If so, to what extent?

In this chapter the results of the study are aggregated in terms of the study aim, research objectives and research questions. The limitations of the study and recommendations conclude the chapter.

9.2 AGGREGATING STUDY RESULTS

The aim and objectives of the have been achieved. Furthermore, the three research questions of the study have been answered.

9.2.1 The research questions of the study

In section 8.4.1 the researcher demonstrates how a context-based problem solving instruction (CBPSI) can be implemented in a Grade 10 mathematics class. All accompanying phases of CBPSI are demonstrated, and evidence is presented to support the workability of CBPSI in mathematics classrooms. Therefore, the first research question of the study is answered.

The second research question of the study was answered in section 8.4.2. In this section, inherent challenges that are likely to threaten the effective implementation of CBPSI in disadvantaged township mathematics classrooms are presented. The presentation of the challenges includes views from both teachers and learners who participated in the present study. Views from teachers and learners are useful in answering the second research question of the study (see section 8.4.2).

The third research question of the study was answered in section 8.4.3. The discussion in section 8.4.3 is presented in terms of the quantitative results of the study which affirmed a statistically

significant improvement of learners' problem solving performance due to the use of CBPSI. Therefore, the results in section 8.4.3 help to answer the third research question of the study.

9.2.2 The objectives of the study

In section 8.3 it is demonstrated that all the objectives of the present study have been achieved.

In section 8.3.1 evidence is presented to demonstrate disparities in mathematics performance between schools located in disadvantaged township background and the historically white schools. The evidence is presented in terms of the first objective of the study (section 8.3.1).

In section 8.3.2 the second and third objectives of the study are discussed in terms of the results of the study. In this section, the beneficial influences of context-based problem solving instruction (CBPSI), and its design, are discussed in terms of the cognitive load theory. In this section it is demonstrated that the second and fourth objectives of the study have been achieved.

In section 8.3.3, a comparison is made between the effectiveness of intervention instruction and conventional problem solving instructions. The results of the present study demonstrated that the CBPSI is superior over CPSI in developing learners' problem solving skills.

The fifth objective of the study attempted to examine participants' views on the implementation of CBPSI (see section 8.3.4). In section 8.3.4 learners' views and teachers' views are discussed in terms of the fifth objective of the study. The results of the study have shown that, generally, participants held positive views on the infusion of CBPSI in mathematics classrooms.

In section 8.3.5, the sixth objective of the study is discussed in terms of the study results. A statistical test (ANCOVA) suggested that CBPSI is more effective ($p < 0.05$) in developing learners' problem solving skills.

On the whole, it is reasonable to conclude that all the objectives that were set out in this study have been met.

9.2.3 The aim of the study

All the objectives of the present study have been achieved (section 9.2.3). The objectives of the study are useful in the attainment of the aim of the study (to investigate the effect of CBPI on learners' problem solving skills). The design of the study made it possible to make this investigation. The results of the study, discussed in terms of the study objectives, suggested a substantial beneficial influence of CBPSI on learners' problem solving skills. Therefore, the aim of the study was achieved. Therefore, it is reasonable to conclude that the aim of the study is achieved, meaning, empirical evidence from the study shows that context-based problem solving instruction has a positive influence on learners' problem solving performance in Grade 10 mathematics ($p < 0.05$).

9.3 CONCLUSIONS

The present study provides evidence that context-based problem solving instruction (CBPSI) can improve problem solving performance of Grade 10 learners in the area of Financial Mathematics. In particular, the real-life context used during instruction facilitated the reduction in learners' cognitive load in experimental schools. Hence the development of learners' problem solving schemas was also facilitated. In addition, the worked-out examples approach facilitated learners' familiarisation of problem solving tasks. Subsequently, this process eradicated the novelty effect that the non-familiarity to the problem tasks would have naturally imposed on learners.

Lastly, the study also showed that the implementation of intervention instruction by the researcher tended to yield better results by reducing the teacher effect. The issue of learners being taught by a stranger, in a form of a researcher, seemed not to have a negative influence on learners' problem solving performance. Instead, the implementation of intervention instruction by the researcher in all experimental schools facilitated uniformity in the implementation of instruction in all schools.

9.4 RECOMMENDATIONS

The results of this study are important to improve Grade 10 mathematics performance of learners in disadvantaged schools. Given that problem solving is included as one of the critical skills in the new mathematics curriculum and the fact that the connectivity to real-life context should be

encouraged, results from this study suggest that teachers should be properly trained in instruction that promotes problem solving. Also, the following aspects of mathematics classrooms should be taken into consideration: reviewing teachers' methodologies towards teaching problem solving; keeping class sizes within manageable limits; ensuring that issues relating to the inclusion of real-life contexts in mathematics instruction are properly addressed, and caution is exercised not to water down the typical actual mathematics content.

9.5 LIMITATIONS OF THE STUDY

Like all studies of this nature, this study is not free from limitations. Acknowledgement and recognition of these limitations are particularly crucial for the way in which the findings of the current study are interpreted. The following limitations inherent to this study have been identified and acknowledged:

- A significant limitation of the present study was its inability to randomly assign participants in experimental and control groups. This aspect is likely to limit the generalizability of the present results to only those who participated in the current study. However, more research is needed to neutralize the effect of the assignment of participants to participating groups;
- Another significant limitation of the present study was the duration in which the intervention instruction (CBPSI) was implemented. The CBPSI was implemented for two weeks in each experimental school. It is however acknowledged that a two-week period may be too short to influence substantial restructuring of learners' problem solving schemas in the long-term memory. A study that is conducted on a relatively longer period is more likely to register the most substantial and significant results;
- This study was confined to Grade 10 learners excluding learners from other grades. It also addressed one topic in the entire Grade 10 mathematics curriculum. However, it is assumed that factors that facilitated the enhancement of learners' problem solving performance in the sample of this study will also be applicable to other grade levels and also in other sections of the Grade 10 mathematics curriculum;
- The study only concentrated in schools found in disadvantaged townships located in specific areas of Gauteng province.

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APPENDIX A: ACHIEVEMENT TEST

SUBJECT   : Mathematics

LEVEL   : Grade 10

TOPICS COVERED   : Simple and compound interests, higher purchase and inflation.

QUESTION TYPE   : Long questions

INSTRUCTION   : If possible, start every question a new page

QUESTION 1: Simple Interest

1.1 Thembi invests R50 000 for 10 years at an interest rate of 15% per annum (p.a.) Simple Interest. Find:

      1.1.1 The future value of the investment;   (4)

      1.1.2 The simple interest received at the end of 10th year;   (3)

      1.1.3 The simple interest received each year.   (2)

1.2 Mapule's parents are unemployed, and she borrows money from the First National Bank in order to buy her school books. How much did Mapule borrow from the bank at 12% p.a. Simple Interest (SI) if she had to pay R510 interest after 5years?   (5)

                                                               [14]

QUESTION 2: Compound Interest

2.1 Mrs Mokoena wants to start a 'spanza' shop (tuck shop) in order to make a living, but she does not have money. She then borrows R4000 from Capitec Bank at 5% p.a. compounded annually. How much will she need to pay after 6 years?   (5)

2.2 R4 250 is invested for 6 years and grows to R14 740. Find the interest rate if interest is compounded annually.   (4)

2.3 Calculate the compound interest on a loan of R800 at 7% p.a. if the interest is compounded half yearly.   (3)

      [12]

QUESTION 3: Higher Purchase

3.1 A car radio costs R960. Uncle Tsepo buys a radio on Hire Purchase (HP) and agrees to pay a deposit of R100 and 24 monthly payments of R45. Calculate:

3.1. 1 The total amount paid, (4)

3. 1.2 The total simple interest paid. (4)

3.2 Nomsa buys a DVD player for R9 800. She takes out a higher purchase loan involving equal monthly payments over three years. The interest rate charged is 14% per annum simple interest. Nomsa also takes out an insurance premium of R10, 35 per month to cover the cost of damage or theft. Calculate:

3.2.1 The actual amount paid for the DVD player; (5)

3.2.2 The interest paid; (4)

3.2.3 How much must be paid each month. (2)

[19]

QUESTION 4: Inflation

Your brother wins a LOTO competition and decides to invest R50 000 now. He secures an interest rate of 9% p.a. compounded annually. The inflation rate is currently running at 12% p.a.

4.1 What will the future value of your brother's money be in 15 years from now? (4)

4.2 Due to inflation, what money will have the same buying power as R50 000 in 15 years' time? (3)

4.3 By how much will the buying power of your brother's money have declined after 15 years? (3)

[10]

QUESTION 5: General

Thembi spent R475 on two skirts and a pair of shoes. How much did she pay for the skirts and the shoes?

[5]

Total score: 60

APPENDIX B: INTERVIEW SCHEDULE

1: Teachers.

1: What is problem solving in mathematics?

2: What is a problem solving strategy?

3: What is your understanding of a problem solving skill?

4: How can learners acquire problem solving skills for mathematics problem solving?

5: What strategies do learners use in mathematics problem solving?

6: Do you think it is good to incorporate problem solving in mathematics classrooms?

7: Can problem solving instruction enhance learners' performance in mathematics? Why?

8: What is your understanding of the phrase '*real-life context*'?

9: Do you think it is important to include real-life contexts in a mathematics lesson?

10: What is the best way to incorporate context-based teaching in a mathematics lesson?

11: What would be a context-based problem solving instruction in mathematics?

12: Do you think this form of teaching is effective in mathematics teaching and learning?

13: How can you teach your learners through a context-based problem solving approach?

14: Do you think there are challenges in implementing a context-based problem solving instruction in a mathematics class?

15: What are the challenges, if any, that can be associated with a context-based problem solving approach?

16: What would you say is the attitude of teachers towards a context-based problem solving instruction in mathematics?

17: What is the attitude of learners towards context-based problem solving instruction in mathematics?

18: Do you think the National Curriculum Statement or the CAPS encourage mathematics teachers to implement a context-based problem solving instruction?

19: In your class, how would you implement a context-based problem solving instruction?

20: How can you advise someone to implement a context-based problem solving instruction effectively?

2: Learners.

1: In your own understanding, what is problem solving in mathematics?

2: Do you think problem solving is important in mathematics?

3: What strategies do you use in mathematics for problem solving?

4: What is a problem solving skill in mathematics?

5: How can learners in a mathematics class learn problem solving skills?

6: Do you think problem solving strategies can improve your performance in mathematics?

7: What is a '*real-life context*'?

8: Do you think real-life contexts can be included in mathematics teaching and learning? Why do you think in that way?

9: Can we integrate problem solving with real-life context to improve learners' problem solving skills in mathematics?

10: How can you describe a context-based problem solving instruction in a mathematics class?

11: Do you think context-based problem solving instruction is implemented in South African mathematics classrooms? If NO, do you think there is a need to introduce this type of teaching in mathematics classes?

12: Do you think using examples can help learners to improve their problem solving skills in mathematics?

13: Did you find the example approach useful in improving your problem solving skills?

14: How did you solve most of the context-based problem in these few days? Why did you use this method?

15: Do you think it is necessary to sit in groups and discuss with other learners when solving mathematics problems? Why do you think in that way?

16: Do you think it is necessary to give learners a chance to explain their problem solving thoughts during problem solving? Why do you think this way?

17: Do you think you have benefited in the problem solving approach that was implemented during the last few days? Why do you think so?

18: Do you think the way in which teachers present problems to learners can influence their problem solving performance? Why do you think that way?

19: Do you think a context-based problem solving instruction is better than other problem solving teaching methods? Why do you think that way?

APPENDIX C: OBSERVATION SCHEDULE

OBSERVATION FOCUS	FOCUS VARIABLE
TEACHERS	1. Integration of context-based tasks with conventional instruction: _____ _____ 2. Integration of problem solving with conventional instruction: _____ _____ 3. Challenges, if any, related to the incorporation of a context-based problem solving instruction: _____ _____ 4. Problem solving approach and strategies: _____ _____ 5. Attitude towards problem solving instruction: _____ _____ 6. Attitude towards incorporation of context related tasks in instruction: _____ _____
CONTROL GROUP	1. Strategies for problem solving _____ _____ 2. Involvement and role during instruction/ participation: _____ _____ 3. Response to the incorporation of context-based material into instruction:_____

CONTROL GROUP	_____ 4. Level of dependence to the teacher: _____ _____ 5. Challenges, if any, related to context –based problem solving approach: _____ _____
EXPERIMENTAL GROUP	1. Problem solving strategies (old/ new/ integrated): _____ _____ 2. Adaptation to new instruction: _____ _____ 3. Innovativeness (how does a learner use context to facilitate problem solving activity): _____ _____ 4. Challenges, if any, related to context-based problem solving instruction: _____ _____ 5. Reaction and attitude to new instruction: _____ _____ 6. Participation and involvement:_____ _____ 7. How do learners use examples to facilitate understanding of new material:_____ _____

APPENDIX D: BACKGROUND CHARACTERISTICS OF ALL LEARNERS IN THE STUDY

<table>
<tr><td colspan="2" align="center">**DEMOGRAPHIC DETAILS OF A LEARNER**

LEARNER CODE[56]: _____

AGE : _____

GENDER[57]: _____

INSTRUCTIONS: Answer the following questions by only ticking (√) the correct option (answer) from those provided. In case of "other" supply your information.</td></tr>
<tr><td align="center">**Parentage status**</td><td align="center">√</td></tr>
<tr><td>Living with both parents
Living with single parent/ live with guardian
No parents
Other: _____</td><td></td></tr>
<tr><td align="center">**Employment status of parent(s)**</td><td align="center">√</td></tr>
<tr><td>Parent employed
Parent self-employed
Parent unemployed
Other: _____</td><td></td></tr>
<tr><td align="center">**Education level of parent(s)**</td><td align="center">√</td></tr>
<tr><td>Less than grade 12
Grade 12
More than grade 12</td><td></td></tr>
<tr><td align="center">**Computer access at home**</td><td align="center">√</td></tr>
<tr><td>Have a computer at home
Do not have a computer at home</td><td></td></tr>
</table>

---

[56] At the beginning of the study all learners were assigned index numbers (codes) to ensure anonymity (see section 5.6.2.1). The same codes were used to administer the above-described tool (appendix D). The rationale for utilizing learners' codes was for comparability purposes and triangulating data drawn from different sources.

[57] The word "gender" was explained to the learners before they started filling the form. In this section the learner was expected to reveal his/ her sex (male/ female).

APPENDIX E: SCHOOL AND TEACHER PROFILE FORM[58]

<table>
<tr><td>

INSTRUCTIONS

- You are kindly requested to complete both sections of the form, section A and section B;
- The questions are formulated in such a manner that you can provide a one-word (or just a number) written response or choose one of the options provided;
- If possible, you are requested to answer all questions;
- Your responses to this questionnaire will form part of data for the current study;
- All your responses will be treated with confidentiality and anonymity.

</td></tr>
<tr><td>

1.1 SECTION A: Teacher profile

1.1.1 Age: _____.

1.1.3 Gender: _____.

1.1.3 List the subject(s) currently taught at school: _____.

1.1.4 List the class(es) or grade(s) in which the subject(s) mentioned in 1.1.3 are taught, and the number of learners in the class(es): _____.

1.1.5 In the subject(s) that you mentioned 1.1.3 your teaching qualification is (choose the category and type of qualification provided, if '*other*' is the response specify):

        1.1.5.1   a diploma: STD, other: _____;

        1.1.5.2   a diploma + ACE, other: _____;

        1.1.5.3   a degree: BA, BEd, BSc, other: _____;

        1.1.5.4   a degree + honors;

        1.1.5.5   a degree + masters;

        1.1.5.6   a doctorate.

1.1.6 What is your teaching experience in subject(s) mentioned in section 1.1.3 (please only specify in years, eg. 2yrs, 15yrs, etc.): _____.

</td></tr>
</table>

---

[58] Both sections of the form were completed by teachers in participating school. The form was discussed with teachers before completion (see section 5.5.1.9).

1.2 SECTION B: School profile

1.2.1   School code (to be provided by the researcher): _____.

1.2.2   What is the status of the school (choose one answer): (public; private).

1.2.3   In which area is your school located (choose one answer): (township; town or city; rural).

1.2.4   What is the total number of learners currently doing mathematics in grade 10: _____.

1.2.5   Does the school have the following facilities:

Facility	YES	NO
Science laboratory		
School library		
Computer laboratory		

1.2.6   If your school has the above-mentioned facilities, are they functional? (YES/ NO):

     1.2.6.1 Science laboratory: _____;

     1.2.6.2 School library: _____;

     1.2.6.3 Science laboratory: _____.

1.2.7   If possible, please provide the school's grade 12 mathematics end-of-the-year pass rates (in percentages) in the following years:

     1.2.7.1   2010 _____;

     1.2.7.2   2009 _____;

     1.2.7.3   2008 _____.

APPENDIX F: A TOOL TO EVALUATE LEARNERS' PROBLEM SOLVING SKILLS[59]

Problem solving skill	RATING		
	weak	average	good
Ability to analyse and organise data			
Can choose correct formula for the problem			
Can relate problem to previously solved problems			
Can arrange and identify useful information for problem solving			
Can verify solution after problem solving			
Can sustain problem solving actions			

---

[59] This tool was implemented to learners in experimental schools (n = 50). The tool was implemented during a problem solving process and also after a problem solving process by using learners' scripts. From the results of the sampled learners (n = 50) that were evaluated a generalized view on learners' problem solving status was conceptualized (see section 7.5.3).

APPENDIX G: A TOOL TO MEASURE LEARNERS' COGNITIVE LOAD

After writing the test you are requested to complete the questionnaire below to report the amount of mental effort which you invested in performing the problem solving tasks in the test. You are required to choose only one of the provided choices from 1 to 9.

Level of difficulty	Mark (X)
1. Extremely easy	
2. Very easy	
3. Easy	
4. Quite easy	
5. Neither easy or difficult	
6. Quite difficult	
7. Difficult	
8. Very difficult	
9. Extremely difficult	

APPENDIX H: **SPLIT-ATTENTION CONTEXT-BASED PROBLEM SOLVING TASK**

Task:

Uncle Thabo wins R500 000 from a LOTTO and decides to invest 10% of his winnings. He goes to Standard Bank and invest his money for 10 years at an interest rate of 15% per annum simple interest. Find:

----

1. the amount of money uncle Thabo invested with Standard Bank;
2. the accumulated amount of the investment after 10 years;
3. the simple interest received at the end of the 10th year;
4. the simple interest received each year.

APPENDIX I: A SAMPLE OF A CONTEXT-BASED PROBLEM SOLVING WORKSHEET

1. Find the future value of R1250 invested for 5 years at:
   (a) 14.7% p.a. compound interest.
   (b) 18.7% p.a. compound interest.

2. Find the present value of an amount which accumulated to R2228.20 in 6 years at:
   (a) 11.8% p.a. compound interest.
   (b) 12.7% p.a. compound interest.

3. Jason invests R100 000 in an account paying 18% p.a. compounded annually. Calculate the future value of his investment after 15 years.

4. Patricia borrows money from a bank in order to finance a new business. The bank charges her an interest rate of 14% p.a. compounded annually. Calculate the present value of the loan (the amount she originally borrowed), if she pays off the loan 6 years from now with a payment of R500 000.

5. R6000 is invested for 4 years and grows to R7000. Find the interest rate if interest is compounded annually.

6. Find the annual compound interest rate that makes R2500 double in 5 years.

7. R50 000 is invested at 10% p.a. simple interest for 3 years. Thereafter, the total amount is reinvested in a different financial institution at 25% p.a. compound interest for 2 more years. What is the future value of the investment after the five-year period?

1. John invests R4000 for 8 years at a simple interest rate of 9% per annum. Calculate:

    (a) the future value of the investment.

    (b) the simple interest received at the end of the 8th year.

    (c) the simple interest received each year.

2. Kgomotso invests R13000 for 12 years at a simple interest rate of 8% per annum. Calculate:

    (a) the future value of the investment.

    (b) the simple interest received at the end of the 12th year.

    (c) the simple interest received each year.

3. In 4 years' time Paul wants to have saved R30 000 in order to visit his cousin who lives in England. He manages to receive an interest rate of 12% per annum simple interest. How much must he invest now in order to achieve his goal?

4. Neeran wants to invest a sum of money now so as to afford a new play station costing R5000 three years from now. He receives a simple interest rate of 6% per annum. Calculate this amount for Neetan.

5. Calculate how long it would take an investment of R2900 to grow to a value of R5000 if the simple interest rate received is 11% per annum.

6. Calculate how long it would take for an investment of R5800 to double if the simple interest rate is 12% per annum.

7. In order for R3000 to grow to R6000 over a period of 5 years, what simple interest rate would you need to secure?

8. James has R4000 to invest and wishes to grow this amount to R5000 over a period of 2 years. What simple interest rate will he need to receive in order to achieve this?

9. An amount of R1000 is invested at 15% p.a. simple interest. A further R1200 is invested at 10% p.a. simple interest. By when will both investments have the same accumulated values?

APPENDIX J: A SAMPLE OF A WORKED-OUT EXAMPLE WORKSHEET

Problem: How much money was invested five years ago if the value of the investment is currently R7000? The interest rate was 8% per annum simple interest.

Tools: **Formulae:** Simple interest formula $\longrightarrow$ $A = P(1 + in)$
Compound interest formula $\longrightarrow$ $A = P(1 + i)^n$

Notations:

P = present value of the investment (original amount at the beginning);

A = accumulated amount (future value) of the investment after n period;

n = time period;

$i = \dfrac{r}{100}$ for the simple interest rate r%.

Steps	Step-by-step explanation
$A = P(1 + in)$	**Step 1:** Choose correct formulae by using key words "simple" and "compound" in problem.
$A = 700; P=?; i=0,08; n = 5.$	**Step 2:** Arrange data by attaching each value in problem to the correct symbol.
$7000 = P(1 + 0,08 \text{ X } 5)$	**Step 3:** Substitute data in formula without changing the arrangement of formula.
$7000 = P(1 + 0,4)$	**Step 4:** Work on more complicated side and apply BODMAS. Start by multiplication inside bracket.
$7000 = P(1,4)$	**Step 5:** Add inside bracket.
$\dfrac{700}{(1,4)} = P$	**Step 6:** Divide by (1,4) both side to make P the subject of formula.
$P = R5000$	**Step 7:** Simplify and solve for P.

Problem task[60]

In 4 years Sipho wants to have saved R30 000 to open a tuck shop in township. He manages to receive an interest rate of 12% per annum simple interest. How much must he invest `now in order to achieve his goal?

---

[60] The context in which this problem solving task is presented was manipulated to fit that of learners. The purpose of manipulating the real-life context in the problem solving tasks was to reduce learners' cognitive load.

APPENDIX K: A SAMPLING TOOL FOR TEACHERS' INTERVIEWS[61]

TEACHER CODE: _____

SCHOOL: _____

CRATERION	YES	NO
Teaching approach		
• Uses conventional style of teaching		
• Uses progressive style of teaching		
• Mixes conventional and progressive styles of teaching		
• Not clear which style is advocated during instruction		
Use of real-life context during instruction		
• Sensitive to learners' real-life context		
• Promotes the use of real-life material during lesson		
• Encourages link between content and real-life context		
• Views on the influence of real-life on the lesson explicit		
• Uses learners' real-life context knowledge to facilitate learning		
Learner-participation during instruction		
• Encourages learner participation during instruction		
• The lesson is leaner-centred		
• Learners work in groups when solving context-based problem tasks		
• Learners work individually when solving problems		
Reaction on implementing context-based problem solving instruction		
• Supports context-based problem solving approach		

---

[61] Data for this purpose were collected during out-of-class researcher-teacher interactions (eg., when planning and discussing context-based problem solving tasks). Mainly, data for this purpose were collected during classroom observations. It should be noted that data collected through this tool were later verified through the interviews as they represented a once-off interaction experience between the researcher and the concerned teacher (for instance during observation which occurred only once).

APPENDIX L: A SAMPLING TOOL FOR LEARNERS' INTERVIEWS

LEARNER CODE: _____

SCHOOL: _____

CRATERION	RATING		
Achievement pre-test score[62]	HIGH	AVERAGE	LOW
Achievement post-test score	HIGH	AVERAGE	LOW
Participation during context-based problem solving tasks	YES	NO	
• Participate effectively in group discussions			
• Participate minimally in group discussions			
• Is non-involved in group discussions			
• Can work independently during problem solving			
• Benefits from other group members or leaners			
• Benefits from the teacher			
Problem solving strategies	YES	NO	
• Follows teacher's method(s) of problem solving			
• Derives own problem solving strategies			
• Problem solving steps systematic			
Attitude towards learning new problem solving strategies	YES	NO	
• Shows willingness to learn new problem solving methods			
• Is motivated to solve more context-based problem tasks			

---

[62] Table 5.3 was used to interpret learners' achievement test scores. Using this table the following categories of performance (in %) were established: HIGH = 60 – 100; AVERAGE = 50 – 59 and LOW = 0 – 49. Learners' test scores were classified according to these categories.

APPENDIX M: SAMPLE OF ATTENDANCE REGISTER DURING A 2-WEEK INTERVENTION PROGRAMME

ATTENDANCE REGISTER										
Class: Grade 10 D					**Number of learners:** 36					
School: E4					**Subject:** Mathematics					
Learner Code[63]	**D1**[64] pre-test	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10** post-test
1. LE4[65]-266	√	√	√	√	√	√	√	√	√	√
2. LE4-267	√	√	√	√	√	√	√	√	√	√
3. LE4-268	√	√	√	√	√	√	√	√	√	√
4. LE4-269	√	√	√	√	√	√	√	√	√	√
5. LE4-270	√	√	√	√	√	√	√	√	√	√
6. LE4-271	**A**[66]	√	√	√	√	**A**	**A**	√	**A**	**A**
7. LE4-272	√	√	√	√	√	√	√	√	√	√
8. LE4-273	√	√	√	√	√	√	√	√	√	√
9. LE4-274	**A**	√	√	√	√	√	√	√	√	√
10. LE4-275	√	√	√	√	√	√	√	√	√	√
11. LE4-276	√	√	√	√	√	√	√	√	√	√
12. LE4-277	√	√	√	√	√	√	√	√	√	√
13. LE4-278	√	√	√	√	√	√	√	√	√	**A**
14. LE4-279	**A**	**A**	√	√	**A**	**A**	**A**	√	√	√
15. LE4-280	√	√	√	√	√	√	√	√	√	√
16. LE4-281	√	√	√	√	√	√	√	√	√	√

---

[63] Learners' real names were not entered. Every learner was given a code name for identification.

[64] D1 implies Day 1, D2 will then imply Day 3, and so on. On D1 and D10 a pre-test and a post-test were written, respectively.

[65] The code LE4 was used to denote learners in school E4 (section 4.3.4). So learners in a control school E1 were given a code LE1 in their attendance register, in which LE1-001 referred to the first learner in the register. Learners in school E4 were given codes from LE4-266 to LE4-301. The allocation of codes and their numerical attachments in each school were done on a numerical continuation basis, meaning LE4-266 was a continuation from LE3-265 which denoted the last learner on the register from the school E3 (see section 4.6.2.1, section 4.8.2.1 and section 4.8.2.2 for explanation).

[66] The symbol **A** denotes 5 learners who were absent during instruction and could not write either one or both tests. The symbol **A** refers to 3 learners who attended all sessions during intervention but did not write either one or both tests (see section 5.3).

17. LE4-282	√	√	√	√	√	√	√	√	√	√
18. LE4-283	√	√	√	√	√	√	√	√	√	√
19. LE4-284	**A**	√	√	√	√	√	**A**	**A**	√	**A**
20. LE4-285	√	√	√	√	√	√	√	√	√	√
21. LE4-286	√	√	√	√	√	√	√	√	√	**A**
22. LE4-287	√	√	√	√	√	√	√	√	√	√
23. LE4-288	√	√	√	√	√	√	√	√	√	√
24. LE4-289	√	√	√	√	√	√	√	√	√	√
25. LE4-290	√	√	√	√	√	√	√	√	√	√
26. LE4-291	**A**	√	√	√	√	**A**	**A**	**A**	√	√
27. LE4-292	√	√	√	√	√	√	√	√	√	√
28. LE4-293	√	√	√	√	√	√	√	√	√	√
29. LE4-294	√	√	√	√	√	√	√	√	√	√
30. LE4-295	√	√	√	√	√	√	√	√	√	√
31. LE4-296	√	√	√	√	√	√	√	√	√	√
32. LE4-297	√	√	√	√	√	√	√	√	√	√
33. LE4-298	√	√	√	√	√	√	√	√	√	√
34. LE4-299	√	√	√	**A**	√	**A**	**A**	**A**	**A**	**A**
35. LE4-300	√	√	√	√	√	√	√	√	√	√
36. LE4-301[67]	√	√	√	√	√	√	√	√	√	√

[67] The actual number of participants in this school (E4) was 67 (Table 4.2). The school had divided these learners into two classes of 36 (grade 10D) and 31 (grade 10A) learners. The register above only reflects on one of these mathematics classes, grade 10D.
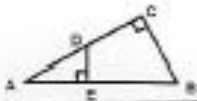
TAXONOMY OF CATEGORIES OF MATHEMATICAL DEMAND

Taxonomy of categories of mathematical demand in exams for the purpose of differentiating between learners' level of competence:

KNOWING		
These are questions that require recall of information or comprehension of knowledge and basic facts.		
GRADE 10	GRADE 11	GRADE 12
• Know that a number pattern with a constant difference has a linear formula. • Solve for x: $2x + 1 = 5$ • Draw the graph of $y = \sin x$ • Reflect a point $(x; y)$ in the x-axis. • Factorise a trinomial like $x^2 + 3x + 2$	• Simplify: $\sin(180° + x)$ • Simplify $\sqrt{3} + \sqrt{12}$ • Rotate a point $(x; y)$ around the origin through an angle of 180° • Give the domain of a polynomial function • Find the y-intercept of a function	• Determine the 25th term of the sequence 7, 11, 15, … • Find $f'(x)$ if $f(x) = 2x^2 - x + 3$ • Determine the mode • Find asymptotes of a rational function Optional: • Prove that opposite angles in a cyclic quadrilateral are supplementary
PERFORMING ROUTINE PROCEDURES		
These are questions that require the pupil to apply learned procedures involving a number of steps to solve questions. Most often these questions are similar to those encountered in class.		
GRADE 10	GRADE 11	GRADE 12
• Solve for x: $x^2 + 3x + 1 = 5$ • Draw the graph of $y = 3\sin(x)$ • Combine a reflection and a translation of a point $(x; y)$ • Determine the formula for a sequence with a first order difference	• Solve for x: $7 \cos x = 2$ • Find the mean and standard deviation using a calculator • Simplify: • $\dfrac{x}{(x^2 - 4)} + \dfrac{1}{3x - 9}$ • Draw the graph of $y = \sin(3x)$ • Draw the graph of $y = 3(x - 2)^2 + 1$ • Rotate $(x; y)$ about the origin through an angle of 90° • Produce a box-and-whisker plot • Find asymptotes • Calculating reducing balance depreciation. Optional: • Fill in values (not all of which are given) on a given Venn diagram	• If the 5th term of an arithmetic sequence is 12 and the 12th term is 33, determine the first term and the constant difference • Change between effective and nominal interest rates • Find $f'(x)$ if $f(x) = 4x^2 + \sqrt{x}$ • Rotating $(x; y)$ about the origin through an angle of 50° • Calculate n in $A = P(1+i)^n$ • Solve the value of an annuity Optional: • Find the correlation between two sets of data using a calculator

SOLVING PROBLEMS

These are unfamiliar (but not necessarily difficult) questions that require a learner to integrate their knowledge. They often require the learner to break the question down into pieces, identify what to solve first and then apply the relevant knowledge to solve the problem. The questions are often real-life or problem-solving questions that the majority of learners have never seen.

GRADE 10	GRADE 11	GRADE 12
• Determine the units digit of the product of the first 100 prime numbers • Solve for x: $2^x = 17$ (trial and error is expected) • Express $0,\overline{1} + 0,\overline{01} + 0,\overline{0001}$ as a simplified fraction • Open mathematical modelling tasks • Non-routine problems	• Connect $(0,0)$ to $(5,3)$ with a line segment, where it goes through 7 unit squares. If you connect $(0,0)$ to (p,q) where p and q are positive whole numbers, how many squares does the line go through? • Patterning tasks set in a context that requires conjecture before a relationship can be found • Open mathematical modelling tasks. • Non-routine problems Optional: • In the figure AE=6, EB=7 and BC=5. What is the area of EBCD?	• Non-routine problems • Determine the maximum value of $\dfrac{5 - 3\cos x}{3 + 2\cos x}$ • Compare higher purchase, micro-lending and bank loan options • Given that $\sqrt{-1} = i$ • Write the roots of $x^2+2x+5 = 0$ in terms of i • Determine i^{2093} Optional: • In how many ways can the letters of SOCCER be arranged so that the arrangements start with C and end with S?

PERFORMING COMPLEX PROCEDURES

These questions require learners to:
- Choose a correct procedure to answer questions in which there is no direct route to the answer.
- Apply procedures or concepts from more than one Learning Outcome in one question.
- Analyse a question by breaking it down before starting the question.
- Apply knowledge directly to realistic problems or in problem solving.

GRADE 10	GRADE 11	GRADE 12
• Solve for x: $5.2^{x+1} - 8 = 32$ • Factorise $4x^4 - 3x^4 - 4x + 3$ • Mathematics modelling where the question is broken into steps • Draw the graph of $y = 2\sin(x) + 1$ • Determine the median of grouped data	• Complete the square to solve a quadratic equation • Solve 3-D trig problems • Solve x: $\dfrac{1+\frac{1}{x}}{1-\frac{1}{x}} = 1$ • Determine a formula for a sequence with a second order difference • Sketch $y = 2\cos(x + 30°)$ • Calculate the standard deviation Optional: • Create a Venn diagram to solve a probability question	• Determine the value of a sinking fund and the required monthly deposits • Solve $x \in [-180°; 180°]$ $\cos x = \frac{1}{2} - \sin x$ • Max and min calculus problems • Rotate a quadrilateral about the origin through an angle of $35°$ • Calculate n in $F = \dfrac{x[(1 + i)^n - 1]}{i}$ Optional: • Solve riders where a number of steps are required to connect the required parts (e.g. prove a line is a tangent to a circle)

APPENDIX O: SAMPLE OF LEARNERS' PROBLEM SOLVING RESPONSES

Top left:

Question4

a) $A = P(1+i)^n$

$A = R50\,000\,(1,027)^{15}$

$A = R50\,000\,(1,21)^{15}$

$A = R50\,000 \times R505,41$

$\quad R25\,470\,500$

$\therefore 25\,470\,500 + 50000 = R25\,520\,500$

b) $A = P(1+i)^n$

$A = R50\,000\,(1+80\%)^{15}$

$A = R50\,000\,(181)^{15}$

$A = R50\,000\,(1,942642449)$

$A = R9,713$

Why add ? (red annotation)

Top right:

1.2. $A = P(1+i \times N)$ ✓

$A = ?$

$P = R510$

$i = 0,12$

$N = 5\,yrs$

$A = R510\,(1+0,12 \times 5)$

$A = R510\,(1,12 \times 5)$

$A = R510 \times 5b$

$A = R2,856$

?? (red annotation)

Bottom left:

Question 1

1.1 $A = P(1+i \times N)$

$A = 50\,000\,(1+0,15 \times 10)$

$A = 50\,000\,(1,15 \times 10)$

$A = 50\,000 \times 11,5$

$A = R575,000$

Bottom right:

Question 2.

2.1.

$A = P(1+i)^n$

$A = 4000\,(1+0,05)^6$

$A = 4000\,(1,05)^6$

$A = 4000 \times 1,340095641$

$A = R5360,38$

Question 3

$\frac{100 + 45 \times 24 = 1180}{100} = 11,8\%$

$A = P(1 + i \times n)$
$= 860(1 + 11,8 \times 2)$
$= 860(1 + 23,6)$
$= 860 \times 24,6$
$= 21156$

3.2 $A = P(1 + i \times n)$
$A = 510(1 + 0,12 \times 5)$
$A = 510(1 + 0,6)$
$510 \times 1,6$

Question 2

① $A = P(1+i)^n$

$A = 4000(1+5)^{6yes}$
$A = 4000(1 + 15,625)$
$A = 4000 \times 15,626$
$A = R62 504 000$

APPENDIX P: TYPICAL LEARNERS' RESPONSES AT PRE- AND POST-STAGES

Experimental school: pre-test	Experimental school: post-test
Question 1 Simple Interest. 1.1. Thembi invests R 50 000 for 10 years at interest per annum (P.a) simple interest find. $A = P(1+i \times N)$ $A = ?$ $P = R 50 000$ $i = 0,15\%$ $N = 10$ yrs $A = 50 000 (1 + 0,15 \times 10)$ $A = 50 000 (1,15 \times 10)$ $A = 50 000 \times 11,5$ $A = R 575,000$	Question 1 1.1. $A = P(1+i \times n)$ $A = 50 000 (1 + 0,15 \times 10)$ $A = 50 000 (1 + 1,5)$ $A = 50 000 \times 2,5$ $A = R 125 000$ a) R 125 000 b) 125 000 − 50 000 = 75 000 c) $\dfrac{75 000}{10} = 7500$
Question 2 ① $A = P(1+i)^n$ $A = 4000 (1+5)^{6 yrs}$ $A = 4000 (1 + 15,625)$ $A = 4000 \times 15,625$ $A = R62 504 000$	Question 2 2.1) $A = P(1+i)^n$ $A = 4000 (1+0,05)^6$ $A = 4000 (1,05)^6$ $A = 4000 \times 1,340095641$ $A = R5 360,38$ 2.2) $A = P(1+i)^n$ $14 740 = 4250 (1+i)^6$ $\dfrac{14 740}{4250} = \dfrac{4250}{4250}$ $= 3,468235294$

Question 4

Compound interest

$A = P(1+i)^n$

$A = 50\ 000\ (1 + 0{,}12)^n$

$A = 50000\ (1{,}12)^n$

$A = 50\ 000 \times 2773078757$

$= R\ 1386{,}53$

$A = P(1+i)^n$

$A = 50\ 000\ (1 + 0{,}15)^9$

$A = 50\ 000\ (1{,}15)^9$

$A = 50\ 000 \times 3517876292$

$= R\ 1758{,}93$

c) $R\ 1386{,}53 - 1758{,}93$

$= R\ 372{,}4$

$A = P(1+i)^n$

$A = 50\ 000\ (1 + 0{,}12)^{15}$

$A = 50\ 000\ (1{,}12)^{15}$

$A = 50\ 000 \times 5{,}473565759$

$A = 273678{,}38$

c) $273678{,}38 - 182124{,}12 =$

$= 91\ 554{,}16$

301

APPENDIX Q: CONSENT LETTERS

(1) Request to validate the achievement test

Mr Joseph Jabulane Dhlamini
138 Hendrick Verwoerd Street
Nigel
1491

Cell   : 076 495 0067
Office : 012 495 2023
Fax   : 012 495 8690
E-mail : dhlamjj@unisa.ac.za

Dear _____

Re: Permission to assist in the validation of an achievement test for grade 10 mathematics learners

My name is Joseph Jabulane Dhlamini. I am studying a PhD in curriculum studies in Mathematics Education, at the University of South Africa (UNISA). The purpose of my study is to develop a context-based problem solving model to enhance learners' problem solving skills in mathematics. As part of the research I need to collect data from schools. The collection of data will involve the administration of an achievement test to grade 10 learners, interviews with these learners and teachers, and observing both teachers and learners during instruction. The results from this study will inform both policy and practice. I have already discussed my research with some teachers and principals who have provided in-practice support. As a requirement, the data collection instruments must be validated prior to administration to the participants. I therefore request you to assist me with the validation of the achievement test. A questionnaire has been designed for this purpose, and is attached with this request.

After reading this letter, please tick the appropriate option: agree or not to agree. Participation is strictly voluntary. Should you wish to get more information, my contact details are on the top of this request letter.

Thank You,

Yours sincerely
Dhlamini, Joseph Jabulane (Mr)

(2) Validation form for the achievement test

<div style="border:1px solid #000; padding:10px;">

TEST VALIDATION FORM

Researcher	Details of the validator
Name: Mr Joseph Jabulane Dhlamini **Institution:** University of South Africa	**Name:** **Institution/ organisation:**

The following questions are based on achievement test to be administered to a group of grade 10 mathematics learners, in the township schools. You are kindly requested to provide feedback about the validity of the test by answering the questions below. You can provide your feedback by inserting a cross (X) in appropriate spaces. Your feedback to the questions will be highly valued for the success of this research.

Question	YES	NO
1. Does the test meet the assessment guidelines as stipulated in the National Curriculum Statement (NCS) policy documents for mathematics?		
2. Are the items in the test representative of the topics covered in financial mathematics in grade 10 mathematics?		
3. Are the items in the test at the level of understanding of the learners in the grade 10 mathematics class?		
4. Is the test representative of the context of learners in township school?		
5. Is the allocation of marks in line with the nature of questions to which they are allocated?		
6. Has the test taken into account different abilities of learners?		
7. Does the test provide opportunities for learners to demonstrate their problem solving skill?		
8. Is the test appropriate and relevant to assess learners' problem solving skills in mathematics?		

Please provide comments, if necessary, on the strengths and weaknesses of the paper.

_____

_____

Signature: _____   **Date:** _____

Official Stamp:

</div>

(3) Request to the principal to access school

Mr Joseph Jabulane Dhlamini
138 Hendrick Verwoerd Street
Nigel
1491

Cell   : 076 495 0067
Office   : 012 495 2023
Fax   : 012 495 8690
E-mail : dhlamjj@unisa.ac.za

Dear Principal

Re: Permission to do research in your school

My name is Jabulane Dhlamini. I am currently doing a PhD degree in mathematics education. The purpose of my study is to develop a context-based problem solving model to enhance learners' problem solving skills in mathematics. As part of the research I need to collect data from schools. I therefore ask for your permission to allow me to use your school as a site for this research to be carried out, and the permission to work with grade 10 mathematics teachers and learners.

The collection of data will involve the administration of an achievement test to grade 10 learners, interviews with these learners and teachers, and observing both teachers and learners during instruction. The results from this study will inform both policy and practice. Lessons and classroom observations will be conducted during school time. However, interviews with teachers and learners will only be conducted after contact time, that is, between 14H00 and 15H00. You will also be provided with the transcript of these interviews. The names of the school, learners and teachers will not be exposed; the school and participants will be referred to by a pseudonym.

After reading this letter you have a right to agree or not to agree. The participation of your school in this project is voluntarily and should you wish to withdraw at any stage of the research you are free to do so.

Should you wish to get more information, my telephone number is: 076 495 0067.

Hoping to hear from you soon.
Mr. Jabulane Dhlamini

(4) Request letter for teacher participation

Mr Joseph Jabulane Dhlamini

138 Hendrick Verwoerd Street

Nigel

1491

Cell   : 076 495 0067
Office   : 012 495 2023
Fax   : 012 495 8690
E-mail : dhlamjj@unisa.ac.za

Dear _____

Re: Request for your participation in research

My name is Jabulane Dhlamini. I am currently doing a PhD degree in mathematics education at the University of South Africa. The topic of my research is "*Investigating the effect of implementing a context-based problem solving instruction on learners' performance*". The purpose of my study is to develop a context-based problem solving model to enhance learners' problem solving skills in mathematics. I plan to work with grade 10 mathematics teachers and. I therefore ask for your permission to participate in this research. As a teacher, you will be expected to use your style of teaching while giving learners context-based problem solving tasks. In one of your lessons you will be observed together with the learners that you will be teaching. At the end of all lessons you will also be interviewed by the researcher to provide your views and ideas on a context-based problem solving approach. Interviews will be conducted between 14H00 and 15H00, after contact time.

After reading this letter you have a right to agree or not to agree. Your participation this project is voluntarily and should you wish to withdraw at any stage of the research you are free to do so.

Should you wish to get more information, my telephone number is: 076 495 0067.

Hoping to hear from you soon.

Mr. Jabulane Dhlamini

(5) Request for learner participation

Mr Joseph Jabulane Dhlamini

138 Hendrick Verwoerd Street

Nigel

1491

Cell   : 076 495 0067
Office   : 012 495 2023
Fax   : 012 495 8690
E-mail : dhlamjj@unisa.ac.za

Dear parent

Re: Request for your child to participate in research

My name is Jabulane Dhlamini. I am currently doing a PhD degree in mathematics education at the University of South Africa. As a student for the PhD programme I will be conducting an educational research with grade 10 mathematics learners. The topic of my research is "*Investigating the effect of implementing a context-based problem solving instruction on learners' performance*", and the purpose of my research is to improve learners' mathematics problem solving skills. If you allow your child to participate in this research, he/ she will participate in a series of problem solving activities. I will also be administering a pre- and post-test in order to track progress. Results from these tests will simply be used to track problem solving progress and will not count against your child's grade.

During lessons, your child will also be observed on his/ her progress. At the end of the project your child might be interviewed in order to give opinion of a context-based problem solving instruction. The benefits of this research study consist of improving mathematical problem solving skills and greater preparation for the future. Participation is completely voluntary. Your child's name and program results will not be released without your permission. I am only interested in seeing how to provide your child with the best education.

If you have any questions please feel free to contact me. My telephone number is: 076 495 0067.

Hoping to hear from you soon.

Mr. Jabulane Dhlamini

Please sign and return the bottom portion of this consent form as soon as you have read the letter above.

I, the parent/ legal guardian of ...., acknowledge that the researcher has explained to me the need for this research, explained what is involved and offered to answer any questions. I freely and voluntarily consent to my child's participation in this research. I understand all information gathered during the research will be completely confidential.

Name of learner: ....

Signature of parent/ legal guardian: ....

Date: ....

(6) Consent forms: To the principal and to all the participating teachers

I ………………………………………………… (please print your name in full) the principal/ a grade 10 mathematics teacher agree to be a participant in the research conducted by Jabulane Dhlamini in which he will be investigating the effect of implementing a context-based problem solving instruction on learners' performance.

I give consent to the following:

- My school to participate in the research.

  Yes ☐ or No ☐ (use a cross to indicate your selection)

- To give lessons in my class(es) for context-based problem solving activities.

  Yes ☐ or No ☐ (use a cross to indicate your selection)

- To administer an achievement test in my class(es).

  Yes ☐ or No ☐ (use a cross to indicate your selection)

- To be interviewed.

  Yes ☐ or No ☐ (use a cross to indicate your selection)

- To be observed during lessons.

  Yes ☐ or No ☐ (use a cross to indicate your selection)

  Signed : …………………………………

  Date   : …………………………………

APPENDIX R: CLEARANCE LETTER FROM THE DEPARTMENT OF EDUCATION

education

Department: Education
GAUTENG PROVINCE

For administrative use:
Reference no. D2012/89

GDE RESEARCH APPROVAL LETTER

Date:	23 June 2011
Name of Researcher:	Dhlamin J.J.
Address of Researcher:	138 Hendrick Verwoerd Street
	Nigel
	1491
Telephone Number:	012 429 2023 / 076 495 0067
Fax Number:	012 429 8690
Email address:	Dhlamjj@unisa.ac.za
Research Topic:	Investigating the effect of implementing a context-based problem solving instruction on learners' performance
Number and type of schools:	EIGHT Secondary Schools
District/s/HO	Ekhuruleni East and Tshwane South

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

1. The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.
2. The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.
3. A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.

1

Making education a societal priority

Office of the Director: Knowledge Management and Research
9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
Email: David.Makhado@gauteng.gov.za
Website: www.education.gpg.gov.za

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APPENDIX S: ETHICAL CLEARANCE TO CONDUCT THE STUDY

UNISA | university of south africa

Ref: 2011/ISTE/019
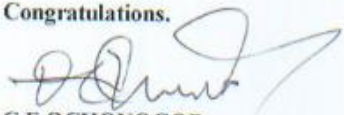
14 November, 2011

Mr. Dhlamini Joseph
ISTE
UNISA.

Dear Mr. Joseph,

REQUEST FOR ETHICAL CLEARANCE: " **Investigating the effect of implementing a contxt-based problem solving instruction on learners` performance.**"

Your application for ethical clearance of the above study was considered by the ISTE sub-committee on behalf of the Unisa Research Ethics Review Committee on 28 October, 2011.

After careful consideration the details and implications of the study, your application was therefore **approved** and hence you can continue with the study at this stage.

Congratulations.

C E OCHONOGOR
CHAIR: ISTE SUB-COMMITTEE

CC. PROF L. LABUSCHAGNE
EXECUTIVE DIRECTOR: RESEARCH

PROF M N SLABBERT
CHAIR- UREC.